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The Application of Grasshopper to Redesign Ship Hulls with a Parametric Approach Method Based on Delftship Reference

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Abstract– **More than a year has passed since Francisco Pérez-Arribas (2023) introduced a parametric-based hull design method using Python scripts, beginning with the cross-sectional area (CSA) design. Several experimental studies have been carried out to improve the method and the quality of ship design. This study aims to generate an optimal hull design by utilizing normal vectors derived from the x and y vectors. These normal vectors are applied parametrically to determine the shape of the hull. The study also employs a cubic spline-based parametric technique for designing yacht hulls. The purpose of this study is to introduce the concept of parametric design through the development of visual programming used to form cross-sectional area curves and generate hull geometry. This study also discusses both the advantages and limitations of using visual programming approaches to accelerate the design process. By varying the CSA shape of the DelftShip model, the resulting parametric model has a high level of accuracy, with a difference of - 0.097016% in LCB and -0.28785% in volume when compared to the DelftShip model. results from Grasshopper reveal significant differences, particularly below a draft of 0.475, where the CP values from Grasshopper are lower than those from DelftShip. The parametric approach using normal vectors not only facilitates design exploration but also holds the potential to enhance overall hull design quality and optimization.**

Keywords— Parametric modelling, Hull Design, Cad, Kapal Yachts, Grasshoper

I. INTRODUCTION

For decades, architects have primarily used traditional methods to design ships. However, in the 20th century, the application of mathematical curves and surface generation in ship shape models began to develop. In the present era, numerical methods are widely utilized, with NURBS curves employed to calculate geometric shapes, as demonstrated in previous research [1]. The shape parameters of the curves are used as inputs in the geometric modeling process, [2] [3][4]. D. Peri [5] used parameterization tool that automatically selects optimal parameters for modifying the hull shape. Perez-Arribas et al. [6] examined the parametric design of a SWATH (Small Waterplane Area Twin Hull) vessel using B-Spline surfaces.

In previous research by Feng Y et.al [7] parametric modeling and computational techniques were employed to optimize the hull shape. From the aforementioned research, it is clear that parametric design is a widely discussed topic. This paper expands on the use of parametric techniques. However, no prior studies have applied normal vectors for designing ship hulls, where normal vectors are the result of x and y vector formulations. The normal vector is applied based on the vector results and calculus formulations [8].

The application of normal vectors and parametric approaches is an intriguing subject of discussion. Although several previous studies have employed parametric methods, none have utilized the point generated by the vector as a parameter in the waterline region. This research introduces a novel methodology that integrates normal vectors derived from x and y formulations into the parametric design process, using them as parameters to define the waterline region in cubic spline-based hull designs. This approach provides a new perspective on the parametric modeling of ship hulls and has the potential to improve design accuracy and flexibility.

II. METHOD

A. *The design concept*

As naval architects, there is a constant demand to expand our knowledge and continuously innovate in creating an ever-improving maritime environment. However, modeling ships, particularly in defining parameters such as length, beam, and draft, can present significant challenges [9]. Design spaces, such as parametric modeling, can be freely explored in this research, as demonstrated in the Holiship project [10]. In parametric methods, only the basic ship parameters are known [11]. from these basic parameters, additional parameters are developed using advanced techniques. This study aims to utilize Grasshopper programming for ship modeling, as demonstrated in prior research [12][13][14]. The models will be compared against data from a reference ship obtained through DelftShip.

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B. Modifying the Shape of the CSA

A new CSA form was constructed using data from the ship, resulting in a different hull shape than before with the use of rhinoceros and grasshoper. The CSA ship has a volume value of less than 0.5% and an LCB of less than 0.1%. The main dimensions of the Delftship ship are: Sectional Area Curve (SAC) is a crucial part in ship design. SAC is a curve representing the area of ship parts. Using the optimization technique, we may immediately incorporate a closed area and its center point into the curve, eliminating the requirement for a nonlinear equation calculation.

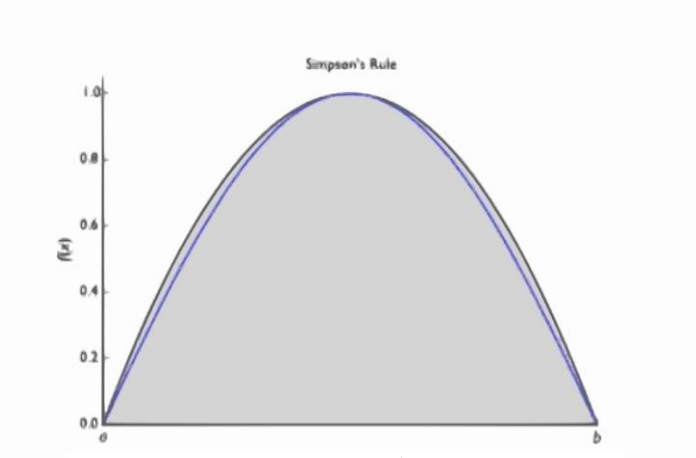


Figure. 1. The Parabola function [23]

