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A Study on the Visualization and Evaluability of Thinking Process in the Field of K12 Education Application

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Abstract

This paper aims to apply the study on the visualization and evauluability of thinking process in the field of K12 education as follows: 1. Introduce the background information of the research, including the study significance, theory basis and essence of human thinking process; 2. Introduce the research achievements, actually the theory basis—Basic Graphic Analysis Method, the praxis of visualization of thinking process—Geomking software and the praxis of evauluability of thinking process—Thinking tree and thinking software. The significance lies in the usage of the Elementary Periodic Table in the field as the set of basic graphics, to deconstruct any geometry problem and simplify the process, so that the geometry problem understanding could be more standardized, concise and traceable. Both human's cognitive structure and machine's information processing levels by the geometry problem could be therefore improved. Based on it the Visualization and Evaluability of Thinking Process in plane geometry could be realized per two developed software Geomking and Thinking. On this basis it is possible to extend the research field from education to other fields. It can then accumulate the data of "the Visualization and Evaluability of Thinking Process" for different fields and questions one by one, finally achieve the goal to simulate the human thinking activities and promote the artificial intelligence research a step forward.

Keywords: *visualization and evaluability of thinking process; geometric language; natural language; symbolic language; basic graphic analysis method; thinking tree*

INTRODUCTION

Artificial intelligence (AI) is a branch of computer science and is considered one of the three cutting-edge technologies (genetic engineering, nanoscience, artificial intelligence) in the 21th century.

The purpose of AI scientific research is to let the computer think and perform tasks that normally require human intelligence, such as visual perception, speech recognition, decision-making, etc. The foundation of "let computer think" is to understand the research object, actually the regularity of human thinking activities, including form of thinking, thinking methods, thinking process and others. Among them, the most basic and important part of thinking is thinking process. If the thinking process is not clear, it is obviously impossible to build a reasonable and successful simulation of thinking.

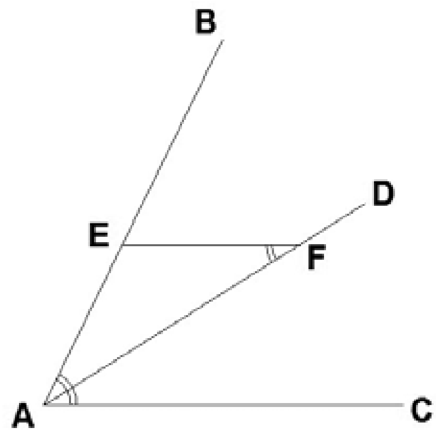

Figure 1: parallel to the side of the angle

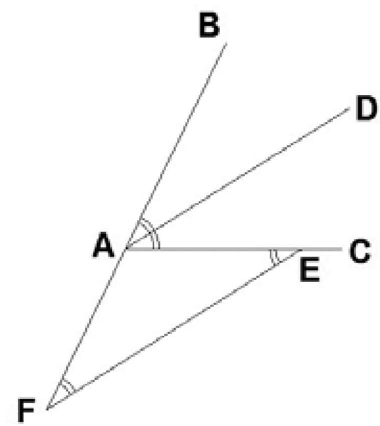

Figure 2: parallel to the bisector of the angle

After years research, our team has chosen *the Visualization and Evaluability of Thinking Process in the field of K12 education application* as a starting point to study and simulate the human thinking process.

Study Significance

First, the visualization and evaluability of thinking process builds the basic study of AI research. The study of human thinking process till now shows mostly only the thinking results, while the thinking process (how the results came out) is rarely mentioned. For example, China's famous mathematician Chen Jingrun spent six years to complete the proof of the Goldbach conjecture (1+2), and finally published paper with more than 100 pages. However, for the descendants, we only see his thinking results (paper with more than 100 pages), but his thinking process about how he completed the proof, is completely unknown. Therefore, in order to simulate it we should make the original thinking process in the human brain become visible and evaluable.

