JGISE Vol. 8 No. 1 (2025), pp. 28 - 36 | https://doi.org/10.22146/jgise.101665

JGISE
Journal of Geospatial Information Science and Engineering
ISSN: 2623-1182 | https://jurnal.ugm.ac.id/jgise

Implementation and Validation of Online Tidal Analysis

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Diterima (*Received*): 19/11/2024 Direvisi (*Revised*): 03/06/2025 Diterima untuk Publikasi (*Accepted*): 03/06/2025

ABSTRACT

Tidal harmonic analysis extracts tidal components to understand regional tides that generally conducted using commercial or non-commercial software that needs to be installed on the user's local device. Currently there is still no online harmonic analysis service for tidal data, only an online tidal prediction service. Auto Tidal Pro is developed to perform harmonic analysis and prediction online and is designed to automate the process. It is built using the least square method and Java programming language for harmonic analysis and tidal prediction programs. This study aims to present the results of the development of the online tidal data analysis system called Auto Tidal Pro and its validation. Validation is conducted by comparing the results of harmonic analysis and predictions from the LP-Tides software and observational data. The tidal observational data used is from Balikpapan station. The validation results show that the amplitude component values are close to the LP-Tides results, but the phase values still show some differences. The RMSE value of the harmonic analysis results with Auto Tidal Pro ranges from 0.032-0.17 m, while the RMSE of LP-Tides results is 0.12 m. The MSL difference in about 0.012-0.004m. Auto Tidal Pro prediction produce wave patterns that are almost identical to the observational data and the LP-Tides predictions. The prediction RMSE gives values between 0.08-0.16 m, and the correlation between Auto Tidal Pro's predictions with observational data and LP-Tides predictions ranges from 0.930816-0.990809. In general, Auto Tidal Pro can be an alternative for tidal harmonic analysis and prediction.

Keywords: Tidal Harmonic Analysis, Tidal Analysis, Tides, Tidal Analysis Least Square Method, Least Square

1. Introduction

Tidal harmonic analysis can be performed with various software, both commercial and non-commercial. Commercial software usually offers a user-friendly interface and ease of use, although it requires a large cost investment due to the requirement of the license. Non-commercial software is also capable of providing results comparable to commercial software and is generally still line-based programs that require more understanding of program usage, but some are equipped with a GUI (Graphical User Interface). In addition, some non-commercial software requires supporting software that is commercial in nature. The similarity between the two software is that both must be installed on the user's computer and the type of installer file is adjusted to the computer operating system used by the user.

Tidal harmonic analysis software is generally performed with the least square method. Besides least square, it can also be done with admiralty and discrete fourier transform (DFT) methods. Least square can give good results. The advantages of the least square method for harmonic analysis are that it can calculate long-period data, and can calculate with data intervals of one hour and below (Pugh & Woodworth, 2014), also can calculate parameter precision.

Several developments of commercial and non-commercial software using least squares for harmonic analysis and tidal prediction exist. T_Tide was developed by Pawlowicz et al. (2002) based on Matlab. LP-Tides was developed by Sulistian (2020) based on Matlab. Tide_pyqt5 was developed by Harrys and Wolfe (2020) based on Python. VBA Excel harmonic analysis and prediction was developed by Ulum (2012) based on VBA in Excel. The web-based application was developed by Syetiawan (2014) using PHP and HTML programming languages and is currently inactive. Continuous Harmonics Analysis (CHD) was developed by Annunziato dan Probst (2016) for the internal use of the Joint Research Center (JRC). Commercial software developments include GeoTide (Taylor, 2022) by Dr. Steve Taylor MinstP, MIEEE, AFRIN; Total Tide Solution (TOTIS) (Sambasivam et al., 2023) by Hydrographyc Interest Group (HIG); and Tidal Analysis Software Kit 2000

(TASK-2000) (PSMSL, 2000) by Permanent Service for Mean Sea Level (PSMSL).

The development of technology and information encourages the development of data processing not only in the form of software but also online. Online data processing has begun to develop a lot and can provide good results. GNSS data processing online has long existed. Current developments lead to the processing of aerial photography data or point clouds. Some online services related to tides but the services are limited to predictions only such as NOAA Tide Predictions (NOAA, nd) which provides predictions for the US region only and Tide-Forcast which provides worldwide predictions for 196 countries. The advantages of online tidal data processing services are that users do not need to install software on their devices, can be used using various computer operating systems via a web browser, and can be used anywhere as long as they are connected to the internet. The number of devices that can access the service is unlimited, unlike commercial offline software that is limited by software licenses.

Online processing of tidal data or online tidal analysis can be built with various programming languages that support it. Java is one of the programming languages that can be used. Java is a programming language that can be used to create desktop, mobile, and web-based programs or applications. In addition, Java in its application is designed to have little dependence so that it is "write once, run anyware" (WORA) (Hariyanto, 2017). Java can be used as a front-end or back-end application for a web application and can be run on any computer operating system with the same file extension. This can support the creation of an online tidal analysis system.

