Software Development for Determination and Transfer of Chart Datum

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Abstract- **For the idea that serve for the uniform of chart datum and sailing safety, this paper presents the software development of determination and transfer of chart datum. Two key technologies, the tidal harmonic analysis and datum transfer, are studied firstly. Then the design method, features, structure and operation model of the software are depicted in detail. Finally, the software performance is tested. The experimental results proved the software to be reliable and stable.**

I. INTRODUCTION

In hydrographic measurement, the expression of vertical solution of underwater footprint needs to refer to chart datum, and serves the sailing. It is well known that the chart datum is different from each other at various tidal gauges.

That the chart datum is given to be correct or not decides the sailing safety. There are many types of chart datum, such as lowest astronomical tide (LAT)，lower low water large tide(LLWLT), mean lower low water(MLLW) and so on. In China, the LLWLT was adopted before 1956, while the theoretical bathymetrical datum proposed by the former Soviet Union Vladimir has been used in China since 1956 [1]. Both of the two chart datum have been adopted in different water areas.

In addition, the chart datum is defined artificially in some water areas. Therefore, the phenomenon of non-uniform chart datum exits in China. Besides, in practice, different kinds of tidal observations, such as tidal gauges, temporary tidal observations implemented by water rulers or pressure tidal observation meters, exist in the same surveying area. In order to express the seabed in a uniform vertical reference frame, it is necessary to fulfill the determination and delivery of chart datum from long-period tidal gauges to the temporary one.

With GPS applying in hydrographic measurement, another requirement becomes urgent, which is how to transform the GPS ellipsoid height to chart height. In the transformation, the separation between ellipsoid surface and chart datum needs to be known for the construction of the transformation model.

Based on above requirements, the software development for the determination and transfer of chart datum is very necessary.

II. KEY TECHNOLOGY USED IN THE SOFTWARE

The software mainly includes two tasks, namely the determination and transfer of chart datum.

A. Determination of chart datum

In the work, some key technologies and algorithms are studied and used in the software. Firstly, tidal harmonic analysis based on the least squares harmonic analysis method is studied. The analysis method can be expressed as following [1][2][3].

$$T(t) = MSL + \sum_{i=1}^{m} f_i H_i \cos\left[q_i t + G_i(V_0 + u) - g_i\right] \qquad (1)$$

where, $T(t)$ is the tidal height; MSL is the mean sea level; f_i is the intersection factor of tidal component; H_i and g_i are the harmonic constants; q_i is the angular rate of tidal component; the $G_i(V_0 + u)$ is the astronomical phase at zero hour of Greenwich. In the software, the types of harmonic analysis are divided into three categories, which are the harmonic analysis of eight main tidal components (M_2, S_2, N_2, K_2, K_1, O_1, P_1, Q_1), that of eleven tidal components (besides above eight main tidal components, three shallow-sea tidal components, M_4, MS_4, M_6 are added) and that of thirteen tidal components (on the basis of eleven tidal components, two meteorological tidal components, such S_a and S_{Sa} are added) [4]. The 13 tidal components basically reflect the variation of actual tides. The 11 ones and 8 ones are adopted sometimes under low-accuracy tidal requirements.

Based on the three-category harmonic analysis, the theoretical bathymetrical datum can be determined with the harmonic constants by Vladimir model. The software also provides the models for the determination of other chart datum according to user needs.

B. Transfer of chart datum method

In order to solve the non-uniform problem of chart datum at different tidal gauges and the chart datum absence at temporary tidal gauges, the chart datum transfer is also studied in this paper, which is used for acquiring the chart datum or mean sea level (MSL) of short-period tidal gauge from long-period tidal gauge. There are many transfer methods for the transfer, such as synchronous correction method, tidal difference ratio method, and integrative transfer method and so on. These algorithms are made program in the software. By the comparison and analysis of experimental results, the integrative transfer method is thought to be optimum in accuracy and reliability. This method calculates the mean sea

Funded by Nature Science Foundation of China (NSFC) with authorized number of 40776048 and NSFC with authorized number of 40976061

978-1-4244-5222-4/10/$26.00 ©2010 IEEE

level and chart datum at the same time according to the physics properties of tide. It assumes that the water levels of long-period tidal gauge and short-period one can be expressed as function $C(i)$ and $D(i)$, both of the relationship can be depicted as following [5].

$$D(i) = xC(i+y) + z \tag{2}$$

Where, x is the ratio of tidal amplitude of the two tidal gauge; y is retardation coefficient of the tidal wave, namely phase difference; z is the difference of observation datum (zero point).