Second, currently AI has begun to penetrate into almost all areas of human life step by step, except education. The goal of education is to let students learn the ways of thinking and understand the thinking process. Only developing from pursuing the previous thinking results to pursuing the cultivation, training and formation of the thinking process, a real innovation could then happen in education. Therefore, in order to make this innovation happen, not only display the analyzing process of a problem, actually the visualization of thinking process; but also evaluate the thinking process of a problem by a student, actually the Evaluability of then thinking process, are our study topics.

Theory Basis

The study of the simulation of human thinking process should base on science rather than experience.

Experience has the following characteristics:

Know it is so, but don't know why it is so.

This one could do so, but don't know whether that one could do so.

It could do so today, but don't know whether it could do so tomorrow.

It could do so today, but don't know when it could do so again.

By contrast, science has the following four important characteristics (take the plane geometry we are studying as an example):

<u>1) Causality</u>

The causality of science refers to the relationship between the cause and the result which is between things and things, phenomena and phenomena. It is the relationship based on a logical reason which can be derived from one thing or phenomena to another.

For example: In the combination of the angle bisector and the parallel, the basic graphic "Isosceles Triangles" could be recognized. No matter where the parallel line is draw, whether it's parallel to the

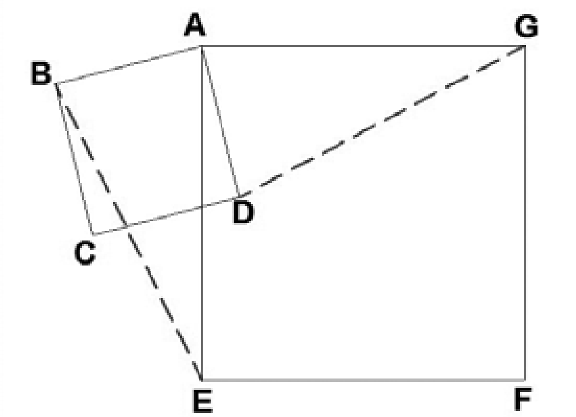

Figure 3: Rotary Type of Congruent Triangles

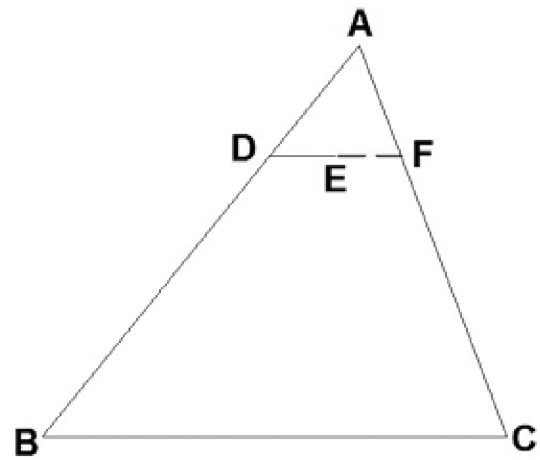

Figure 4: Parallel Line Type of Similar Triangles

side of the angle or it's parallel to the bisector of the angle, it must have the isosceles triangle. That's the causality of science.

2) Universality
The universality of science refers to the common nature of all the objects, things, and phenomena.

For example: In the plane geometry, when there are two squares with a common vertex, the basic graphic "Rotary Type of Congruent Triangles" could be recognized. The way to find this pair of congruent triangles is to constitute two sets of equal lines from the common vertex to form congruent triangles. This characteristic is established for any two squar3s Rotary Type of Congruent Trianglest is show the universality of science.

3) Predictability
The predictability of science refers to the accurate estimation, evaluation and judgment of the trend and the development of things or objects over a certain period of time in the future.

For example: In the plane geometry, when two proportional line segments overlap, the basic graphic "Parallel Line Type of Similar Triangles" could be recognized. The way to form this type of similar triangles is to add parallel line from end-point or internal point. At this time, it can predict as long as the parallel line is added, the basic graphic "Parallel Line Type of Similar Triangles" could be recognized. Even it can accurately predict where the Parallel Line Type of Similar Triangles appear. That's the predictability of science.