From the (CSA), it is possible to derive the coefficients of prismaticity (Cp) and longitudinal center of buoyancy (LCB) [15]. This process allows for the determination of both the area (displacement) and the centroid of the cross-section. The method used to calculate the centroid follows the well-known Simpson's rule [16]. Where this rule is sometimes known as simpson’s 1/3 rule, as other approaches use interpolation with larger exponents. [16]

The formula for the cross-sectional area (station) using Simpson's method is as follows [16]*:*

$$A_{up} = 2 \times \frac{1}{3} \times h \times \sum \ (m^2) \qquad (2)$$

Formula for Volume Displacement (Volume of Air Displaced) [16]:

$$V_d = \frac{1}{3} \times \sum \ \times \frac{L_{pp}}{10} \ (m^3) \qquad (3)$$

Both formulas are derived from Figure 1.

C. Design Bodyplan

To create a curve at the station, this study utilizes a cubic spline like a study from [16].

The cubic spline formula [17] *:*

$$z^* = c_1(x^*)^3 + c_2(x^*)^2 + c_3(x^*) + c_4, \quad (4)$$

D. Boundary representations

This study takes a different approach than prior studies by designing the hull using Grasshopper's, specifically examining how displacement influences the vessel's performance. [18] , LCB Additionally, (LCB) can affect the ship's resistance [19] , and the vessel’s coefficients are aligned with reference data obtained from DelftShip.. In Figure 2, this program is applied to modify the hull shape by adjusting the width of the stations along the n-th waterline.

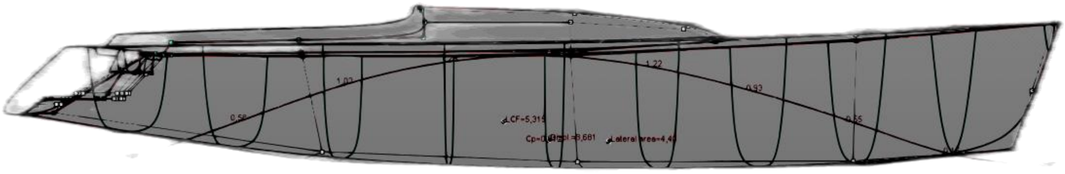


Figure. 2. Model Yacht from Delftship

TABLE 1.
COMPARISON OF THE SHIP’S MAIN DIMENSION

No	Main Comparison	Dimension(m)
1	Loa	11.8682
2	Breadth	3.529
3	Depth	1.6848
4	Draft	0.541
5	Cb	0.541

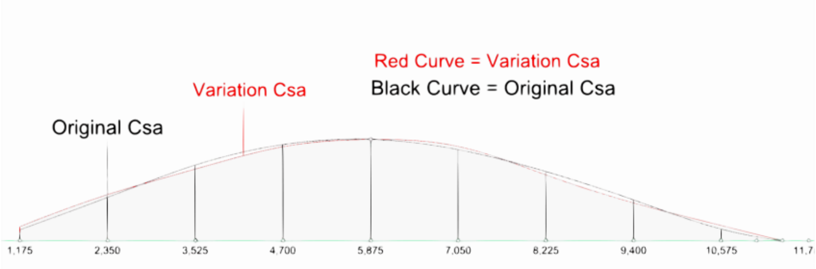


Figure. 3. Csa Based on Vessel Model Area

TABLE 2
BEFORE &VARIATION AREA STASION

Stasion	Before Variation	After Variation
F(1)	0.1471	0.1889
F(2)	0.581515	0.619
F(3)	1.01547	0.9611
F(4)	1.290353	1.261
F(5)	1.35999	1.3599
F(6)	1.2221	1.2564
F(7)	0.92904	0.882
F(8)	0.5493	0.5065
F(9)	0.156754	0.2046
F(10)	0	0

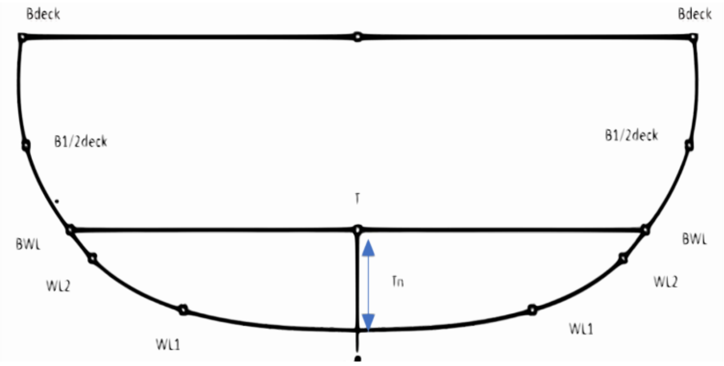


Figure. 4. The shape of the cubic spline curve on the hull

The point locations along the waterline utilize Waterline 1 at a height of 0.211 meters and Waterline 2 at a height of 0.423 meters. Notably, Waterline 3, with an elevation exceeding 0.423 m, is present only at Station 1, while Waterlines 1 and 2 are absent because they cannot reach the parameters at Station 1 due to their elevations being higher than those of Waterline 3