There is no online tidal analysis system, especially in Indonesia. Several agencies in Indonesia use offline software such as GeoTide, LP-Tide, TASK, and Admiralty. The existing online analysis systems only provide services for tidal prediction using tidal models and harmonic constants from tidal station locations provided by the service providers, and no one has provided services for online harmonic analysis using tidal data. Based on the explained background, this study aims to report the results of making an online tidal data analysis system using the least square method using the Java programming language and named Auto Tidal Pro. The results of its implementation and validation are given to provide a comparison with other software.

2. Data and Methods

2.1. Data and Location

The tidal data used is the tidal data of Balikpapan station, Indonesia, owned by BIG (Badan Informasi Geospasial or Geospatial Information Agency) for validation. The data used is data for the period of January 1, 2023 to July 25, 2024 with a one hour data interval. The data is divided into two periods, that is year 2023 and year 2024. The 2023 data is used for harmonic analysis and prediction using Auto Tidal Pro and LP-Tides. The 2024 data is used for comparison of 2024 prediction graphs, calculating the RMSE and the correlation between 2024 predictions and observational data.

2.2. Methodology

The stages of this research include 1) designing and developing online tidal analysis system called Auto Tidal Pro 2) comparing the RMSE, 10 harmonic constants (M2, S2, N2, K2, K1, O1, P1, M4, MS4, Q1), and MSL from the harmonic analysis of Auto Tidal Pro and LP-Tides; 3) comparing the wave graph patterns of Auto tidal predictions, observation data, and LP-Tides predictions in January 2024; 4) compute the RMSE of predictions from prediction data and observation data for the period January - July 2024; and 5) compute the correlation of Auto Tidal Pro predictions with observation data and Auto Tidal Pro predictions with LP-Tides predictions in the period January - July 2024. The equation used by Auto Tidal Pro for the harmonic analysis program is Equation 1 and for the prediction program is Equation 11.

2.2.1. Design and development of Auto Tidal Pro System

Auto Tidal Pro is designed to runs on a VPS (Virtual Private Server) and can be accessed online through a web browser. Users interact with the system on the front-end through Auto Tidal Pro web pages created with HTML, PHP, and Javascript programming languages to upload data and some information. On the back-end, there are two Java programs for harmonic analysis and prediction that run independently, as well as a SQL database to store data and result information. Auto tidal pro can be opened and accessed online through the web address autotidalpro.com. The menu provided by Auto Tidal Pro consists of five menus that can be accessed, the menus are Harmonic Analysis, Prediction, Trend Analysis, Tutorial, and About. The maximum number of files that can be uploaded for harmonic analysis and prediction is 20 files each with *.txt file format. The tidal data format uploaded by the user must match the Auto Tidal Pro data format in the Tutorial menu and users do not need to write blank data. The Auto Tidal Pro system design can be seen in Figure 1

Auto Tidal Pro provides several choices of tidal harmonic constant groups, such as synodic period group (Synodic_Period), nine constants (IHO-9), 10 constants (UHO-10), 37 constants (NOAA-37), 214 constants (UKHO-214). The harmonic analysis process is users can upload tidal data and select the type of tidal harmonic constant group through the Harmonic Analysis page, the uploaded data goes into the harmonic analysis folder. This data information is stored in the database. The Java program for harmonic analysis reads the data in the harmonic analysis folder, the information in the database, finds the speed value of the harmonic constant group used, and processes the data. The result of the harmonic analysis is a text file with the format *.txt and the file name suffixed ARS, as well as a graphic image of the analysis in jpg format. These results are sent by the program via email to the user and the result information is also stored in the database. The java program for harmonic analysis operates 24 hours a day and is active every three seconds. .