4) Periodicity
The periodicity of science refers to one or more cycles in which certain repetitive features occur during the movement of things after a certain period of time.

Based on the above mentioned four important characteristics of science, we could execute our study of the thinking process.

Essence of human thinking process
The essence of human thinking process is actually to answer three questions:

- How to think when get a question?
- How to think about it step by step?
- Why think so?

First, How to think when get a question?
This is actually the starting point for every one of us to take thinking activities. Thinking about any problem should start from the problem with given information including conditions, conclusions and other nature. However, the given information of the target problem is not unique, so there is a thought of all the possibilities. In essence, this is a divergent thinking process. In the divergent thinking through the various possibilities, some are correct directions to solve the problem while some are wrong directions, some are very simple directions while some are quite complicated directions. So

there is a comparison and choice in the thinking process, in essence, this is a concentrated thinking process. Linking divergent thinking process and concentrated thinking process, that is, an innovative thinking process. In this sense, the real process of analyzing and solving the problem takes innovative thinking as the starting point of thinking process.

Second, How to think about it step by step?
After the start of the thinking activities, the most important part of the thinking process is how to come out step by step until the problem is solved. Take our study of plane geometry as an example, the key point is also how to think when we get a question, how to come out step by step. Including the most difficult part in plane geometry education—adding auxiliary line, it is also need to make it clear how to come up with each of the auxiliary line and how to add them one by one.

Third, why think so?
Because the thinking process comes out step by step, there is a logical causal relationship between the previous and the next step. This means that every step of thinking process is justified and can be answered with certain reason.

Therefore, the study of human thinking process, in fact, is to thorough research these three questions and achieve results.

RESEARCH ACHIEVEMENTS

After clarifying the essential problems and basic conditions to be solved in the study of thinking process, we developed the **<Geomking—junior middle school plane geometry learning software>** (Abbr. Geomking) based on "the Visualization of Thinking Process" and **<Thinking—student's thinking process visualization and evaluation system>** (Abbr. Thinking) based on "the Evaluability of Thinking Process" in the field of junior middle school math education.

Basic Graphic Analysis Method

The theoretical basis of "Geomking" is the "**Basic Graphic Analysis Method**" which can reveal the regularity of geometric problem analysis.

Plane geometry is one of the most basic and important subjects in developing junior high school students' thinking ability (including intuitive thinking, logical thinking and innovation). In the specific age of junior middle school students' growth, no other subject could replace it inland and abroad [1]. For a long time, geometry is a subject which teachers feel difficult to teach and students feel difficult to learn. The most difficult part is that the traditional geometric teaching can't clearly explain how to think about when get a problem, how to think step by step, especially how each of the auxiliary lines is coming out. In theory, it doesn't reveal the thinking process of the geometry problems. "Basic Graphic Analysis Method" is a method of thinking and analysis based on the identification, analysis and application of graphics and graphic properties [2]. Any geometric graphic is composed of one or more basic graphics. When a number of basic graphics are combined to be one geometry problem, the nature of the basic graphics is hidden. So the analysis and thinking process of the geometry problem is essentially to reverse this comprehensive process, that is, to analyze and identify these basic graphics, the use the basic graphics' properties to solve the problem. When the basic graphic is not complete, it makes the incomplete basic graphic into complete by adding auxiliary lines, then use the properties of the basic graphic to solve the geometry problem. The original creation of the "Basic Graphic Analysis Method" is to scientifically introduce the thinking process about each geometric problem.

In "Basic Graphic Analysis Method" the number of basic graphics is 32 [2]. We call these 32 basic graphics as "Elementary Periodic Table" in plane geometry area. The 32 basic graphics constitute the basic elements of plane geometry, and their infinite combination will deduce an infinitely changed plane geometry. The 32 basic graphics are divided into 7 types:

1. parallel line
2. isosceles triangle
3. angle related to circle
4. congruent triangles
5. similar triangles

