QULITY DETECTION FOR CHINESE PAPER CHART PRODUCTION BASED ON KNOWLEDGE RULES

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ABSTRACT:

The quality of chart production is the core and soul of the foundational marine information. However, at present there exist some problems such as much repeated work, low efficiency and a great of waste in quality detection for paper charts in China. Aiming at these problems, a new method of quality detection for paper charts based on knowledge rules and quality standard database is presented in this paper. The core idea of this method is to study the criterion and production process of paper charts to form the knowledge rules for quality detection, and build a standard quality detection database of paper charts. Based on the quality detection database and knowledge rules， relative detection algorithms can be designed for detecting each chart element. In this paper we focus on the quality detection for three typical chart elements that are labels, navigation markers, and tide tables. And the application system named ChartQD was developed. It has been applied in TianJin Marine Safety Administration Bureau and obtained a good evaluation.

1. INTRODUCTION

It is well known that quality is the soul of hydrographic survey work. The International Hydrographic Organization (IHO) always emphasizes the fast, perfect hydrographic products and achievements of global coverage of reliable hydrographic data (Angrisano, 2001). In China, a lot of researches in the quality detection and control of charts especially digital charts have been made and several systems have already been developed such as quality detection and evaluation system for digital chart and quality checking system for chart publishing, etc(Li, S.J. 2001; Sun, W.M., Sun, Q., Shen, J.S., Xiao, Q., 2004). Although digital charts are more and more popular in recent years, the printed chart is still very important for some users. The printed chart and electronic chart will coexist for a long time in twenty-first century (Li, 2001). So the quality detection system for paper charts production is still important and urgent for Chinese Marine Safety Administration Bureau (CMSAB).

At the beginning of the 1990's, CMSAB begun to use CARIS (one software for hydrographic and marine industries produced by Universal Systems Limited of New Brunswick in Canada) and other small softwares to produce charts of ports and channels along China coast. At present, the quality detection and control for paper charts mainly adopts manual means that are done by naked eyes through personal experiences. After several reviews and several revisions, the final marine charts are published. The main problem of these detection methods is that not all of the quality problems can be detected completely. It is precisely these undetected problems that may bring on a great catastrophe to shipping. And there exist some other problems such as much repeated work, low efficiency and a great of waste. Therefore, it is very urgent to develop an effective method to solve the problems of quality detection for paper charts in China.

Aiming at above problems, a new method and strategy of quality detection for paper charts based on knowledge rules and standard database is presented in this paper. This method can realize semi-automatic detection with artificial assistance and greatly improve the efficiency and accuracy of paper chart quality detection compared to the current quality detection methods for paper charts.

2. THE ARCHITECTURE OF CHART QUANLITY DETECTION

The chart quality detection can be divided into two parts: the design of quality detection algorithms based on knowledge rules and quality standard database, and the process of charts detection with quality detection modules and standard database. The architecture of the chart quality detection is described as Fig.1.

The core idea of the method based on knowledge rules and quality standard database is that: Firstly, the criterions and production process of paper charts, the properties of each object in charts as well as the relationships between them and expert experience are studied and induced to form the knowledge rules of quality detection for paper charts. Secondly, the quality standard database of paper charts according to these knowledge rules and suited marine chart elements for quality detection are designed and built. Thirdly, considering the contents of chart quality detection and all the possible types of errors for each

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suited chart element, corresponding detection algorithms are designed through the combination of obtained knowledge rules and quality standard database. At last, based on these algorithms, so-called COM techniques are employed to design flexible chart quality detection modules. Each suited chart element can be detected by corresponding detection module and quality standard database.

In this paper, the quality detection of three typical and important chart elements including labels, navigation markers, and tide tables are emphasized. There are several forms to express the results of quality detection including error hint texts, error postil layers (using specific symbols to mark out all the wrong elements, and give clear indication of the wrong types and how to revise), and chart publication. So, the users can rapidly correct all the errors of paper chart according to the hints of these detection results.