By shifting the water level of long-period tidal gauge along the horizontal and vertical direction as well as in scale, the water level of long-period tidal gauge matches well with the water level of short-period tidal gauge in maximum extent. The parameters x, y and z are also got. According to (3) and (4), the mean sea level and theoretical bathymetrical datum of short-period tidal gauge can be got by the transfer [6].

$$MSL_{short} = xMSL_{long} + z \tag{3}$$

$$L_{short} = xL_{short} + z \tag{4}$$

Now the mean sea level and the chart datum of all tidal gauges are transferred to a unified vertical datum system.

III. THE WHOLE PROCESS OF SOFTWARE SYSTEM AND ARCHITECTURE

The main interface of the determination and transfer of chart datum software is shown as Fig. 1. The software contains three parts, in which the menu bar is located in the top of main interface, the display window is set in the middle location, and the function frame is designed on the left of the interface.

The menu bar mainly includes five major function modules, which are open tidal file, quality control of tidal data, tidal harmonic analysis, transferring, browse report and help respectively. The functional modules are described in turn as following.

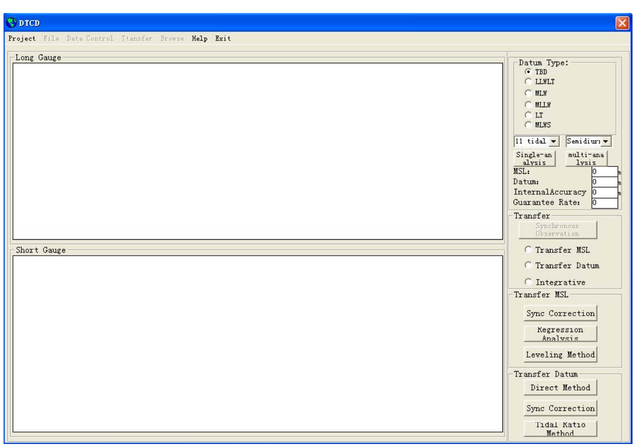

Figure1. The main interface of software

A. *Open tidal file*

The software can read tidal file in three formats. Each format is depicted in detail in the software's help file. User should firstly choose a tidal format before implementing the harmonic analysis so as to the software can recognize the file. The tidal curve will be displayed in the middle of the main interface, the name of tidal gauge and tide time also be annotated at the upper left of display window after determining the format and importing the tidal file.

B. *Quality control of tidal data*

This function module is mainly used to eliminate the gross error in the original tidal observation data, namely data filtering. The idea of the filtering is to get rid of the high-frequency observation noise based on the fast Fourier transform. The filtered data will automatically be saved.

C. *Tidal harmonic analysis*

In the upper-right side of the function frame, the determinations of six kinds of vertical datum, which are respectively theoretical bathymetrical datum, lower low water large tidal level (LLWLT), mean low water level (MLW), mean lower low tidal level (MLLW), lowest tidal level (LT), mean low water springs (MLWS) from top to bottom, are concerned and displayed . Below the six kinds of datum, there are two drop-down list boxes which represent the number of tidal components and the tidal nature at the tidal gauge respectively. User should choose the type of chart datum, tidal components number and the nature of the local tide before the harmonic analysis. The harmonic analysis has been divided into single-year analysis and multi-year analysis, the former will be applied to the tidal observation which the time length of tidal level series is not longer than one year, and the latter will be used for the tidal analysis which the length of tidal data is more than one year. Through (1), the analysis results can be got, which include mean sea level (MSL), harmonic constants of tidal components. Based on these parameters, the chart datum can be determined according to some chart datum model. The MSL, chart datum, internal accuracy analysis and guarantee rate of channel are displayed in the following text box. The results will be automatically saved. See in the Fig. 2.