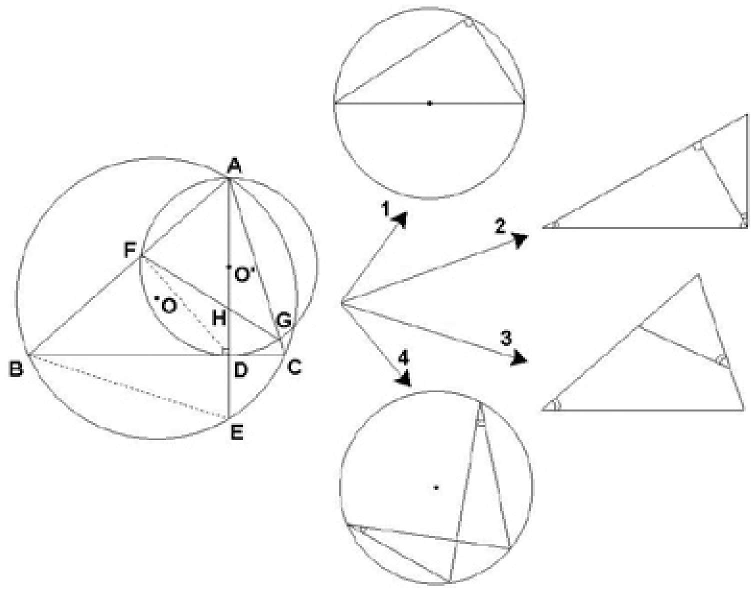

Figure 5: Basic Graphic Analysis Method

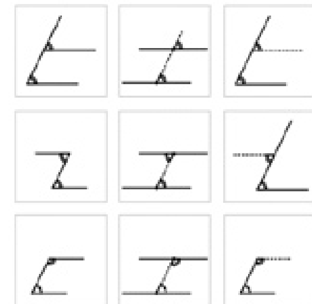

Figure 6: Basic graphics in parallel line as example

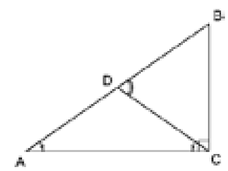

Figure 7: Basic graphic "midline on the hypotenuse of a right triangle"

Table 1. Properties of Basic graphic "midline on the hypotenuse of a right triangle"

Item	Description
Graphic description	midline on the hypotenuse of a right triangle
Property	$\triangle ABC$, $\angle ACB=90°$ $AD=BD \Leftrightarrow CD=AD=1/2AB$ $AD=BD \Leftrightarrow \angle DAC=\angle DCA$, $\angle BDC=2\angle DAC$
Position property	midline on the hypotenuse of a right triangle
Application condition	It exists midline on the hypotenuse of a right triangle
Application method	If it exists midline on the hypotenuse of a right triangle, could use properties of the basic graphic "midline on the hypotenuse of a right triangle" to do the calculation or proof.

Source: The authors.

6. triangle with special angle
7. triangle related to area method

For every single basic graphic in it there exists a complete system consisting of standardized description, property, position property, application condition and application method. For example, for midline on the hypotenuse of a right triangle mentioned above as second basic graphic, it has the following characters:

Geomking software

Geomking is a junior middle school plane geometry learning software which is based on the "Basic Graphic Analysis" as theoretical basis and "the Visualization of Thinking Process" as core technology. "The Visualization of Thinking Process" technology of Geomking is mainly through the following two ways to achieve:

1. **Geometry Fundamental Graphic Analysis Model (GFGAM)**—Using sophisticated language to describe complex logical relationships

   Through data acquisition, data calculation, data analysis and data modeling of tens of