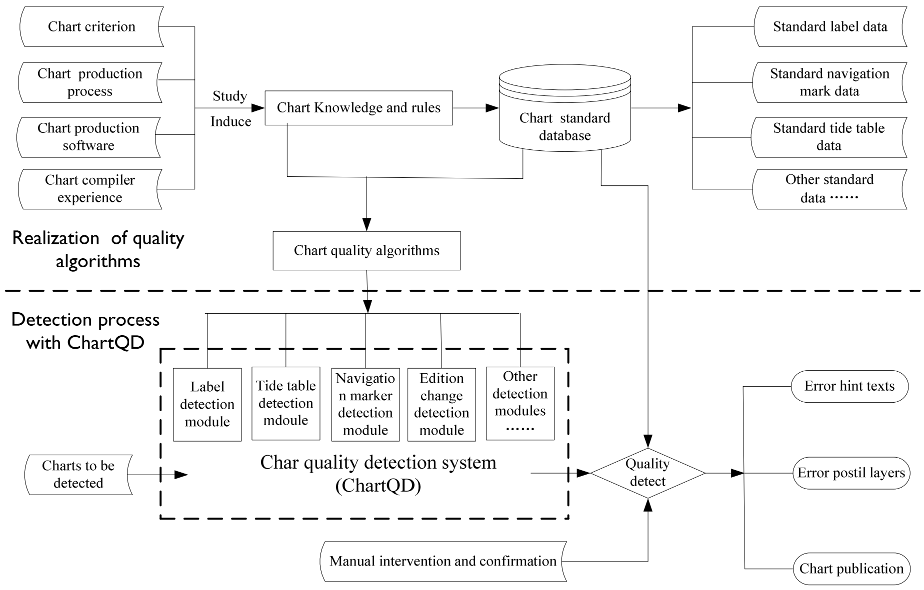


Figure 1. The architecture of chart quality detection

3. THE DESIGN AND CREATION OF CHART QUALITY STANDARD DATABASE

Considering there are lots of chart elements, such as labels, navigation markers and tide tables, which commonly do not change in their spatial information and attribute information for a long time and the errors of which often follow a pattern, we propose a strategy based on quality standard database to detect the quality of these chart elements. Chart quality standard database is the basis and standard to detect and control the quality of paper charts. We can detect the quality of paper charts through the comparison with the data of detected charts and the data of chart quality standard database. In order to improve the efficiency and accuracy of quality detection based on standard database, the design of standard database structure that can be easily extended should be considered foremost.

3.1 The Overall Design of Quality Standard Database

Before the design of quality standard database for marine charts, the classification of chart elements and the characteristics of each element should be considered first in order to make sure which elements can be detected by the strategy of quality standard database. Then we can design the structure of quality standard database based on marine chart knowledge for quality detection and the characters and mapping criterions of suited chart elements.

The chart quality standard database is composed of foundation information standard dataset, chart rules standard database, label standard database, navigation marker standard database, tide table standard database, and other assistant standard database, etc.. The architecture of the chart quality standard database is shown as Fig.2.

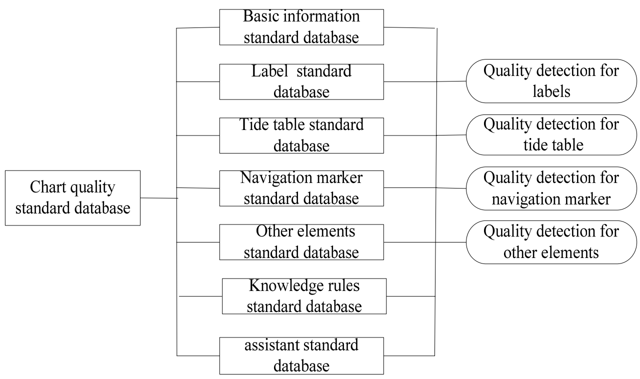


Figure 2. The architecture of chart quality standard database

3.2 The Design and Creation of Label Standard Database

It is extremely important that the labels are in every map. So are the chart labels. The quality of chart labels can be detected by the label standard database. All of the standard label data, including Chinese labels, English labels and digital labels, are stored into the label standard database which can be used to detect the completeness of label’s contents, check the rationality of label’s position, judge the validity of label’s colour, and reflect the veracity of object’s quantity, etc.

According to the difference of chart labels, we establish several different tables in the chart label standard database. The classification of label standard database is shown as table 1.