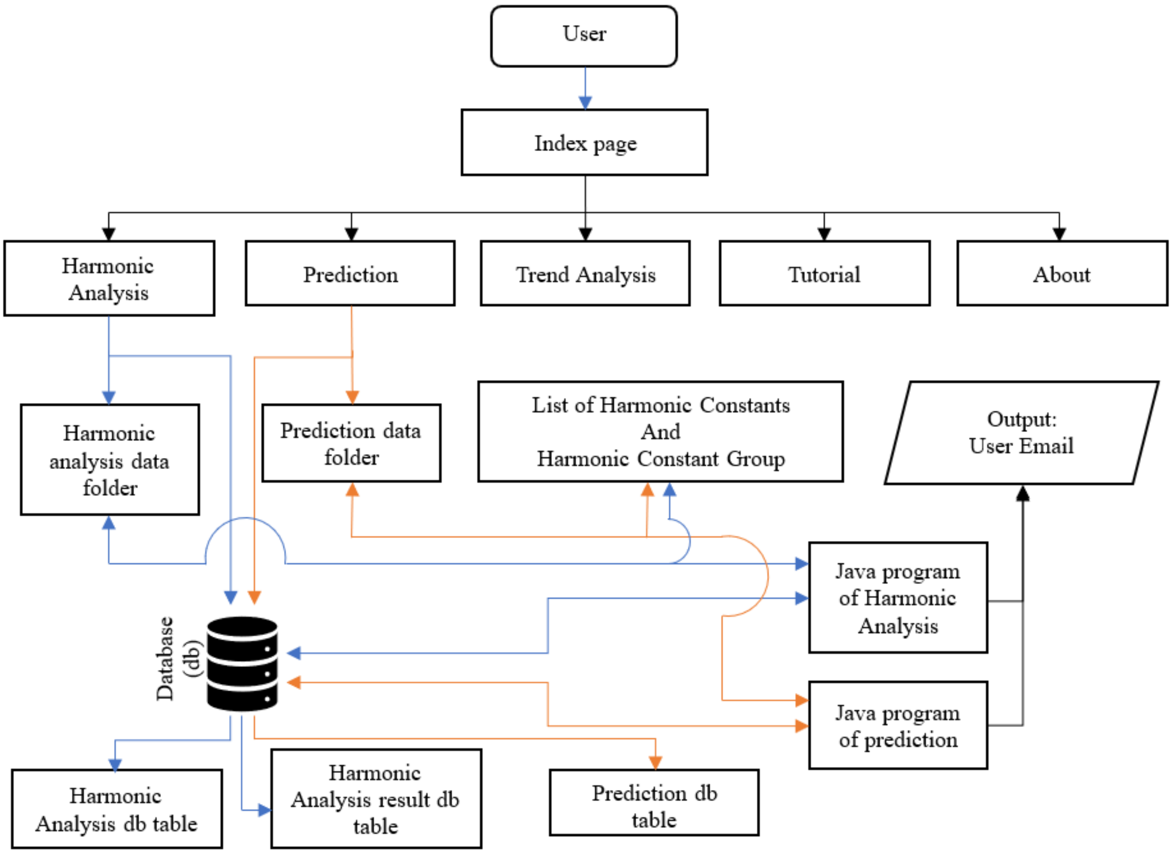

Figure 1. Design of Auto Tidal Pro system

The prediction process is like the harmonic analysis process. The user uploads the harmonic analysis result file with the ARS suffix on the Prediction page, and specifies the prediction date, as well as the prediction interval. The user is also given the option to make table predictions with a certain interval or not. The uploaded data goes into the prediction folder. The data information is stored in the database. The Java program for prediction reads the data in the prediction folder, the information in the database, finds the speed value of the harmonic constant group used, and processes the data. The prediction results are two text files in *.txt format with the filenames PRL and PRT (optional), and a jpg image of the prediction graph. These results are sent by the program via email to the user. The java program for prediction also operates for 24 hours every day and is active every three seconds.

The java programs for harmonic analysis and prediction each process data automatically in a queue one by one not in parallel due to the limited memory size on the VPS. This is done because if processing is done in parallel and with a large amount of data at once, it will consume a lot of memory. Trend analysis can be performed using formatted data as for harmonic analysis. Trend analysis can only process one file per process. The trend analysis output is displayed on the web page and the analysis report can be downloaded via the “Download Pdf” button provided.

2.2.2. Tidal Harmonic Analysis

Harmonic analysis is used to compute amplitude and phase lag values, also known as harmonic constants (IHO, 2011). The tidal harmonic analysis used by Auto Tidal Pro uses the least square method with Equation 1 (Kowalik dan Luick, 2019).

$$\zeta(\mathrm{t}) = \zeta_0 + \sum_{n=1}^{n=N} f_n(\mathrm{t}).\zeta_n.cos\big(\omega_n\mathrm{t} - g_n + V_n(t_0) + u_n(\mathrm{t})\big) \quad (1)$$

Remarks:

ζ_0 = mean sea level (MSL)

ζ_n = harmonic constant amplitude

ω_n = harmonic constant angular speed (degree/hour)

$V_n(t_0)$ = phase of the speed reference signal ω_n at time t_0

g_n = phase lag of the harmonic constant n

$f_n(\mathrm{t})$ = nodal factor to adjust the amplitude value

$u_n(\mathrm{t})$ = nodal phase to adjust the phase value

t_0 = reference time is generally 0000 UT

t = time in decimal since t_0

Harmonic analysis is computed in the Coordinated Universal Time (UTC) time zone, so if the observation data is not in UTC, it must be converted (Pugh & Woodworth, 2014).