III. Results and Discussion

A. *Changes in CSA in Stasion Area*

Grasshopper is utilized in this study to vary the shape of the stations, allowing for adjustments that alter the hull configuration and produce the desired ship model. The modified parameters include volume and the longitudinal center of buoyancy (LCB). The volume variation remains under 0.5%, while the LCB deviation is less than 0.1%.

$$Correction\ Volume : \frac{|VCalculation - Vplanning|\ x\ 100}{VCalculation} \quad (5)$$

$$Correction\ Lcb : \frac{|Lcbcalculation - Lcbpplanning|\ x\ 100}{Lcbcalculation} \quad (6)$$

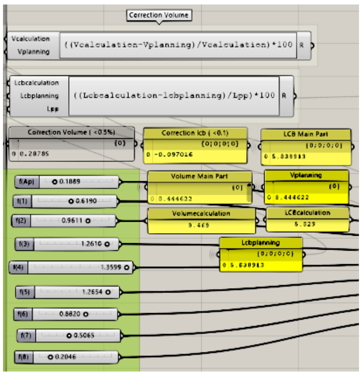
a) Vcalculation: Volume on delftship

b) Vplanning: Volume after csa

c) Lcbcalculation: Lcb on delftship

d) Lcbplanning: Lcb after csa

- Volume correction value of 0,28785 % > 0,5 % (qualified)
- Lcb correction value of -0,097016 % > 0,1 % (qualified)



Correction Volume

Vcalculation
Vplanning
((Vcalculation-Vplanning)/Vcalculation)*100

Lcbcalculation
Lcbplanning
Lpp
((Lcbcalculation-lcbplanning)/Lpp)*100

Correction Volume (<0.5%) {0} 0 0.28785

Correction lcb (<0.1) {0;0;0;0} 0 -0.097016

LCB Main Part {0;0;0;0} 0 5.838913

Volume Main Part {0} 0 8.444622

Vplanning {0} 0 8.444622

Volumecalculation 8.469

LCBcalculation 5.829

Lcbplanning {0;0;0;0} 0 5.838913

f(Ap) 0.1869
f(1) 0.6190
f(2) 0.9611
f(3) 1.2610
f(4) 1.3599
f(5) 1.2654
f(6) 0.8820
f(7) 0.5065
f(8) 0.2046

Figure. 5. The CSA results based on Grasshoper

B. *Generation of hull forms*

Each curve is labeled with a distinct color: the deck line is orange, the displacement line is green, the draft line is black, and the starboard and portside deck lines are blue. Points (d1, ..., d7, p1, ..., p2, s1, ..., s3, c1, ..., c2, t1, ..., t2) are shown in the Figure and can be modified based on the specified parameters. In this software, the parameters WL2 (with d2 = d6) and WL1 (with d3 = d5) are utilized to shape the ship's displacement station, as illustrated in Figure 13. The original reference line is split into two waterlines in order to construct the intended station: the first waterline is situated 0.211 meters from the baseline, and the second waterline is 0.423 meters away. The points on each waterline are derived using vector Z, [20].

In this visual programming approach, planes are placed at points along the centerline. Initially, these planes exist in a flat two-dimensional space and are subsequently manipulated. This local plane generates a normal vector, known as vector Z. Vector Z is derived through a manipulation process that directs it towards the Y-axis in three-dimensional (3D) space. Vectors X and Y are adjusted to create a normal vector directed toward the Z-axis, enabling vector Z to establish a new orientation toward the Y-axis on the flat plane in Rhino, as illustrated in Figure 7.