The sort of label	Standard database	Corresponding object
Label with scale	Standard database of Chinese label with scale	Populated place name; ocean, river, lake, island name; boundary line of region; mountain range name; offshore installation; sweeping label; note of magnetic variation; magnetic anomaly label; dock, berth, radio waves, anchorage berth label; etc..
	Standard database of English label with scale	
Label without scale	Standard database of Chinese label without scale	Navigational channel mark label; title of tide table and tidal stream table and the Chinese label in them; map sheet decoration label; bottom characteristics label; wreck, barriers and discoloured water label; front view; proprietary name and other descriptive name; etc.
	Standard database of Chinese label without scale	

Table 1. The classification of chart label standard database

Because of the differences between Chinese labels and English labels, the corresponding methods for quality detection are discrepant. So the standard database of Chinese labels and English labels should be built separately. The labels, which vary along with the map scale, should be stored in standard database in all of the scales. While the labels that do not vary along with the map scale are enough to be recorded in standard database one time. This can largely reduce the work load and enhance the efficiency.

3.3 The Design and Creation of Navigation marker Standard Database

As an important navigation tool, the navigational channel mark plays an important role in ports and channels in China, which is essential to the security of waterborne transport and maritime operations (Wu, J.P., Cai, S.Z., Liu, H.S., 2006). So the quality of navigation markers is all-important in charts, which can be inspected and controlled by the navigation marker standard database.

Name of database	Structure of standard database	Function description
Navigation marker standard database	Including navigation marker position; light height; light range; light characteristics; light structure colour; etc.	Checking the veracity of navigation marker position and annotations
Navigation markercharacter code standard database	Including navigation marker character code; corresponding type code; navigation marker name; etc.	Associating navigation marker with type code in the standard database of navigation marker
Navigation marker label character standard database	Including the characters of navigation marker label, including font, width, height, colour, interval, etc.	Detecting the correctness of the navigation marker label characters

Table 2.The structure of navigation marker standard database

The navigation marker standard database, including three parts: standard database of navigation marker character code navigation marker and standard database of navigation label character, which is used to detect the quality of navigation marker. The navigation marker standard database can check the location of Navigation markers and detect the veracity of navigation marker annotations including height of light, light characteristics, and light range, etc. The structure of navigation marker standard database is described as table 2.

3.4 The Design and Creation of Tide Table Standard Database

The tide tables shown in charts provide basic status of tides for the Mariners to roughly calculate the height of tide and the time of flood or ebb of sea areas. The formats of the tide tables are decided by the types of the tide tables, which include three types: tabular statement of diurnal tide, tabular statement of semidiurnal tide, and tabular statement of mixed tide (GB 12319-1998).

The quality of tide tables including the correctness of the tide table lines and the tide table labels can be inspected by the tide table standard database, which includes following tables: tide table format standard database, tide table line format standard database, standard database of tabular statement of diurnal tide, tabular statement of semidiurnal tide standard database, tabular statement of mixed tide standard database, tide table label character standard database. The structure of tide table standard database is shown as table 3.

Name of database	Structure of standard database	Function description
Tide table format standard database	Including fixed formats of every tide table	Judging the type of tide tables in chart for checking
Tide table line format standard database	Including fixed formats of the lines of every tide table	Checking the correctness of the lines of tide tables
Tabular statement of diurnal tide standard database	Including all of the annotations in tabular statement of diurnal tide	Detecting the correctness of the annotations in tabular statement of diurnal tide
Tabular statement of semidiurnal tide standard database	Including all of the annotations in tabular statement of semidiurnal tide	Checking the correctness of the annotations in tabular statement of semidiurnal tide
Tabular statement of mixed tide standard database	Including all of the annotations in tabular statement of mixed tide	Detecting the correctness of the annotations in tabular statement of mixed tide
Tide table label character standard database	including the characters of tide table label, such as font, width, height, colour, interval, etc.	Detecting the veracity of the tide table label characters

Table 3． The structure of tide table standard database

4. THE METHODS OF QUALITY DETECTION FOR CHARTS BASED ON KNOWLEDE RULES

Knowledge discovery and data mining is a multidisciplinary effort to mine or extract useful information from data (Liu F.Y., 2006). We can design quality detection algorithms according to discovered knowledge rules. So a new method of quality detection for paper charts based on knowledge rules and quality standard database is proposed in this paper, which can be used to detect all the possible quality errors of paper charts more accurately and efficiently.