2.2.3. Nodal Correction

Nodal corrections are applied to the amplitude (ζ_n) and phase lag (g_n). The nodal corrections are f values for amplitude correction and (V+u) for phase lag correction. The f and u values use the equations from Simon dan Page (2017). The astronomical argument or longitudinal formula is calculated first before calculating the V value. The astronomical argument is computed once at the center time of the analysis period (Foreman, 2004). The astronomical argument or longitudinal formula equation is written as Equations 2 through 8 (Kowalik dan Luick, 2019) with the values of the mean longitudinal elements of the sun and moon modified with values for the beginning of the year 2000 (Schureman, 1958).

$$s(t) = 211.744 + 481267.8906T + 0.0011T^2 \quad (2)$$

$$h(t) = 279.973 + 36000.7689T + 3.03x10^{-4}T^2 \quad (3)$$

$$p(t) = 83.294 + 4069.0340T - 0.0103xT^2 \quad (4)$$

$$N(t) = 125.069 - 1934.142T + 0.0021T2 \quad (5)$$

$$ps(t) = 282.940 + 1.7192T + 0.00045T2 \quad (6)$$

Time T is defined at 0000 UT on day D of year Y, T for 21st century time (Kowalik dan Luick, 2019) is calculated using Equations 7 and 8.

$$T = [365(Y - 2000) + (D - 1) + i]/36526 \quad (7)$$

$$i = INT[0.25(Y - 2001)] \quad (8)$$

Remarks:

s = mean longitud of the moon
h = mean longitud of the sun
p = longitudinal mean perigee of the moon
N = negative of the longitudinal line of the mean ascending node
ps = mean longitude from solar perigee (perihelion)

The value of V is determined using Equation 9 ((IHO, 2006) and (Foreman, 2004)).

$$V = \tau.d1 + (h - s).d1 + s.d2 + h.d3 + p.d4 + N.d5 + ps.d6 + 90°.d7 \quad (9)$$

The variables d1 to d7 are the alphabetic values of XDO (Extended Doodson Number) harmonic constants (Simon & Page, 2017), while τ is the mean solar time angle from Equation 10 (Badejo dan Akintoye, 2017).

$$\tau = 15°t + 180° \quad (10)$$

2.2.4. Tidal Prediction

Tidal prediction used by Auto Tidal Pro using Equation 11 (Kowalik dan Luick, 2019).

$$\zeta(t_i) = \zeta_0 + \sum_{n=1}^{n=N} A_n.cos(\omega_n t - \varphi_n) \quad (11)$$

Remarks:

$\zeta(t_i)$ = predicted water level at time t to i, i=1, i=2, ..., and so on
ζ_0 = mean sea level (MSL)
A_n = amplitude of the nth harmonic constant
ω_n = angular speed of the nth harmonic constant
t = ith time since the reference time
φ_n = phase constant of the nth harmonic

Where

The phase lag (g_n), V , and u output into Equation 12.

$$\varphi_n = [g_n - (V_n(t_0) + u_n(t))] \quad (12)$$

The amplitude (ζ_n) and f_n output into Equation 13.

$$A_n = f_n(t).\zeta_n \quad (13)$$

2.2.5. RMSE

RMSE is used for accuracy testing (Ghilani, 2018). The RMSE value of the tidal harmonic analysis results is obtained by using observation data and tidal prediction data. RMSE is computed using Equation 14 (Ghilani, 2018).

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}[f(x_i) - x_i]^2}{n}} \quad (14)$$

Remarks:

x_i = predicted water level
$f(x_i)$ = observation water level
n = number of observations

2.2.6. LP-Tides

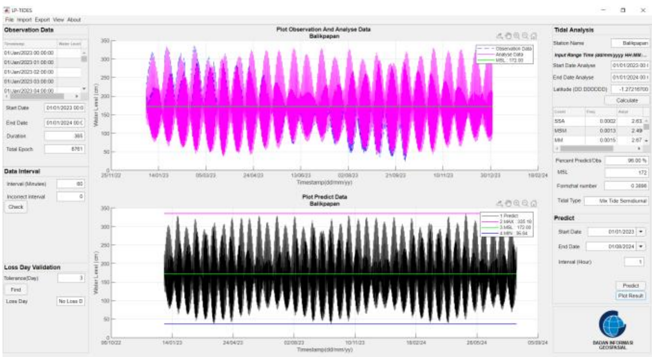

Figure 2. LP-Tides software program interface

LP-Tides is a development of T_Tide version 1.4 beta by Sulistian (2020) using Matlab by adding a GUI and can be downloaded via the Github web and Matlab online. This development makes it easier for users to use T_Tide, especially users do not need to add NaN to empty data, it can be done by the software. However, LP-Tides does not produce RMSE values so they must be calculated by the user. LP-Tides can be seen in Figure 5.

3. Result and Discussion

3.1. Auto Tidal Pro Interface

Auto Tidal Pro can be accessed at the web address autotidalpro.com using a web browser. The Auto Tidal Pro harmonic analysis page can be seen in Figure 3. The data used uses a specific writing format that the system can read. The first line to the sixth line is the data description and starting from the seventh line is the observation data with the writing format “dd/mm/yyyy<space>hh:mm:ss<space/tab>high”. Further explanation of the data format and harmonic analysis steps can be seen on the Tutorial page. The harmonic analysis result consists of data description, data statistics, RMSE, tidal type, tidal datums, and harmonic components.

The file of the harmonic analysis result is used for prediction. System read the constituent group name and harmonic components value from the file, inputed prediction date and inputed prediction interval from database. Further explanation of the prediction steps can be seen on the Tutorial page. The prediction page can be seen in Figure 4.