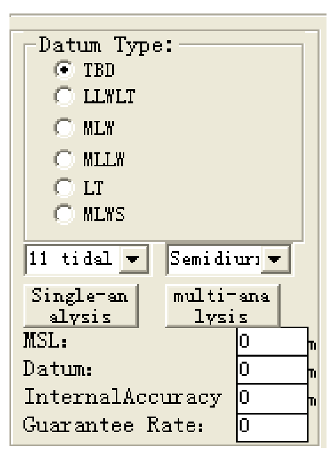

Figure2. The function frame

D. *Transferring of vertical datum*

This function module is to solve the non-uniform problem of chart datum at different tidal gauges and the chart datum absence at temporary tidal gauges. Firstly, the tidal data at the temporary tidal gauge need to be input. Then the observation data, which is synchronous with that from the long-period tidal gauge, is extracted out. Choosing a transfer method in the function frame or in the menu bar, the MSL or the chart datum of a long-period tidal gauge will be transferred to short-period tidal gauge. After transferring, the results will be displayed in the following text box. Using the integrative transfer method depicted in (2), Fig. 3 shows the transfer of chart datum. In the upper-half graphic window, the synchronization observations from the short period tidal gauge and the long period tidal gauge are shown. In the lower-half graphic window, the match degree of two synchronous tidal curves is shown. The blue line represents the mean sea level and the red represents the chart datum in the upper-half graphic window. In the lower-right corner of the main interface, the results which include the transferred mean sea level, chart datum, and the three parameters x, y and z. The results will be automatically saved.

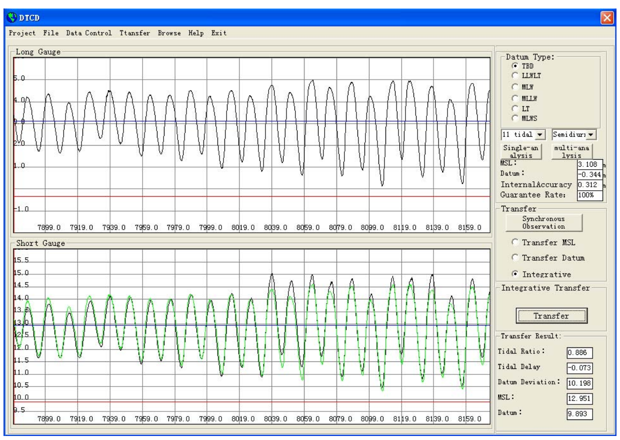

Figure3.Transfer of chart datum

E. *Browse the report and help*

In above harmonic analysis and transfer processes, the software will provide the reports of harmonic analysis and transfer. User can click the browse button in the menu bar to view the report so as to analyzing the credibility of results. The content of the harmonic analysis report includes the name of tidal gauge, tidal observation time, harmonic constants of tidal components, mean sea level (MSL), chart datum, the internal-consistent accuracy. Similarly after transferring, the transfer report will be generated which includes the long period tidal gauge and short period tidal gauge, tidal observation time, transfer method, transfer results and so on.

The "help" is used for browsing help files. At any operation procedure, user presses F1 button, the current operation explanation will be presented for user browse.

The overall running processes of the software and data steams are shown in the software structure (see Fig. 4).

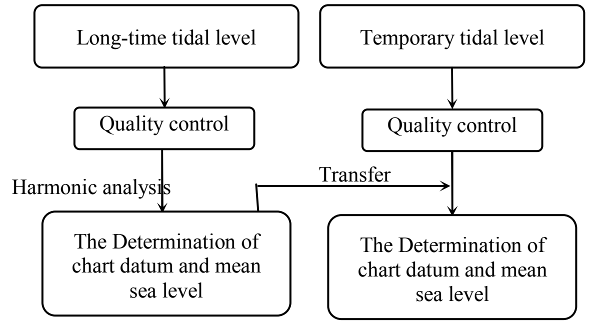

Figure4. Structure map of software

TABLE I

THE REQUIREMENT OF HARDWARE AND SOFTWARE ENVIRONMENT

Hardware environment			Software environment
CPU	Memory	Hard	Operating system
1.6 G	128MB	10 G	Window 98, 2000, XP

The structure map shows that all of function modules in the software serve the two main tasks, getting the MSL and chart datum of long period tidal gauge and short one.

IV. THE HARDWARE AND SOFTWARE ENVIRONMENT

The software is developed under the Visual Basic 6.0 environment. The hardware and software environment required are shown in Table I.

According to Table I, the hardware and software requirements of the software are not high. General computer configuration can meet it.

V. SOFTWARE TEST

In order to test the accuracy and stability of the software, a set of tidal data in Yangtze River estuary is used in the experiment.