4.1 The Methods of Discovering Knowledge Rules for Quality Detection

In this paper, the purpose of knowledge rules discovery is to design quality detection algorithms that can be used to detect and control the quality of paper charts. Before acquiring these knowledge rules, the most important thing is to have a certain source of knowledge rules. The knowledge rules for quality detection mainly source from the following aspects:

- The existing norms and regulations for nautical charting, such as nautical chart symbols and abbreviations, chart compilation outline, nautical charting database building specification, and chart production processes etc.
- Each suited chart element's characteristics and mapping standards as well as the summarization of quality error laws.
- Expert experience and summarization from solving actual problems in hydrographic charting.

According to above sources, the knowledge rules can be discovered through specific methods or means. Generally speaking, there are mainly two approaches to discover knowledge rules for chart quality detection. One is statistical approach, and the other is classification approach (Liu F.Y., 2006).

4.1.1 Statistical Approach: The statistical approach can automatically select useful attributes to construct knowledge rules through the results of statistic. This type of induction is used to generalize patterns and to construct rules from the noted patterns.

4.1.2 Classification Approach: The classification approach classifies data according to similarities or classes of nautical charting sources so as to form corresponding knowledge of each classification.

4.2 The Label Quality Detection Algorithm

4.2.1 Types of Label Errors: Through all the possible reasons of the chart labelling errors, the characteristics and mapping requirements of chart labels, we can summarize the main types of chart labelling errors as follows:

a) The location of chart label is incorrect.

b) The existent label is forgotten to draw.

c) The label contents are wrong.

d) The characters of the label are incorrect.

e) The label does not conform to the principles of chart labelling.

While developing the algorithm of label quality detection, it is essential to consider all possible types of chart labelling errors.

4.2.2 Core Idea of the Algorithm: The method of label quality detection algorithm is used to inspect the rationality of label's position, the completeness of label's contents, the correctness of label's colour, font, font size, shape and interval, etc. The idea of this arithmetic is to gain the knowledge and rules of chart labels firstly, then analyze the inspecting contents and all of error types of chart labels, and design the algorithm of chart label quality detection based on rules and label standard database at last. The algorithm of labels quality detection is shown as Fig.3.

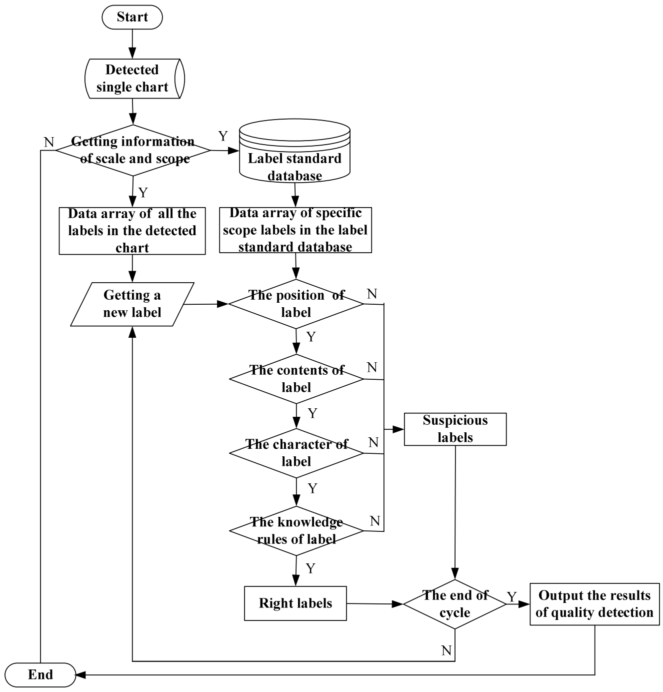


Figure 3.The algorithm flowchart of labels quality detection

4.2.3 Some Rules of Chart Labels: According to the characters and criterions of chart labels, some main label rules can be summarized as follows:

- Each label in detected chart must have corresponding matching label in label standard database, or the label is wrong.
- For single point label (the location of a label is confirmed by a coordinate), it must match the label directly in label standard database, otherwise the label is suspicious.
- In a multi-character label (the number of characters of a label is more than one), each character in font, height, width, colour and shape is consistent with the one in label standard database, or the label is incorrect.
- The character intervals of a label including more then two characters must be equal in certain scope, or the label is an incorrect one.
- The Angle of the link between characters of a label including more then three characters must more then 90^o, and each angle is basically same, otherwise the label is suspicious.
- When the arranging direction of a label is the upper left corner, which doesn't accord with reading habits, the label is a suspicious one.