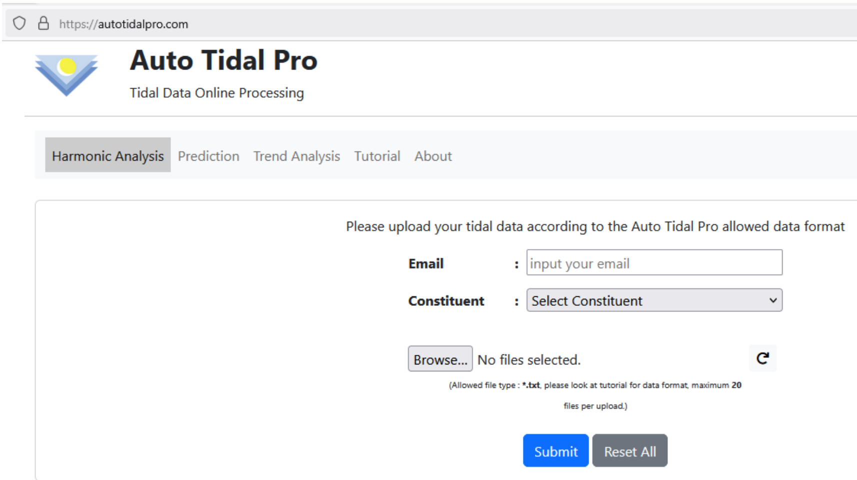

Figure 3. Harmonic analysis page interface

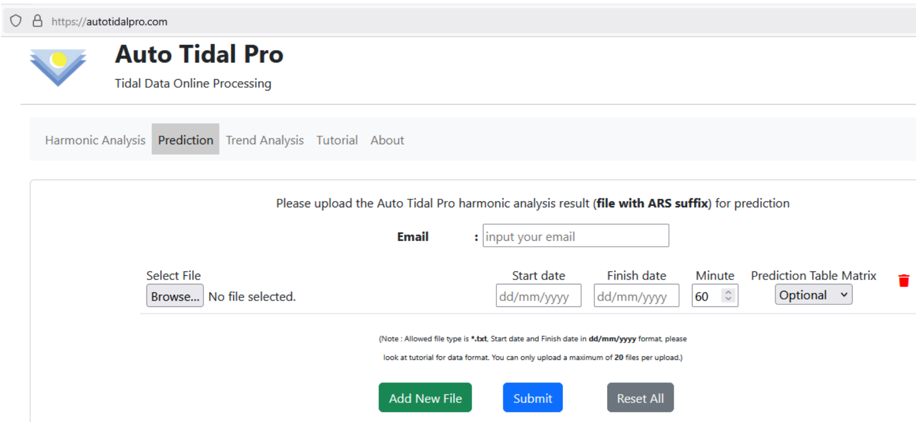

Figure 4. Prediction page interface

The trend analysis is using the same data that used for harmonic analysis. The result is directly displayed at the web page and can be downloaded as a pdf file. Further explanation of the trend analysis steps can be seen on the Tutorial page. The trend analysis page can be seen in Figure 5.

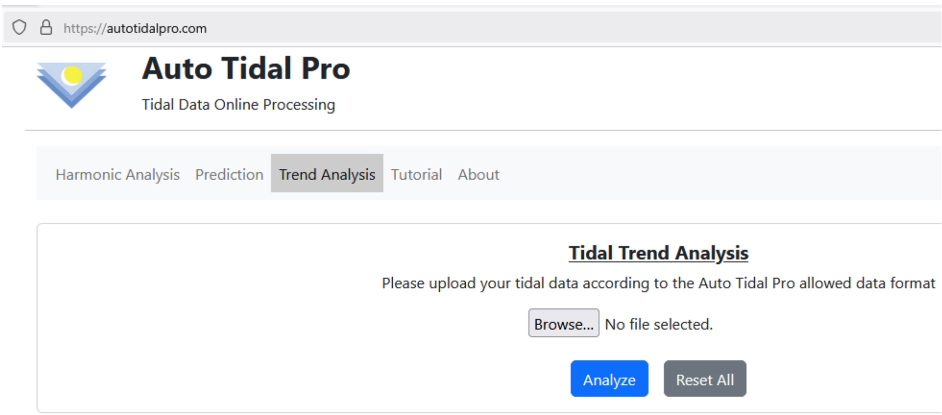

Figure 5. Trend analysis page interface

3.2. Harmonic Analysis RMSE

This RMSE is the RMSE of the harmonic analysis results of 2023 tidal data from Auto Tidal Pro and LP-Tides. Table 1 shows the accuracy of harmonic analysis for each group of harmonic constants in RMSE values. The RMSE of the Auto Tidal Pro harmonic analysis ranges from 0.043 m to 0.17 m, while the RMSE of LP-Tides is 0.121 m. However, the RMSE values from Auto Tidal Pro are quite small, which is 0.032 m for the UKHO-214 constant group and 0.043 m for the NOAA-37 constant group. These RMSE values are smaller than the RMSE values from LP-Tides.

