H-infinity for autonomous surface vehicle position estimation

T Herlambang\textsuperscript{1}, D Rahmalia\textsuperscript{2}, A Suryowinoto\textsuperscript{3}, F Yudianto\textsuperscript{1}, F A Susanto\textsuperscript{1}, M Y Anshori\textsuperscript{4}

\textsuperscript{1}Department of Information System, Universitas Nahdhatul Ulama Surabaya
\textsuperscript{2}Department of Mathematics, Universitas Islam Darul Ulum Lamongan
\textsuperscript{3}Electrical Engineering Department, Institut Teknologi Adhi Tama Surabaya
\textsuperscript{4}Department of Management, Universitas Nahdhatul Ulama Surabaya

E-mail: teguh@unusa.ac.id

Abstract. Indonesia is a country with a very prominent marine charm, and it is the largest archipelago in the world, covering about 50\% of the coral triangle area, providing marine tourist resorts. Therefore tourism development is quite promising. For that purpose, simple boats are of necessity for tourists to enjoy the beauty of such marine tourism. One solution to support such marine tourism sector is the availability of Autonomous Surface Vehicle (ASV). This vehicle will be the interest of this paper. This study used Touristant ASV with dimensions of 1.5 m in diameter, 4 meters in length and 1.3 meters in height. The purpose of this paper is to conduct a study with a focus on the estimation of ASV position with ASV motion influenced by wind speed and wave height by applying the H-infinity method. The position error generated from the simulation shows that the position error has an accuracy of about 96\%.

1. Introduction
Tourism is one of the sectors of priority, playing an important role in the economic activities of a country. Even this sector exceeds the oil and gas sector as well as other industries if managed properly. Thus, many countries in the world are competing to develop their tourism potentials as an effort to increase their state income.

In the current tourism development, the central government makes efforts so as to ensure that its tourism targets be achieved. Indonesia's tourism targets are stated in Law no. 10 of 2009 Article 4, that is, to increase economic growth, to improve people's welfare, to eradicate poverty, to overcome unemployment, to conserve nature, environment and resources, to promote culture, to raise the image of the nation, to foster a sense of love for the homeland, to strengthen the national identity.

One of the strategic elements in tourism activities is the transportation sector. Referring to the structure of the tourism system proposed by Lepier in Cooper et al (1993), Transportation is a medium in tourism bringing tourists from their area of origin to tourist destinations. The illustration above indicates that transportation plays a very important role in the tourism system.

Indonesian is a tourist destination, one on hand for tourists from Australia, Malaysia, Singapore, Japan, Taiwan, Hong Kong, Middle East, Europe and America. Imagine how they can reach Indonesia without transportation. On the other hand, Indonesia's geographical condition is as an archipelagic and maritime country [1], meaning it surely makes maritime tourism transportation an important thing in connecting among regions in Indonesia [2].
To enjoy the beauty of marine tourism, it is necessary to provide a simple boat which is controlled by man. One solution to support the marine tourism sector is to use an Autonomous Surface Vehicle (ASV). Therefore, this study used Touristant ASV with dimensions of 1.5 m in diameter, 4 meters in length and 1.3 meters in height [3]. The objective of the study was to conduct a study on the estimation of ASV position with ASV motion under the influence of wind speed and wave height using the H-infinity method.

**Autonomous Surface Vehicle**

ASV is equipped with GPS (Global Positioning System), sensors, gas, pH sensors, bluetooth, and telemetry. When the location has been determined, the vehicle will move automatically in real-time. The Profile and Specification of Touristant ASV are listed in Figure 1 and Table 1.

![Figure 1. Profile of Touristant ASV [3,4].](image)

**Table 1. Specification of Touristant ASV [3,4].**

|       |       |
|-------|-------|
| Length| 4.12 m|
| Beam  | 1.625 m|
| Depth | 1.027 m|
| DWL   | 0.3 m  |
| AP    | -2.618 m|
| FP    | 2.618 m|

The study uses the equation of water vehicle motion with 3 degrees of freedom from 6 degrees of freedom, that is, surge, sway and, yaw. In general, the water-vehicle motions are divided into two types, namely translational and rotational motions. Translational motion is divided into three, that is, surge, sway and heave. While rotational motion is divided into three, that is, roll, pitch, and yaw [5].