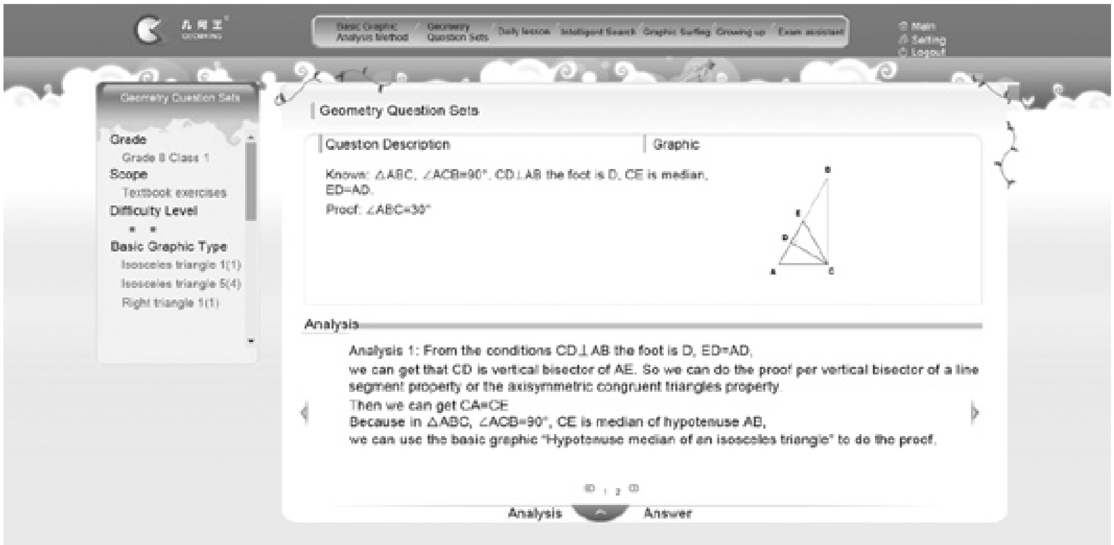

Figure 8: Example function of Geomking

thousands of geometric questions, GFGAM which is the analysis model based on the "basic graphic analysis method" is finally formed. For a certain geometric problem, GFGAM acquires and analyzes the application conditions of the basic graphics contained in this geometric problem, and expresses logical relationships, logical reasoning in sophisticated language. In the analysis of the same geometric problem, GFGAM is repeatedly called and finally the complete thinking process of the geometric problem is expressed in sophisticated language.

2. **Dynamic Graphic Distribution Technique (DGDT)**—Performing complex graphical relationships with dynamic graphics

   DGDT is to find and break down one or several basic graphics of a certain geometry problem and form them into a collection of graphics. When the basic graphic is not complete, by adding the auxiliary line to complete the basic graphic, dynamically generate new graphics, sort the graphics according to the order of thinking process and add them into the original collection of graphics. DGDT loops these steps until finally form a sequence of ordered graphics. No matter how complex the graphical relationship is, DGDT can break it into the most basic, ordered set of basic graphics.

"The Visualization of Thinking Process" which uses the information technology to visualize the thinking process step by step is recognized as "the brain CT of thinking process" by many teachers. The successful realization of this technology in plane geometry subject also solves the problem of the deep integration of information technology and subject teaching, moreover, the normalized application of information technology in classroom teaching.

After realizing "The Visualization of Thinking Process", we face a new challenge that is "the Evaluability of Thinking Process". The purpose of "Geomking" is to reveal analysis process of a certain geometry problem, but the purpose of teaching is more needed to be able to show the thinking process of each different student and evaluate it so that finding unique problems of thinking process for each student. This turns out to be "Thinking" software.

Thinking tree

The theoretical basis of "thinking" is the "**Thinking Tree**" which reveals the possibilities of different thinking paths. To show and evaluate the thinking process of each different student, the most basic