Table 1. RMSE value of each harmonic constant group

Constant group	RMSE (m)
IHO-9	0.138
IHO-10	0.134
NOAA-37	0.043
Synodic Period	0.17
UKHO-214	0.032
LP-Tides	0.121

Based on Table 1, it can be obtained that the harmonic constant group that is suitable for use for 1 year data is NOAA 37 and UKHO-214 on Auto Tidal Pro because it produces the smallest RMSE value. Meanwhile, LP-Tides does not have a choice of harmonic constant groups used that allows selection to obtain the best RMSE value. The harmonic constants of LP-Tides harmonics follow the Rayleigh criterion which affects the number and type of constants used.

3.2. Harmonic Constant

The results of the harmonic analysis of each group of Auto Tidal Pro harmonic constants provide a different number of constants as well as LP-Tides. The number of constants discussed in this study are the 10 main constants (M2, S2, N2, K2, K1, O1, P1, M4, MS4, Q1) and the SO or MSL values from the harmonic analysis. Table 2 shows the difference of the amplitude values of each group of harmonic constants from Auto Tidal Pro and LP-Tides. The SO or MSL value between Auto Tidal Pro and LP-Tides has the largest difference of 0.012 m and the smallest of 0.004. The amplitude values of the other harmonic constants have differences ranging from 0 m to 0.043 m. The largest difference in amplitude values between Auto Tidal Pro and LP-Tides is generally found in the harmonic constants M2, K1, O1, and K2, which have a difference value of between 0.014-0.043 m. This shows that the amplitude and MSL values of each group of harmonic constants and LP-Tides are close. Negative values indicate that the constants from Auto Tidal Pro are smaller than those from LP-Tides. Column cells that contain only the character "-" mean that the constant is not generated by either or both so that it cannot be disputed.

Table 2. Difference in amplitude of Auto Tidal Pro and LP-Tides

Constituents	Amplitude (Auto Tidal Pro - LP-Tides)				
	IHO-9	IHO-10	NOAA-37	Synodic_Period	UKHO-214
SO.	-0.010	-0.010	0.004	-0.012	0.004
M2.	-0.016	-0.016	-0.024	-0.017	-0.023
S2.	0.004	0.004	0.002	0.040	0.007
N2.	0.001	0.001	-0.005	0.000	0.002
K2.	0.036	0.035	0.043	-	0.043
K1.	0.024	0.025	0.032	0.014	0.032
O1.	0.025	0.028	0.027	0.027	0.027
P1.	-0.002	0.000	0.003	-	0.003
M4.	-0.003	-0.002	-0.001	-0.001	-0.001
MS4.	0.000	0.000	0.001	0.001	-0.003
Q1.	-	0.006	0.000	0.005	0.000

Table 3 shows the difference between the phase values of each group of harmonic constants from Auto Tidal Pro and LP-Tides are quite different. The magnitude of the difference in phase values between each group of harmonic constants is 3.519 to 330.416 degrees. This difference occurs in all harmonic constants. The largest phase difference most often occurs in component S2.

Table 3. The difference between Auto Tidal Pro and LP-Tides phases

Constituents	Phase (Auto Tidal Pro - LP-Tides)				
	IHO-9	IHO-10	NOAA-37	Synodic_Period	UKHO-214
M2.	-106.217	-106.223	-106.291	-106.131	-106.226
S2.	-330.049	-330.014	-330.028	-322.949	-330.416
N2.	21.742	21.568	24.631	23.021	21.057
K2.	-161.178	-161.211	-161.571	-	-159.684
K1.	9.72	9.541	9.42	15.211	8.91
O1.	-116.795	-117.522	-117.824	-116.372	-117.632
P1.	24.296	25.245	28.865	-	28.516
M4.	-210.1	-209.906	-213.264	-211.927	-218.151
MS4.	290.222	290.146	289.417	288.317	279.536
Q1.	-	4.802	3.768	4.163	3.519

The difference in amplitude and phase values is in line with research conducted by El-Geziry and Said (2014) which compared the results of tidal harmonic analysis between T-Tide and World Tides software where the values obtained for amplitude and phase were different. Differences may be possible due to differences in the model equations used and the number and type of harmonic constants used in the least square fitting process.

3.3. Prediction Graph

The predictions of each group of harmonic constants of Auto Tidal Pro, LP-Tides, and observational data are plotted on one plot graph as shown in Figure 6. The predictions and observational data plotted is the period of January 2024. The results of the prediction plot show that the Auto Tidal Pro prediction gives the same wave pattern as the observation data and predictions from LP-Tides. The Auto Tidal Pro predicted waves look quite close to each other. This indicates that the amplitude heights (lowest and highest tides) look close together although there are some parts that look not close together. The phases of the predictions are similar indicating that the timing of the high and low tides is almost similar at each peak and valley of the tidal predictions.