By using a simplified nonlinear model [5]:

**Surge**

\[(m - X_u)\dot{u} = X_{u|u}|u|u + (1 - h)X_{prop} + (m + X_{ur})vr + (mx_G + X_{rr})r^2 + X_{\delta \delta} \delta^2 + X_{ext} \tag{1}\]

**Sway**

\[(m - Y_\psi)\dot{\psi} + (mx_G - Y_r)\dot{r} = -(m - Y_{ur})ur + Y_{uv}uv + Y_{u|v}|v|v + Y_{|v|v}|v|r + Y_{\delta} \delta + Y_{ext} \tag{2}\]

**Yaw**

\[(mx_G - N_\psi)\dot{\psi} + (I_z - N_r)\dot{\gamma} = -(mx_G - N_{ur})ur + N_{uv}uv + N_{|v|v}|v|v + N_{|v|r}vr + N_{\delta} \delta + N_{ext} \tag{3}\]
2. H-Infinity Algorithm
The H-infinity algorithm can be seen in figure 2 [6].

![Figure 2. H-infinity Algorithm.](image)

3. Simulation Result
The simulation on this spring used the H-infinity method, divided into three simulations with a time of 200 seconds, 300 seconds and 400 seconds. The implementation of the ASV 3-DOF model on the H-infinity algorithm was used to determine the ASV movement. The movement of the ASV modeled with 3-DOF enabled to see each movement in 2 dimensions, namely on the x and y axes.

![Figure 3. Estimation of x and y position using H-Infinity with simulation time 200 second.](image)
Figure 4. Estimation of XY Plane position using H-Infinity with simulation time 200 second.

The first simulation results with a time of 200 seconds appears in the X plane. The estimation results showed a high accuracy because they could follow the real movement of the ASV. Likewise in the Y plane, the movement estimation results had high accuracy. So, Figure 4 representing the ASV movement in 2 dimensions showed accurate results, in which the estimation results could follow the real movement of the ASV.

Figure 5. Estimation of x and y position using H-Infinity with simulation time 200 second.
Figures 4 show the simulation results with a time of 300 seconds. The estimation results by the H-infinity algorithm had a fairly high accuracy on the real ASV movement. The accuracy reached was more than 95%. The combination of Figure 5 and Figure 6 which is a representation of ASV movement in 2 dimensions also had a small error that we can see from the movement of the estimated and real results. It shows that H-infinity method is one of the estimation methods applicable in nonlinear models.

Figure 7. Estimation of x and y position using H-Infinity with simulation time 400 second.
Tables 7 and 8 show the simulation results using a time of 400 seconds. In this simulation we can compare with the highest time of 200 and 300 seconds. With a time of 400 seconds it has an accuracy value. This can also be seen in the comparison in Table 2 both the estimate at the x position and that at the Y position using 400 seconds were more accurate, so that the estimate on the XY plane also had a high accuracy value.

**Table 2.** RMSE value from Computational Result.

|          | 200 Second | 300 Second | 400 Second |
|----------|------------|------------|------------|
| X position | 0.008546 m | 0.007831 m | **0.00649 m** |
| Y position | 0.00877 m  | 0.00721 m  | **0.006831 m** |
| XY Plane   | 0.0255 m   | 0.0194 m   | **0.0134 m** |

4. Conclusion
The result of the analysis of the three simulations shows that H-infinity method can be effectively used to estimate the nonlinear system trajectory of Touristant ASV with significantly high accuracy.

**Open Problem.** How to implemented Particle Filter for position estimation of ASV.

**Acknowledgement**
We gratefully acknowledge the support form LPPM - University of Nahdlatul Ulama Surabaya (UNUSA).
References

[1] Herlambang T, Subchan and Nurhadi H 2018 Design of Motion Control Using Proportional Integral Derivative for UNUSAITS AUV International Review of Mechanical Engineering IREME Journal 12 No 11 Pp 928-938 ISSN 1970 – 8734

[2] Nurhadi H, Herlambang T and Adzkiya D 2019 Position Estimation of Touristant ASV Using Ensemble Kalman Filter“, International Conference on Mechanical Engineering, 28-29 August 2019

[3] Adzkiya D, Nurhadi H and Herlambang T 2019 Design of Sliding Mode Control for Linearized Touristant ASV Model International Conference on Advance Mechatronics, Intelligent Manufacture, and Industrial Automation IEEE ICAMIMIA

[4] Nurhadi H, Herlambang T and Adzkiya D 2019 Trajectory Estimation of Autonomous Surface Vehicle using Square Root Ensemble Kalman Filter International Conference on Advance Mechatronics, Intelligent Manufacture, and Industrial Automation, IEEE, ICAMIMIA

[5] Herlambang T, Adzkiya D, Nurhadi H 2019 Trajectory Estimation of Autonomous Surface Vehicle Using Extended Kalman Filter The Third International Conference on Combinatorics, Graph Theory and Network Topology

[6] Anshori M Y, Herlambang T, Karya D F, Rahmalia D, Inawati P A 2019 H-Infinity for World Crude Oil Price Estimation The 1st International Conference on Lesson Study of Science, Technology, Engineering, and Mathematics