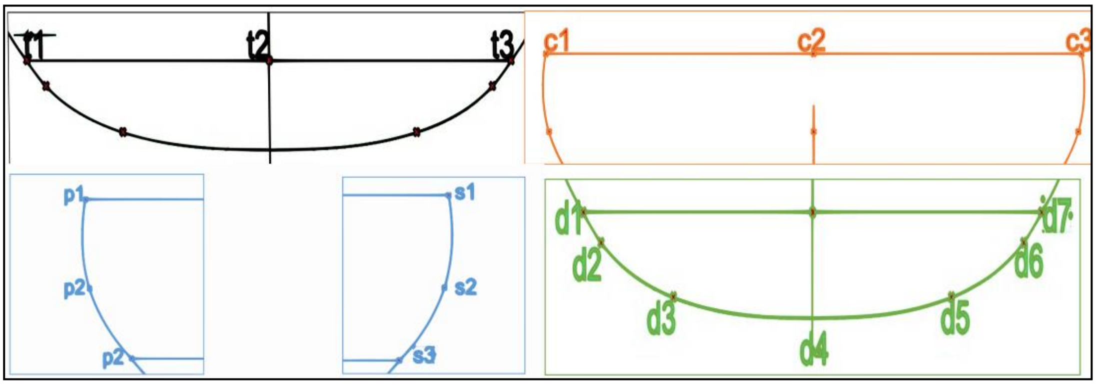


Figure. 6. Model of the ship hull based on grasshopper

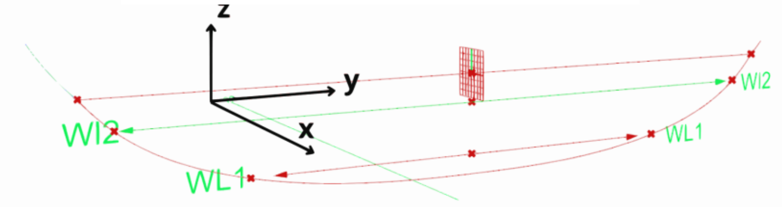


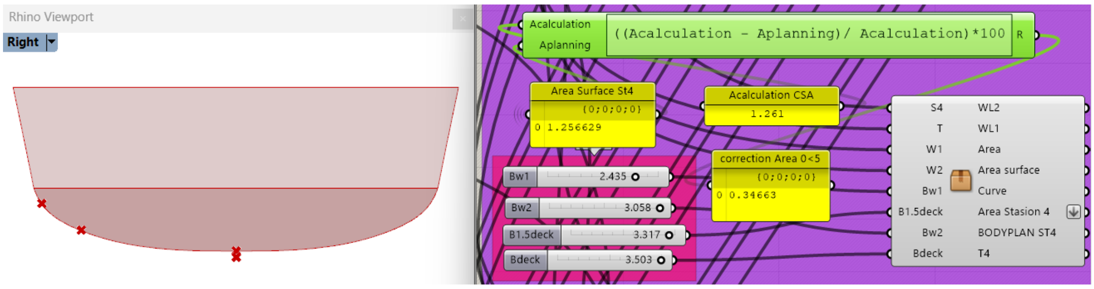
Figure. 7. The z vector forms the coordinate points WL1-WL2

This process then produces WL1 and WL2, which will generate hull. Variations in the cross-sectional area (CSA) lead to a calculated area (Acalculation), which is then corrected against the planned or modified station area, showing a minimal difference of less than 0.5%. This correction ensures that the computed results align with the actual conditions or desired specifications.

This small difference indicates that the mathematical model used is highly accurate in predicting changes in the station area resulting from modifications to the hull shape. With such minimal variation, it can be concluded that the calculations and corrections were executed with a high degree of precision. This accurate correction enhances efficiency by ensuring compliance with the established specifications, while also expediting the calculations of the ship's dimensions and shape in a more accurate and effective manner.

C. *Ship sturctural design*

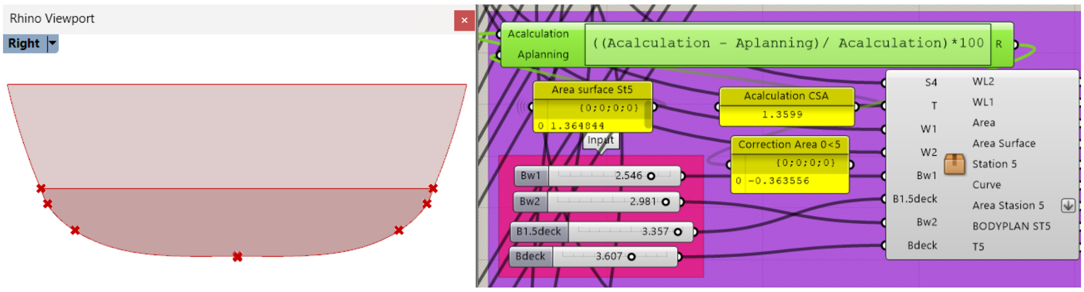
This study produces a model using Grasshopper that facilitates the modification of hull shapes at the waterline. This method is projected to improve the ship's hydrodynamic efficiency and overall performance according to findings in prior research.[12]



```
((Acalculation - Aplanning)/ Acalculation)*100
```

0 1.256629
1.261
0 0.34663
Bw1 2.435
Bw2 3.058
B1.5deck 3.317
Bdeck 3.503

Figure. 8. Hull shape of Station 4



```
((Acalculation - Aplanning)/ Acalculation)*100
```