4.3 The Navigation marker Quality Detection Algorithm

4.3.1 Types of Navigation marker Errors: Due to system analysis, the main types of navigation marker errors can be summarized as follows:

a) The navigation marker position is incorrect.

b) The symbol of navigation marker is wrong.

c) The contents of navigation marker label, such as height of light, light characteristics, light range, structure colour, etc., are incorrect.

d) The characters of navigation marker label are improper.

e) The selection and rejection of navigation marker symbols and labels does not conform to the requirement.

It is extremely important to consider all possible types of chart navigational channel mark errors to develop the arithmetic of navigation marker quality detection.

4.3.2 Core Idea of the Algorithm: The position of navigation marker and the navigation channel mark label, including light characteristics, height of light, light range and the colour of structure can be inspected by the arithmetic of navigation marker quality detection. The idea of this arithmetic is that: first gaining the knowledge and rules of chart navigation marker, then analyzing the inspecting contents and all of error types of them, lastly designing the algorithm of chart navigation marker quality detection based on above rules and navigation marker standard database.

4.3.3 Some Rules of Navigation marker: According to the characters and the production process of navigation marker, some main rules of navigation marker can be summarized as follows:

- If a navigation marker appears in a detected chart, there must be the same datum in navigation marker standard database; otherwise this navigation marker is a suspicious one.
- The name and serial number of navigation channel mark in navigation marker standard database and in detected chart must be unique, or the navigation marker is suspicious.
- The navigation marker that has luminescence symbols must have corresponding labels, whereas the one that doesn't have luminescence symbols is incorrect to have corresponding navigation marker labels.
- The navigation marker labels including light characteristics, height of light and light range must be in a certain range around the navigation marker.
- The characters of navigation marker labels must be consistent with the corresponding data in navigation marker database.

4.4 The Tide Table Quality Detection Algorithm

4.4.1 Types of Tide Table Errors: Owing to system analysis of the tide tables, we can summarize the main types of tide table errors as follows:

a) The format of tide table is improper.

b) The format of lines composing tide table is wrong.

c) The label contents in tide table are incorrect.

d) The characters of labels in tide table are wrong.

While developing the algorithm of tide table quality detection, it is essential to consider all possible types of chart tide table errors.

4.4.2 Core Idea of the Algorithm: The purpose of studying the method of tide table quality detection algorithm is used to inspect the correctness of tide table line and the labels in tide tables. The idea of this arithmetic is to first gain the knowledge and rules of chart tide tables, analyze the inspecting contents and all of error types of them, and design the algorithm of chart tide table quality detection based on tide table rules and tide table standard database.

4.4.3 Some Rules of Tide Table: According to the characters of tide tables, some main rules of tide tables can be summarized as follows:

- Tide table includes three type tables: tabular statement of diurnal tide, tabular statement of semidiurnal tide and tabular statement of mixed tide. Each type of tide tables has fixed format, and the height and width of it has fixed size. If tide tables in detected chart don't accord with the rules, the tide tables are wrong.
- The formats of the lines composing tide table, such as line's width, line's colour, and line's type, must accord with the records in the tide table line character standard database, otherwise the tide table is incorrect.
- The label in the tide tables must be one-to-one corresponding with the data in tide table standard database, otherwise the tide table label is a suspicious one.
- The characters of tide table label must be consistent with the corresponding data in tide table database, or the corresponding label is incorrect.

5. THE IMPLEMENTATION OF CHARTQD

According to the quality detection algorithms based on knowledge rules and the chart quality standard database, we have accomplished a prototype system named as ChartQD. ChartQD, in which Access database is the management system for quality standard database, mainly includes creating module and maintenance module of quality detection standard database, label detection module, tide table detection module, navigation marker detection module and different edition change detection module, etc. The interface of ChartQD is shown as Fig, 4.