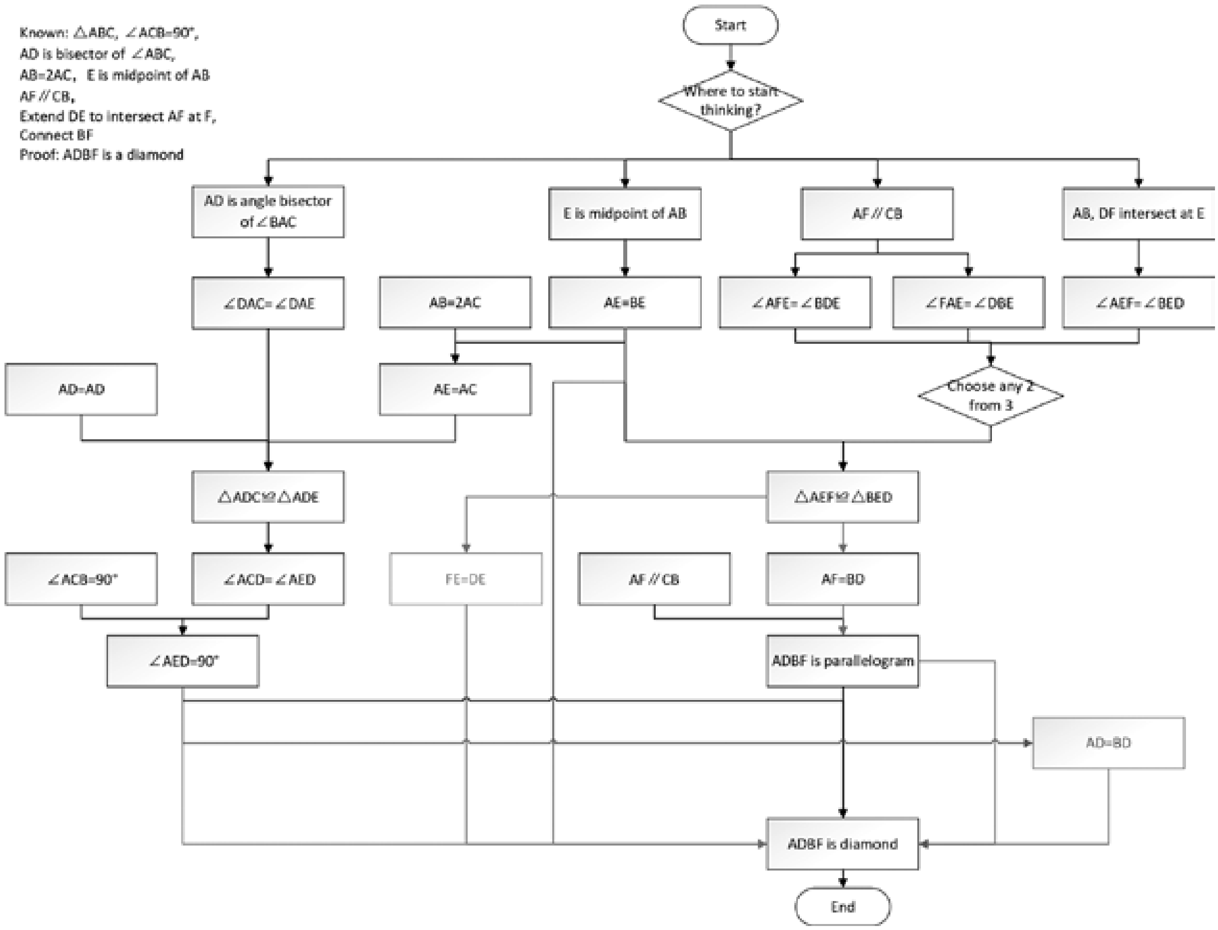

Figure 9: Thinking Tree model: demonstrating a simple geometry problem different color means different thinking path

step is to list all the possibilities of every thinking node for each student without missing. Among them, the most important question is "without missing". It includes not only the right path, but also the wrong path, even the path which the students can't be think completed. Because in one certain geometry problem, the number of conditions and conclusions are limited, so the number of thinking nodes and thinking paths are limited. When we summarize and modeling all the thinking possibilities of all the thinking nodes of the problem, we get a "Thinking Tree" covering the whole thinking process about this problem.

The "thinking tree" model consists of two parts:

1. **Mathematical knowledge database**
   Storing the mathematical thinking tree which contains the thinking analysis methods of mathematical problems and mathematical arguments causal relationship. It's the fundamental basis of all the mathematical thinking and analysis like an analysis knowledge base of mathematical problems.
2. **Thinking method Rule database**
   The simulation rule of artificial thinking process for mathematical problem solving. This algorithm can identify the user's way of thinking and determine the accuracy of the user thinking.