0 1.364844
1.3599
0 -0.363556
Bw1 2.546
Bw2 2.981
B1.5deck 3.357
Bdeck 3.607

Figure. 9. Hull shape of Station 5

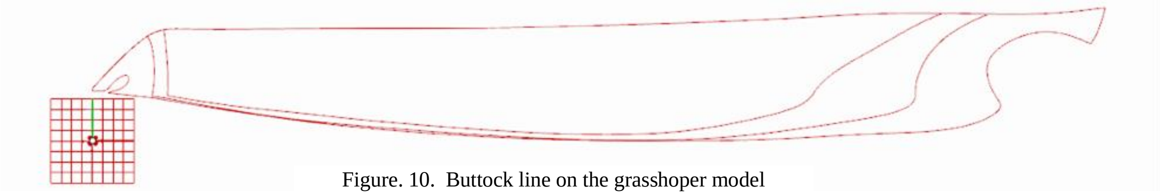


Figure. 10. Buttock line on the grasshoper model

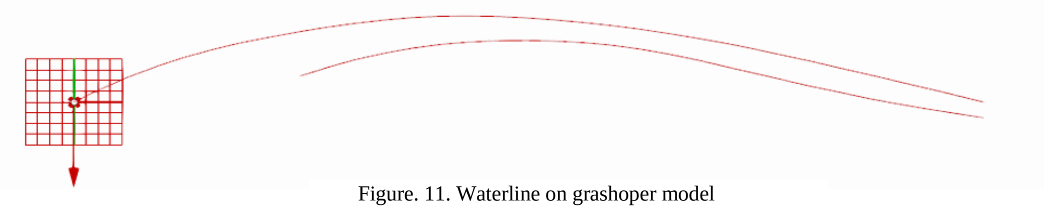


Figure. 11. Waterline on grashoper model

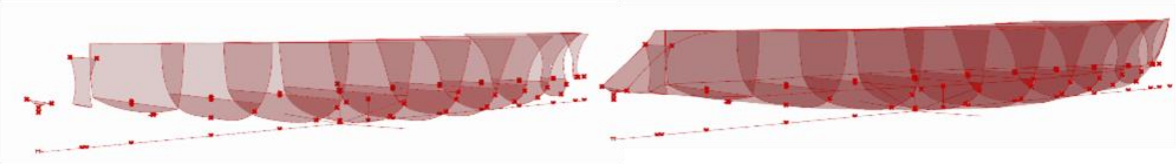


Figure. 12. Wireframe model on grasshopper

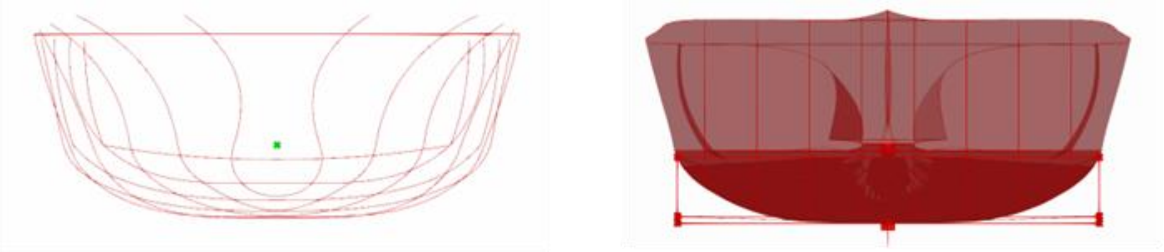


Figure. 13. Front view of the grasshopper model

Figure. 14. Surface Model in Grasshoper

D. Strutural design in Gaussian

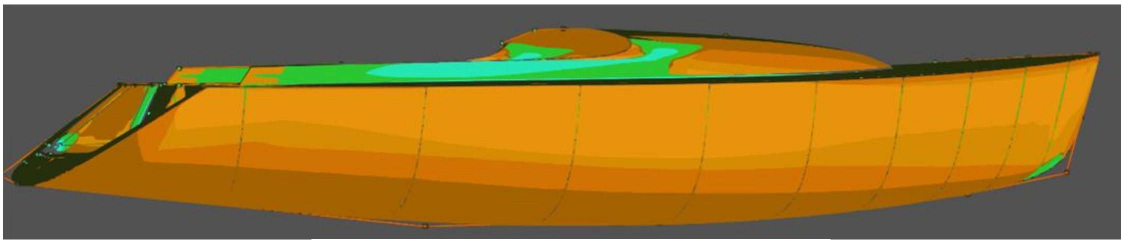


Figure. 15. Curvature representation from delftship

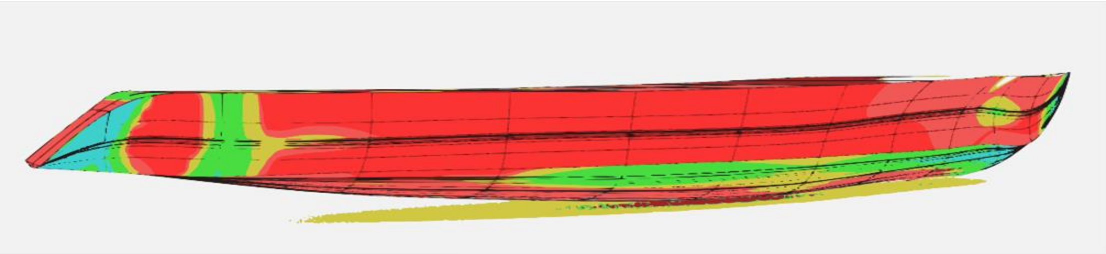


Figure. 16. Curvature representation from Grasshoper

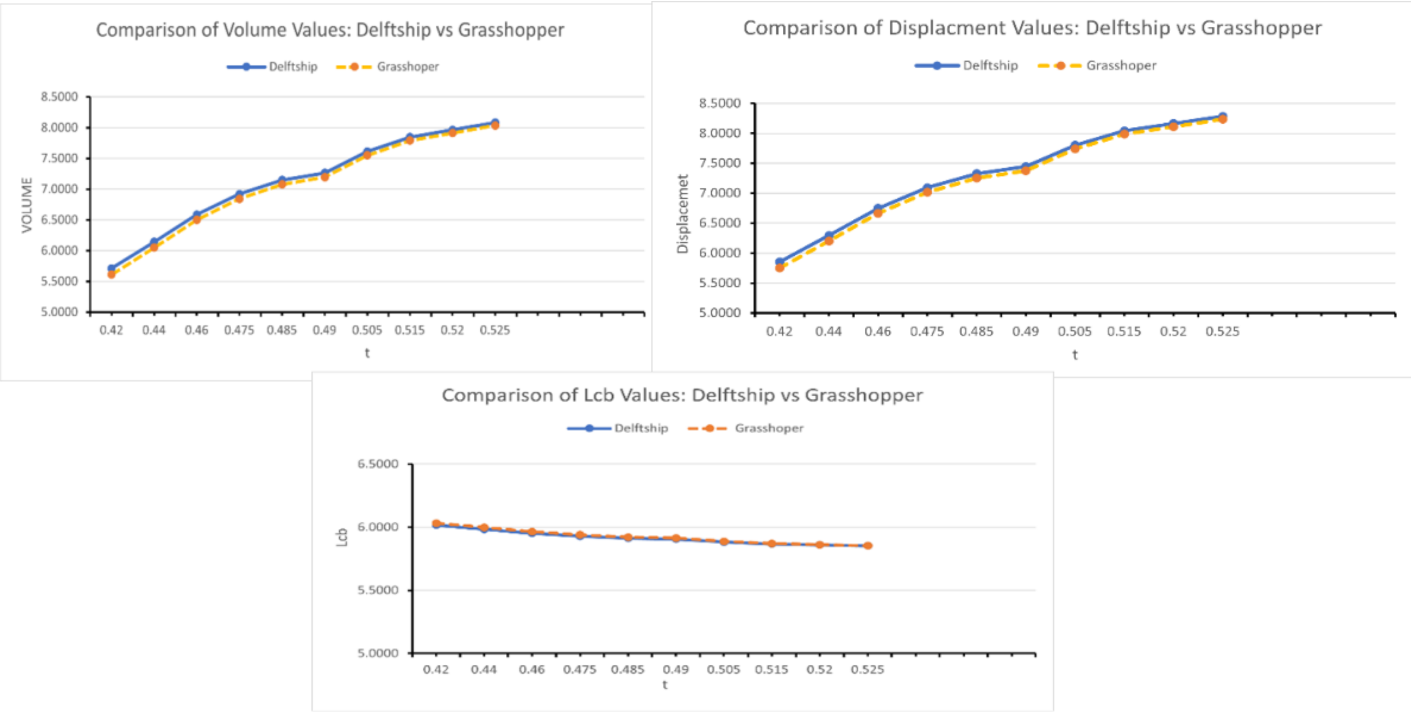


Figure. 17. Comparison of Delftship vs Grasshoper.

E. Analysis of Draft Variation on Volume, Displacement, and Longitudinal Center of Buoyancy (LCB)

This study demonstrates that variations in the ship's draft have a significant impact on volume, displacement, and the position of the Longitudinal Center of Buoyancy (LCB). Comparative results between Delftship and Grasshopper software show strong consistency, particularly in the calculation of volume, which increases as the draft rises. The minor discrepancies identified in the LCB calculations suggest that Grasshopper offers accuracy comparable to Delftship.

Overall, these findings confirm that Grasshopper's calculation model produces trend patterns nearly identical to Delftship, indicating that both software tools are reliable for hydrostatic analysis in optimizing ship design and stability.

F. Analysis of Load Variations on Coefficients Cw, Cm,, Cb, and Cp.

The hull design approach implemented by Grasshopper significantly differs from Delftship. Based on the graphical analysis, Grasshopper shows a lower block coefficient (Cb) after reaching a certain draft point.

This indicates that hull designs generated by Grasshopper tend to have a sleeker shape, which effectively reduces water resistance, leading to increased energy efficiency. Additionally, the differences in prismatic coefficient (Cp) and midship coefficient (Cm)