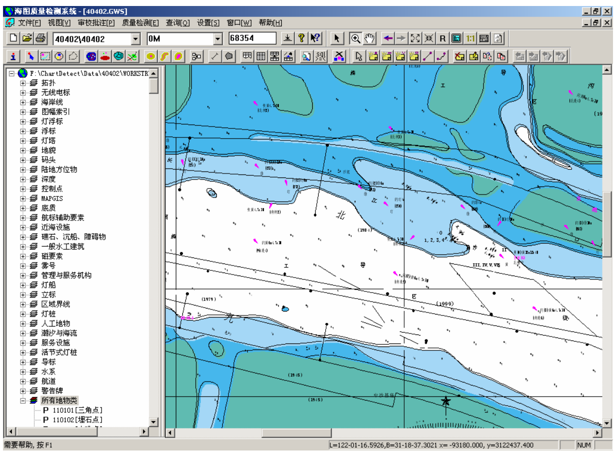
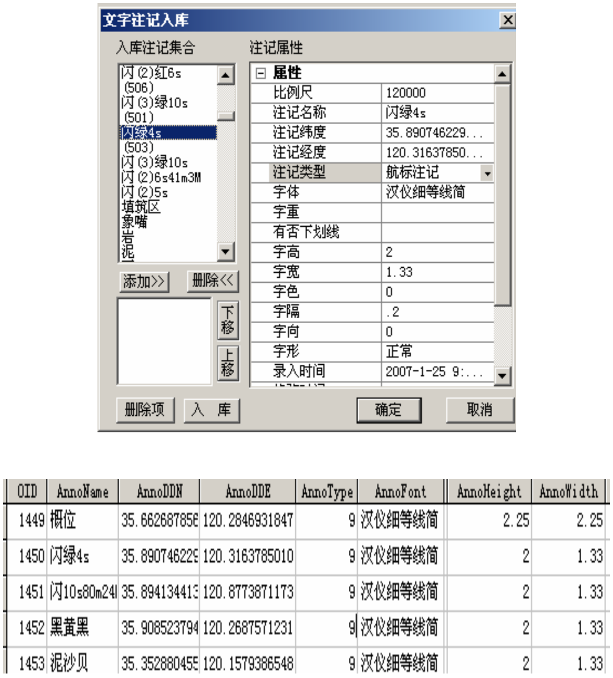


Figure 4.The interface of ChartQD

5.1 The Implemented Functions of ChartQD

5.1.1 The Creation and Update of Chart Quality Standard Database: The creation of quality standard database is through database-building tools, by means of manual assistance. The updating operation of standard database can add, delete, and modify records, so the standard database is integrated and up to date.

To create and update the quality standard database, the key is to define well, easily enlarged database structure and provide creating tools as well as update tools with good capability. Only in this way, quality detection standard database is a real, suitable standard database, and will be created, updated conveniently, rapidly and exactly. The user interface of creating label standard database and according data in label standard database are shown in Fig. 5.



OID	AnnoName	AnnoDDN	AnnoDDE	AnnoType	AnnoFont	AnnoHeight	AnnoWidth
1449	楣位	35.66268785	120.2846931847	9	汉仪细等线简	2.25	2.25
1450	闪绿4s	35.89074622	120.3163785010	9	汉仪细等线简	2	1.33
1451	闪10s80m24	35.89413441	120.8773871173	9	汉仪细等线简	2	1.33
1452	黑黄黑	35.908523794	120.2687571231	9	汉仪细等线简	2	1.33
1453	泥沙贝	35.35288045	120.1579386548	9	汉仪细等线简	2	1.33

Figure 5. The user interface of creating label standard database and according data in label standard database

5.1.2 The Quality Detection for Label: We can detect incorrect or doubtful labels in every chart by the label standard database and the label detection module. The results of label quality are in the forms of mistake hint texts and wrong postil layers. The users can modify the error labels accordingly. The comparison of the interfaces before and after label quality detection is shown in Fig.6, the upper figure is a chart before detected, and the nether one is the corresponding chart after detected. From the nether figure, we can see that the dialog box lists all the wrong labels, while the window on the right locates the error labels and produces mistake postil, so that user can correct those mistakes under the clues.

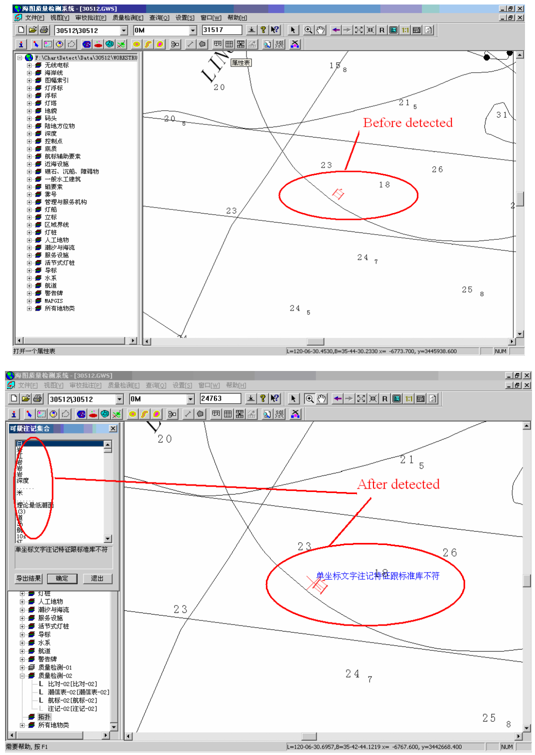


Figure 6. The comparison of the interfaces before and after label quality detection