Thinking software

Thinking is a junior middle school math learning software which is based on the "Thinking Tree" as theoretical basis and "the Evaluability of Thinking Process" as core technology. "The Evaluability of Thinking Process" technology of Thinking is mainly through the following four ways to achieve:

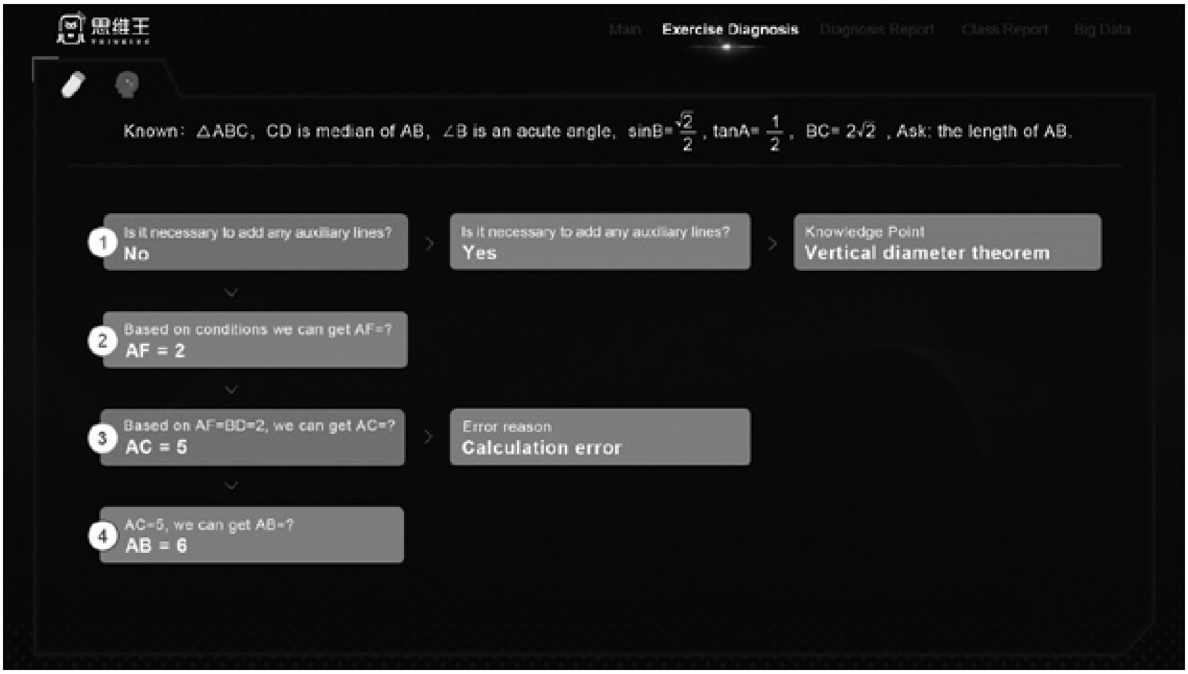

Figure 10: Recorded thinking process of one geometry problem by one student

1. **Thinking tree display and guide interface**
   Through the human-computer interaction, the user answers the question provided by the system to complete the problem solving of the mathematical problem. At the same time, the user can view the thinking and proof process of each question, and in which step mistakes have been made.
2. **Human-Computer Interaction Interpretation System**
   It is to explain why the system adopts a rule and the result is based on what. For example, a mathematical problems have varieties of solutions, the system can determine the user finally come to which solution based on the different thinking process for different users. For another example, there is a loop in the thinking process of the user, the system can tell the user what is the reason for the loop and the thinking solution without loop.
3. **Mathematical Thinking Simulation Deriving System**
   The system can identify the user's thinking mode according to the information provided by the user, use the optimization query algorithm from the "Thinking Tree" model to find the matching knowledge and rules. Through the deriving algorithm to find out the most appropriate response steps to ensure the normal process of solving the problem.
4. **Integrated database**
   The database consists of three main databases:
   Dynamic database is a temporary database generated by the system during operation. It is used to store the system rules activated by the user in the process of solving the mathematical problems, the intermediate solution generated by the system and the reasoning process of the system interruption.
   Information Guidance Database stores the guide message when the user thinks about the math problem. For example, in a mathematical problem, the user using the same condition may be derived completely different conclusions in different process of solving the problem. So the deriving of the condition in the process of solving the problem is not unique. The database will provide different guidance tips based on different derivations to help connect the user's thinking

process, to avoid the user's thinking process interrupted.