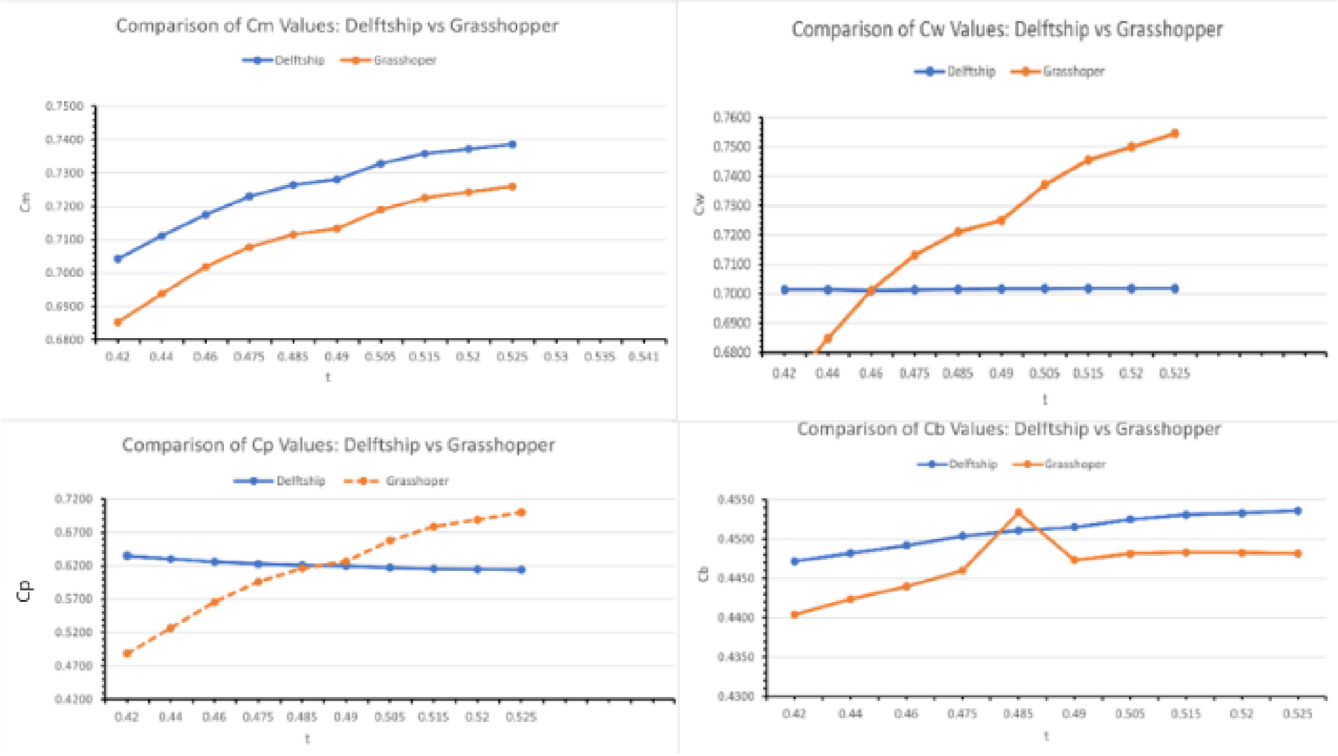


Figure. 18. Comparison of Coefficient Delftship vs Grasshoper.

between the two software programs reveal that Delftship produces a fuller, more stable hull, whereas Grasshopper emphasizes a more streamlined, hydrodynamically efficient design. The comparison of waterplane area coefficient (Cw) values also shows that Grasshopper's design is more flexible in responding to draft variations, with a sharper increase in Cw compared to Delftship, which, although more stable, is less adaptive to draft changes. Overall, the model generated by Grasshopper offers advantages in terms of energy efficiency, hydrodynamic performance, and adaptability to draft variations, making it a superior choice for a more streamlined and efficient hull design. The comparison of *waterplane area coefficient* (Cw) values also indicates that the Grasshopper design is more flexible in responding to draft variations, with a sharper increase in Cw compared to Delftship, which, while more stable, is less adaptive to changes in draft.

Overall, the model produced by Grasshopper offers advantages in terms of energy efficiency, hydrodynamic performance, and adaptability to draft variations, making it a superior choice for a more streamlined and efficient hull design.

IV. CONCLUSION

This study successfully demonstrates that the application of normal vectors in parametric hull design can produce an optimal design with high accuracy. By utilizing Rhinoceros and Grasshopper software, a new Cross-Sectional Area (CSA) shape was designed, resulting in a volume discrepancy of less than 0.5% and a Longitudinal Center of Buoyancy (LCB) deviation of less than 0.1% compared to the reference model from DelftShip. The analysis shows that the block coefficient (CB) and midship section coefficient (CM) in the parametric model are smaller than in the reference model, while the prismatic coefficient (CP) in the parametric model presents a significant difference, especially at drafts below 0.475. These findings confirm that the parametric approach not only offers efficiency in design exploration but also has the potential to enhance the quality and optimization of ship hull design overall. Therefore, this study makes a valuable contribution to the development of superior hull designs in the future and expands the understanding of normal vector applications in parametric design.

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REFERENCES

[1] Y. Feng, O. el Moctar, and T. E. Schellin, “Parametric..Hull Form Optimization..of Containerships for Minimum Resistance in Calm Water and in Waves,” *Journal of Marine Science and Application*, vol. 20, no. 4, pp. 670–693, Dec. 2021, doi: 10.1007/s11804-021-00243-w .

[2] T. Katsoulis, X. Wang, and P. D. Kaklis, “A T-splines-based parametric modeller for computer-aided ship design,” *Ocean Engineering*, vol. 191, Nov. 2019, doi: 10.1016/j.oceaneng.2019.106433.

[3] F. Marques Sanches, M. Ventura, and C. Guedes Soares Supervisor, “Parametric Modelling of Hull Form for Ship Optimization Naval Architecture and Marine Engineering Examination Committee,” 2016.