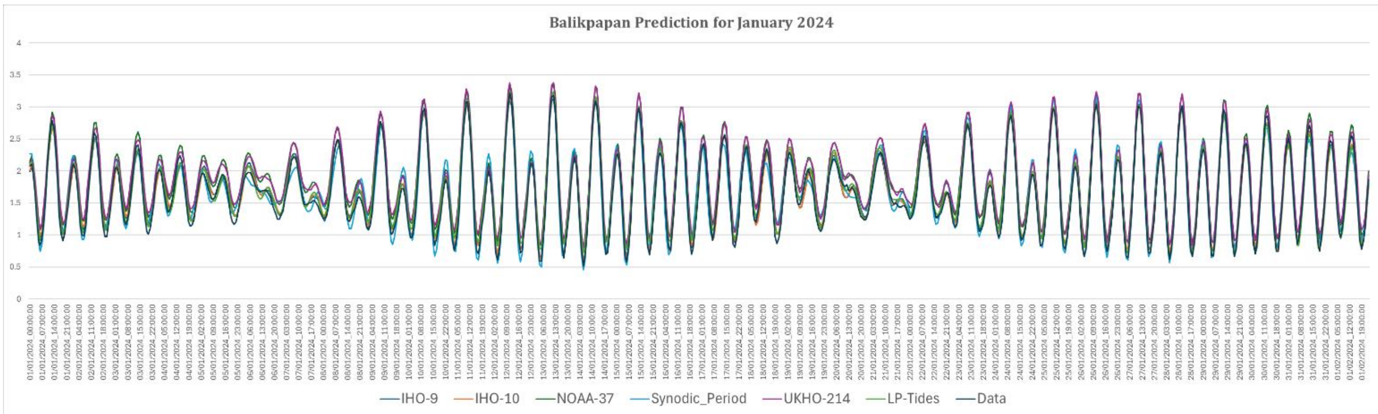

Figure 6. Balikpapan Prediction Chart for January 2024

3.4. Prediction RMSE of the year 2024

Table 4. Prediction RMSE of the year 2024

RMSE	Nilai RMSE (m)
2024 Data – IHO-9	0.08
2024 Data – IHO-10	0.075
2024 Data – NOAA-37	0.114
2024 Data - Synodic_ Period	0.16
2024 Data – UKHO-214	0.119

The results of the harmonic analysis of the 2023 data from Auto Tidal Pro and LP-Tides were used to compute predictions for the period January 1 to July 25, 2024. The prediction results were then used to compute the prediction RMSE against the 2024 observation data. The total data used to compute the prediction RMSE was 4945 hours. The results of the RMSE prediction for 2024 are shown in Table 4 where the largest RMSE value is in the RMSE 2024 Data - Synodic_Period of 0.16 m and the smallest is in the RMSE Data 2024 - IHO-10 of 0.075 m. The RMSE value of 2024 predictions in the NOAA-37 and UKHO-214 harmonic constant groups becomes greater than the RMSE in 2023. This shows that the further away from the observation data, the prediction results begin to move away from the observation data, although not too far. In general, the prediction RMSE value ranges from 0.075-0.119 m and is still within the RMSE range of the 2023 harmonic analysis. This means that the predictions produced are still good because the RMSE produced in 2024 is still as good as in 2023, which is shown by the 2024 prediction RMSE value still within the range of the 2023 RMSE value for all harmonic constant groups.

3.5. Correlation of Prediction with Observation Data

The correlations of the predictions of each group of Auto Tidal Pro harmonic constants with observational data and the predictions of each group of Auto Tidal Pro harmonic constants with LP-Tides are shown in Table 5. The correlation value is indicated by the R^2 value. If the R^2 value is closer to one, it means that the correlation between predictions and observational data is getting better. The period of prediction and observation data used to calculate the correlation is January 1 to July 25, 2024. In Table 5, the correlation values all show correlation values above 0.9 and close to one. The best correlation of Auto Tidal Pro predictions with observational data is in the IHO-10 constant group of 0.985616 and the least is in NOAA-37 of 0.930816. The correlation of Auto Tidal Pro predictions with LP-Tides predictions is best for the IHO-10 constant group at 0.990809 and less for NOAA-37 at 0.938061. Even so, all correlations are still within good limits.

Table 5. Correlation of 2024 Auto Tidal Pro Prediction and 2024 observation data

Correlation	R^2
2024 Data –IHO-9 prediction	0.983163
2024 Data – IHO-10 prediction	0.985616
2024 Data – Synodic_Period prediction	0.976142
2024 Data – NOAA-37 prediction	0.930816
2024 Data – UKHO-214 prediction	0.973087
LP-Tides prediction – IHO-9 prediction	0.987700
LP-Tides prediction – IHO-10 prediction	0.990809
LP-Tides prediction – Synodic_Period prediction	0.964604
LP-Tides prediction – NOAA-37 prediction	0.938061
LP-Tides prediction – UKHO-214 prediction	0.961536

4. Conclusion

Based on the results and discussion of this research, the following are obtained:

1. An online harmonic analysis system called Auto Tidal Pro was successfully created using HTML, PHP, and Javascript programming languages as user interfaces; Java programming language to create harmonic analysis and prediction programs; and SQL databases to store data information.
2. This system can help users to perform harmonic analysis, prediction, and trend analysis online.
3. The validation results show that Auto Tidal Pro can be used for harmonic analysis and prediction like LP-Tides software although there are differences in the value of harmonic constants, especially the phase value which is quite significant.