The tidal data from three tidal gauges which are Xuliujing gauge, Chongtou gauge, Yanglin gauge respectively. The locations of three gauges are shown in the Fig. 5. The observation time length of these tidal gauges is from 2004 year to 2007 year.

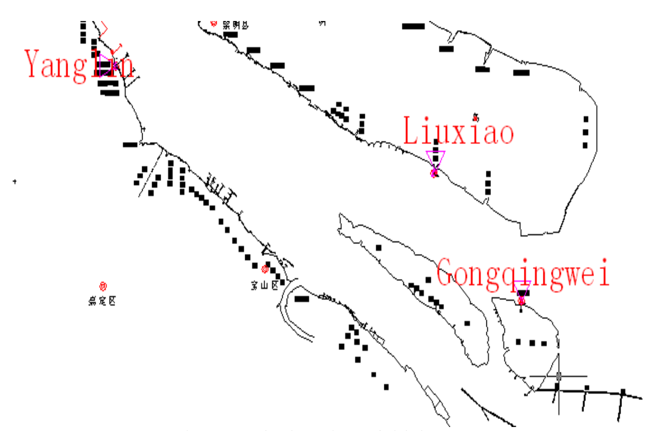

Figure5. The location of tidal gauge

TABLE Ⅱ

THE MSL AND CHART DATUM OF EACH TIDAL GAUGE

Gauge Year	Yanglin		Liuxiao		Gongqingwei	
	MSL	L	MSL	L	MSL	L
2004	2.552	0.462	2.476	0.211	2.271	0.041
2005	2.592	0.551	2.458	0.242	2.264	0.081
2006	2.568	0.476	2.428	0.194	2.258	0.014
2007	2.587	0.488	2.394	0.214	2.269	0.044
average	2.575	0.494	2.439	0.215	2.266	0.045
Multi-year	2.577	0.472	2.411	0.204	2.264	0.029

The mean sea level and chart datum of each year at the tidal gauge are calculated and shown in TABLE Ⅱ.

The L represents the chart datum, which is theoretical bathymetrical datum. According to the results in Table II, from the upstream Yanglin to downstream Gongqinwei, the MSL and chart datum are getting lower and lower. The maximum difference of MSL between each year is less than 5 centimeters at the Yanglin gauge, and the maximum difference of chart datum is about 9 centimeters. Similarly, the maximum differences between each year at the other gauges are about 5 centimeters. The results in Table II show the software results of the determination of chart datum and MSL are very stability.

An experiment is implemented for the test of vertical datum transfer from Yanglin gauge to Liuxiao gauge. Both the accuracies of different transferring methods and the results are shown in Table III

TABLE Ⅲ

THE RESULTS AND ACCURACIES OF DIFFERENT TRANSFERING METHOD

Yanglin ⩔ Liuxiao	Transfer		Harmonic analysis		difference	
	MSL	L	MSL	L	△MSL	△L
2004	2.474	0.187	2.476	0.211	-0.002	-0.024
2005	2.474	0.252	2.458	0.242	0.016	0.010
2006	2.421	0.133	2.428	0.194	-0.007	-0.061
2007	2.379	0.125	2.394	0.214	-0.015	-0.089

The integrative transfer method is used in this transfer experiment. Yanglin is thought to be long-period tidal gauge, while Liuxiao is thought to be short-period tidal gauge. The observation data in May is defined synchronous observation data. The results show that the maximum bias between the transfer and harmonic analysis is not more than 9 centimeters in the determination of chart datum and 2 centimeters in the determination of MSL. These statistic parameters show that the accuracy of transfer can meets the requirement of the chart datum determination.

In addition, the performance of the software has been tested. The test includes the size of memory occupied, the time consuming and largest file number in reading the tidal files in software operation. The test results are shown in the Table IV

TABLE Ⅳ

THE PERFORMANCE OF THE SOFTWARE

Test content		
Memory occupied	Time consuming	Maximum file size
20 MB	Less than 4 seconds	4.0 MB

VI. CONCLUSION

The determination and transfer of chart datum software has been developed in this paper. Whose design, structure and the function modules in the software are depicted and analyzed in detail. And the experimental results prove its advanced performance.

ACKNOWLEDGMENT

The research is supported by nature science foundation of China (NSFC 40976061 and 40776048). Authors acknowledge Mr. Zhou Fengnian, chair of the Survey Bureau of Hydrology and Water Resources of Yangtze Estuary, who support us to finish the research.

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