User Thinking Record Database is permanently storing a user's problem-solving process. The establishment of the database provides a good basis for data mining and a strong data support for the improvement of performance and education.

The evaluation of traditional education is the "right and wrong" evaluation only for the answer. As long as the answer is right, the student can get a full score. No matter how the student gets the answer, whether it's by copying, by guessing or by cheating. At some time, there're twice wrong steps during the way to achieve the answer and these mistakes have been offset so that the result turns out to be "right". Therefore the evaluation of traditional education can't accurately reflect the real quality of learning and teaching quality.

The creation of **Thinking** is to reveal how the student start to think when getting a mathematical problem and how to think step by step. On the basis of thinking process, analysis and evaluate the correctness of every thinking steps for the students. As long as the student has a thinking behavior, the software can record, reveal and evaluate. The reason why the student can make the mistake at the certain step; the reason why the student can't complete the whole thinking path; the reason why the student make the loop during the thinking path. All of these can be analyzed clearly. This is "the Evaluability of Thinking Process" based on "Thinking Tree" method.

CONCLUSION

The significance of our research lies in the usage of the Elementary Periodic Table in the field as the set of basic graphics per Basic Graphic Analysis Method, to deconstruct any plane geometry problem and simplify the process, so that the plane geometry problem understanding could be more standardized, concise and traceable [3]. It builds a solid base of bilingual cognitive features by geometry that not only the human' cognitive structure by geometry problem could be standardized and improved, but also information processing by computer for geometry problem could be established [4][5][6].

After years of development, the Basic Graphic Analysis Method has been widely applied and achieved good results. Besides the more standardized and accurate description of geometry problem per Basic Graphic Analysis Method, we have achieved the combination of Basic Graphic Analysis Method and modern Information Technology in the field of K12 education and realized the Visualization and Evaluability of Thinking Process in plane geometry per two developed software Geomking and Thinking.

But it is only a first try in the field of K12 education. In fact, on the basis of the realization of the thinking process, it is possible to extend the research field from education to other fields. As long as it involves human thinking activities, the research can be done by "the Visualization and Evaluability of Thinking Process". So that it can accumulate the data of "the Visualization and Evaluability of Thinking Process" for different fields and questions one by one. Finally achieve the goal to simulate the human thinking activities and promote the artificial intelligence research a step forward.

REFERENCES

Gan, Hongli (2015). The 'law' of junior high school plane geometry education—Basic Graphic Analysis Method, *School Mathematics in Shanghai*. No.1-2, pp.9-11.

Xu, Fangqu (1998). *Basic Graphic Analysis Method*, (in Chines) Zhengzhou: Elephant Publishing House.

Xu, Fangqu and Xu, Wen (2017). *Transparent Geometry—New Practice of Internet + Planar Geometry*, (in Chinese) Shanghai Education Publishing House.

Zou, S. and Zou, X (2017). Understanding: How to Resolve Ambiguity. In: Shi Z., Goertzel B., Feng J. (eds) *Intelligence Science I. ICIS 2017. IFIP Advances in Information and Communication Technology*, Vol. 510. Springer, Cham

Zou, S., Zou, X. and Wang, X (2018). How to Do Knowledge Module Finishing. In: Shi Z., Pennartz C., Huang T. (eds) *Intelligence Science II.*

ICIS 2018. IFIP Advances in Information and Communication Technology, Vol. 539. Springer, Cham

Zou, Xiaohui and Zou, Shunpeng (2015). Bilingual Information Processing Method and Principle. *Computer Applications and Software*, (11):69-76 and 102.

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