5. Conflict of Interest Statement

The authors declare no competing interest.

6. References

Annunziato, A., & Probst, P. (2016). *Continuous Harmonics Analysis of Sea Level Measurements tidal component*. https://doi.org/10.2788/4295

Badejo, O. T., & Akintoye, S. O. (2017). High And Low Water Prediction At Lagos Harbour, Nigeria. *Nigerian Journal of Technology (NIJOTECH)*, *36*(3), 944–952.

El-Geziry, T. M., & Said, M. A. (2014). Comparison Of Two Packages For Tidal Analysis And Prediction: An Exemplar Case Study Of Abu-Qir Bay, Alexandria, Egypt. *Blue Biotechnology Journal*, 3(06 July 2015).

Foreman, M. G. G. (2004). Manual for tidal heights analysis and prediction, Institute of Ocean Sciences, Sidney. In *Pacific Marine Science Report* (Issue October 2004, pp. 77–10). Institute of Ocean Sciences Patricia Bay Victoria, B.C. http://champs.cecs.ucf.edu/Library/Journal_Articles/pdfs/Manual for tidal heights analysis and prediction.pdf

Ghilani, C. D. (2018). *Adjustment Computations: Spatial Data Analysis.* (Sixth). John Wiley & Sons, Inc.

Harrys, R. M., & Wolfe, C. L. P. (2020). *Tidal Analysis (T Tide and U Tide) GUI using PyQt5*. https://github.com/rifqiharrys/tide_pyqt5/tree/master. Accessed on July 26, 2024.

IHO. (2006). Harmonic Constituents with Nodal Corrections. In *HARMONIC CONSTANTS Product Specification* (Vol. 1, Issue November).

IHO. (2011). *Manual on Hydrography: Vol. 1st Editio* (Feb 2011). International Hydrographic Bureau.

Kowalik, Z., & Luick, J. L. (2019). Modern Theory And Practice Of Tide Analysis And Tidal Power. In *Austides Consulting* (August 201). Austides Consulting.

NOAA. (n.d.). *NOAA Tide Predictions*. Retrieved June 2, 2024, from https://tidesandcurrents.noaa.gov/tide_predictions.html. Accessed on June 6, 2024.

Pawlowicz, R., Beardsley, B., & Lentz, S. (2002). Classical tidal harmonic analysis including error estimates in MATLAB using T_TIDE. *Computers and Geosciences*, *28*(8), 929–937. https://doi.org/10.1016/S0098-3004(02)00013-4

PSMSL. (2000). *PSMSL/POL Tidal Analysis Software Kit 2000 (TASK-2000 Package)*. https://psmsl.org/train_and_info/software/task2k.php. Accessed on July 6, 2024.

Pugh, D., & Woodworth, P. (2014). *Sea-Level Science: Understanding Tides, Surges, Tsunamis and Mean Sea-Level Changes*. Cambridge University Press.

Sambasivam, T., Din, A. H. M., Hamden, M. H., Zulkifli, N. A., & Adzmi, N. H. M. (2023). Interpretation of Current and Tidal Pattern At Selangor River, Kuala Selangor. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives*, *48*(4/W6-2022), 303–310. https://doi.org/10.5194/isprs-archives-XLVIII-4-W6-2022-303-2023

Schureman, P. (1958). *Manual Of Harmonic And Prediction Of Tides* (June 2001, Issue Special Publication no. 98). United States Goverment Printing Office.

Simon, B., & Page, C. J. (2017). *Tidal Constituents* (Issue May). IHO.

Sulistian, T. (2020). *LP-TIDES.V.1.0*. https://github.com/teguhsulistian/LP-TIDES.V.1.0?tab=readme-ov-file. Accessed on June 5, 2024.

Syetiawan, A. (2014). Pasut Berbasis Web (Web Based Application Development to Process Harmonic Tide Components). *Jurnal Ilmiah Geomatika*, *20*(2), 95–102.

Taylor, S. (2022). *Geomatix GeoTide*. https://geomatix.net/company/index.html. Accessed on July 6, 2024.

Ulum, Z. (2012). *[XLS-SVY-22]: Rumus Excel untuk Menghitung Konstanta Pasut (Amplitudo Dan Phase) Dengan Metode Hitung Kuadrat Terkecil*. https://cadex.co/2015/01/26/xls-svy-22-rumus-excel-untuk-menghitung-konstanta-pasut-amplitudo-dan-phase-dengan-metode-hitung-kuadrat-terkecil/. Accessed on June 2, 2024.