5.1.3 The Quality Detection for Navigation marker: According to the navigation marker standard database and the navigation marker detection module, the inaccurate or doubtful navigation markers and the labels of them can be detected quickly. Moreover, these detected results are in the forms of mistake hint texts and mistake postil layers, which help chart drawers to modify the error position of navigation markers or the inaccurate labels of navigational channel marks accordingly.

5.1.4 The Quality Detection for Tide Table: Taking the tide table standard database as the basis, we can detect the errors of tide tables, including the mistakes of the tide table lines and the labels in them, by the help of the tide table detection module. The detected results are in the forms of mistake hint texts and error postil layers, which is useful for chart drawers to modify the tide table errors accordingly.

5.1.5 The Change Detection of Different Chart Editions: The change detection for different chart editions is used to detect the difference between every two different chart editions. It is very useful to detect all the elements changed so that chart makers can track and control all the modifications of chart data in different editions, which is very important to the quality detection and control of charts.

5.2 The Analysis of Experimental Results

In order to show the detective effect of the quality detection method based on knowledge rules and quality standard database presented in this paper, a lot of experimental tests have been made to show that whether the errors introduced deliberately can be found by ChartQD. According to the analysis of numerous test results, the ChartQD can find errors of paper charts more effectively and accurately. The experimental results detected by ChartQD are shown as Tab. 4.

	The number of errors introduced deliberately	The number of errors detected by ChartQD	The correct rate of quality detection
Labels	100	93	93%
Navigation markers	100	91	91%
Tide tables	100	95	95%

Table 4. The experimental results detected by ChartQD

From the statistics in Tab. 4, we can see that ChartQD can detect the errors of labels, navigation markers and tide tables in a quite high accuracy. In the label detection, the errors like wrong contents and incorrect labeling characters can be detected without any problem, whereas the errors relating to the connections between the label and corresponding object still can not be detected completely because the connections are quite complex. In the navigation marker detection, most errors can be found properly expect some errors such as the labels of light height, characteristics and range have not been generalized correctly. In the tide table detection, if the forms of tide table are right, almost all the errors can be found. After detected, the users could quickly modify the errors according to the hints of detection results. The comparison of quality detection between traditional method and new method presented in this paper is shown as Tab.5.

	Traditional method	New method
Way used	Manual means completely	Semi-automatic with artificial assistance
Time cost	More than 2 hours	About 10 minutes
Accuracy	65%~85%	80%~95%

Table 5. The comparison of quality detection between traditional method and new method presented in this paper

From the comparison of quality detection between traditional method and new method based on knowledge rules and quality standard database in the Tab. 5, we can see that the new method can enhance the quality detection accuracy and shorten the time cost in detecting a single paper chart.

Therefore, it can be concluded from the experimental results that ChartQD developed by the method based on knowledge rules and quality standard database can be used as an effective tool to detect and control the quality of paper charts.

6. CONCLUSION

In this paper, a new method for paper chart quality detection based on knowledge rules and chart quality standard database is presented. The accomplished quality detection system known as ChartQD has been applied in CMSAB and obtained a good evaluation. The Practices have proved that this method can control the chart quality more effectively compared with many traditional methods used currently. The system realizes the semi-automatic paper chart quality detection with artificial assistance, reduces the workload, and greatly improves the accuracy of paper chart quality detection. Since paper chart is one type of maps, the quality detection method based knowledge rules and quality standard database can be applied in other types of maps to some extent.

Through lots of analyses and experiments, the quality detection method based on knowledge rules and quality standard database is quite suitable to the quality detection for chart elements whose space position and properties hardly change. But for those elements which frequently change and has no regular mistakes, this method is not quite suited because the chart standard quality database has to change frequently and the quality of chart standard quality database is difficult to guarantee. So the quality detection for those elements that change frequently needs a further research.

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