[4] D. Villa, S. Gaggero, A. Coppede, and G. Vernengo, “Parametric hull shape variations by Reduced Order Model based geometric transformation,” *Ocean Engineering*, vol. 216, Nov. 2020, doi: 10.1016/j.oceaneng.2020.107826.

[5] D. Peri, “Optimal ship hull via optimal parameterisation,” *Ship Technology Research*, vol. 63, no. 3, pp. 159–170, Sep. 2016, doi: 10.1080/09377255.2016.1255297.

[6] F. Pérez-Arribas and J. Calderon-Sanchez, “A parametric methodology for the preliminary design of SWATH hulls.”

Ocean Engineering, vol. 197, Feb. 2020, doi: 10.1016/j.oceaneng.2019.106823.

[7] Y. Feng, O. el Moctar, and T. E. Schellin, “Parametric Hull Form Optimization of Containerships for Minimum Resistance in Calm Water and in Waves” Journal *of Marine Science* and *Application,* vol. 20, no. 4, pp. 670–693, Dec. 2021, doi: 10.1007/s11804-021-00243-w.

[8] Bhattacharjee, P. R. (2024). Use of tangent and normal vectors for the derivation of equations of tangent and normal International Journal of Physics and Mathematics, 7(1), 7-15. https://doi.org/10.21744/ijpm.v7n1.2287

[9] D. Majnarić, S. Baressi Šegota, I. Lorencin, and Z. Car, “Prediction of main particulars of container ships using artificial intelligence algorithms” Ocean Engineering, vol. 265, 2022, doi: 10.1016/j.oceaneng.2022.112571.

[10] A. Papanikolaou et al., “A Holistic Approach to Ship Design: Tools and Applications” Journal of Ship Research, vol. 66, no. 1, pp. 25–53, Mar. 2022, doi: 10.5957/JOSR.12190070.

[11] T. Cepowski, “The use of a set of artificial neural networks to predict added resistance in head waves at the parametric ship design stage” Ocean Engineering, vol. 281, p. 114744, 2023, doi: https://doi.org/10.1016/j.oceaneng.2023.114744.

[12] P.M. Guilcher and J.M. Laurens, “Development of Rhino/Grasshopper tools for Ship Design Graduation project report Nemo”

[13] Y. Zhang, D.-J. Kim, and A. Bahatmaka, Parametric Method Using Grasshopper for Bulbous Bow Generation. 2018. doi: 10.1109/iCCECOME.2018.8658464.

[14] F. Romanelli, M. Filipe Simoes Franco Ventura, Â. Palos Teixeira Supervisors, and M. Filipe Simões Franco Ventura, “Parametric modelling of hulls for small crafts “Naval Architecture and Ocean Engineering Examination Committee,” 2021.

[15] X. Jiang and Y. Lin, “Relevant integrals of NURBS and its application in hull line element design” Ocean Engineering, vol. 251, 2022, doi: 10.1016/j.oceaneng.2022.111147.

[16] E. J. Sasono, “Aplikasi Metode Numerik Dalam Perhitungan Luas dan Volume Badan Kapal yang Berada di Bawah Permukaan Air Laut” 2006.

[17] F. Pérez-Arribas, J. A. Suárez-Suárez, and L. Fernández-Jambrina, “Automatic surface modelling of a ship hull” CAD Computer Aided Design, vol. 38, no. 6, pp. 584–594, Jun. 2006, doi: 10.1016/j.cad.2006.01.013.

[18] D. E. Calkins, R. D. Schachter, and L. T. Oliveira, “An automated computational method for planning hull form definition in concept design” 2001.

[19] N. Sogihara, A. Sakurada, M. Kuroda, M. Tsujimoto, Y. Sugimoto, and K. Hasegawa, “Development of a numerical model on displacement correction for ship performance in calm seas based on full-scale measurement” in Proceedings of the International Offshore and Polar Engineering Conference, 2019, pp. 4719–4724. [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85079829675&partnerID=40&md5=b28cb31af19536b01ac8eb5590d92414

[20] N. K. Vu and H. Q. Nguyen, “Influence of Ship’s longitudinal center of buoyancy on the ship resistance by panel method,” Journal of Mechanical Engineering Research and Developments, vol. 43, no. 6, pp. 349–359, 2020, [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85091440555&partnerID=40&md5=3c4aaf756f5d47a91f5a2534a67c891e

[21] P. Liebeck, “Chapter 3 -Vectors in Three Dimensions” in Vectors and Matrices, P. Liebeck, Ed., Pergamon, 1971, pp. 32–53. doi: https://doi.org/10.1016/B978-0-08-015823-5.50006-5.

[22] F. Pérez-Arribas, “Parametric Generation of Small Ship Hulls with CAD Software” J Mar Sci Eng, vol. 11, no. 5, May 2023, doi: 10.3390/jmse11050976.

[23] R. G. McClarren, “Chapter 15 – Numerical Integration with Newton – Cotes Formulas,” in Computational Nuclear Engineering and Radiological Science Using Python, R. G. McClarren, Ed., Academic Press, 2018, pp. 267–285. doi: https://doi.org/10.1016/B978-0-12-812253-2.00017-0.