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DEVELOPING ALGORITHM OF DRONE TRANSPORTATION FOR REDUCING RESPONSE TIME FOR MARITIME SAR OPERATIONS

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Abstract

This research focuses on the development of a control algorithm for drones to improve response time in maritime Search and Rescue (SAR) operations. The study evaluates the effectiveness of Proportional-Integral-Derivative (PID) control in stabilizing the quadcopter's position and reducing positional error relative to the setpoint. Initial tests indicated an average position error of 0.055% without PID control. With the first PID tuning, this error reduced to 0.031% with a stabilization time of 20 seconds. A second PID tuning further minimized the error to 0.024%, achieving stability within 10 seconds. These results demonstrate that PID control can significantly enhance the drone's responsiveness and accuracy in reaching the target position. The findings provide valuable insights for optimizing drone algorithms in dynamic maritime conditions, making them more effective for SAR operations. Future recommendations include exploring adaptive control strategies to better address environmental variables, such as wind and sea currents, for further improvements in operational efficiency and stability.

Keywords: Algorithm development, Drone control, Maritime search and rescue (SAR), PID control, Positional accuracy, Quadcopter, Response time.

1. Introduction

Maritime search and rescue (SAR) missions are one of the most challenging and complex operations, especially in terms of response time, which is very important for saving lives. The unpredictable marine environment and rapidly changing weather conditions often slow down the rescue process, which has a significant impact on the safety of victims at sea. In some cases, delays in rescue operations result in victims not being saved because the SAR team is late in reaching the scene. Therefore, innovation is needed to accelerate response time in marine SAR operations to increase the chances of victim safety.

Previous research shows that drones have great potential to accelerate response time in SAR operations. Drones offer advantages in monitoring large areas faster than traditional methods such as ships or helicopters, especially in accessing areas that are difficult to reach or dangerous for SAR personnel. Another study found that drones equipped with thermal sensors can detect signs of life at sea, even in low visibility conditions. However, the use of drones in SAR operations still faces obstacles such as battery life and limited range, which affect their effectiveness in extreme weather conditions. To support faster and more accurate deployment of drones in search and rescue operations, it is essential to develop reliable flight control systems. In this regard, control algorithms particularly the Proportional-Integral-Derivative (PID) controller play a vital role in stabilizing drone movement and minimizing positional error, especially under unpredictable maritime conditions. In maritime SAR operations, drones are frequently deployed in highly dynamic and unstable environments where wind gusts, wave motion, and the absence of stable landing platforms can compromise positioning and responsiveness. In such settings, reliable control systems are critical to ensure that the drone can maintain accurate trajectories, hover with minimal drift, and respond quickly to setpoint changes, all of which are vital for timely victim detection and resource delivery.

Research on the use of drones in SAR at sea has increasing urgency, especially in an effort to cut response time for the safety of human lives. In SAR operations, every second counts, because the chances of survival of victims in extreme environments such as the open sea decrease as time goes by. This condition requires technological solutions that are able to detect the location of victims faster than conventional methods such as ships or helicopters, which are often limited by the terrain and require a long travel time to the search point. Drone technology offers unparalleled flexibility and speed in monitoring large areas, especially in locations that are difficult to access with traditional means of transportation. Drones equipped with high-resolution cameras, infrared sensors, or thermal imaging can map and identify signs of life at sea even in low-visibility conditions, such as thick fog or bad weather. The response speed generated by drone technology can improve the effectiveness of SAR operations, allowing rescue teams to immediately focus their efforts on an accurate location without wasting time on lengthy initial surveys. The urgency of this research is also increasingly felt considering the increasing number of maritime accidents due to extreme weather changes and dense marine activities. As a cost-effective technology compared to the operation of helicopters or large ships, drones can be an efficient solution for wider and routine SAR operations in the future. This research not only has the potential to save more lives but also helps SAR agencies strengthen preparedness and efficiency in handling incidents at sea quickly and accurately.

This study aims to examine the effectiveness of using drones in transportation in SAR operations at sea, especially in accelerating response time and overcoming environmental constraints faced at sea. By providing various parameters such as detection speed, search range, and cost efficiency, this study is expected to provide significant contributions to technology-based SAR optimization strategies.

2. Literature Review

The following relevant research studies strengthen the position of researchers researching the role of drones in the disaster realm. The study evaluates monitoring using drones in real-time in the disaster area, accelerating the identification of danger points for rescue priorities [1]. Thermal imaging on drones improves the ability to detect victims at night or in low visibility conditions, speeding up response time [2]. The integration of drones in urban emergency response has been shown to reduce response times in SAR operations, especially for the initial mapping of disaster areas [3]. This study shows the effectiveness of flood mapping using drones to speed up the identification of affected areas and help rescue teams [4].

In another study, an evaluation process of using drones to assess post-earthquake damage was used to speed up the rescue process by mapping critical areas [5]. Drones are used for medical distribution in disaster areas, improving the efficiency of drug distribution to affected areas [6]. The drone provides a temporary communication network in the disaster zone, which speeds up the coordination of rescue teams in areas without signals [7]. Unmanned aerial networks have proven to be very effective in critical missions, reaching hard-to-reach areas to provide critical assistance [8]. Poledrone can be used as learning aid in order to obtain accurate point more precision landing system without any damage [9]. Using drones for emergency resource allocation in flooded areas accelerates response and assists SARs in targeted distribution [10].

Drones help assess building damage after disasters, accelerate identification of risk areas and improve the effectiveness of SAR teams [10]. The use of drones demonstrates the effectiveness of UAVs in avalanche rescue operations, speeding up the detection and rescue time of victims [11]. By bridging the gap between cutting-edge technology and life-saving applications, Drone and IoT technologies have the potential to redefine the search and rescue mission landscape, ushering in an era of increased efficiency, precision, and impact [12]. The use of drones for post-tsunami monitoring helps the SAR team in detecting victims in coastal areas quickly [13]. Mapping oil spills using drones is a quick and accurate identification stage of the stage to reduce economic losses and environmental pollution [14]. The use of drones can increase the flexibility of unmanned aerial vehicles (UAVs), new and dynamic communication and sensing solutions can be used in at-risk areas in a limited time on earthquake recovery, forest fire detection, and biological disease management are discussed in depth [15]. Image processing also can recognize the arUco ID and its location coordinates on a Master of Multi-Quadcopter for Optimizing Area Boundary Monitoring System [16].

3. Platform Architecture and Design

The software on this side uses the Robot Operating System (ROS), which is installed with the MAVLink, MAVROS and Rosbridge_suite packages. The data signal sent by the Quadcopter controller via ESP8266 telemetry is received by the computer operator via Wi-Fi on UDP port 14557 and IP address 192.168.2.1. Data received by the operator's computer with the installed MAVLink protocol, translated into data that can be understood by ROS using MAVROS, then stored in the ROS database. The data is then used in the quadcopter mission according to the movement program that has been created. The system of drone can be seen in Fig. 1.

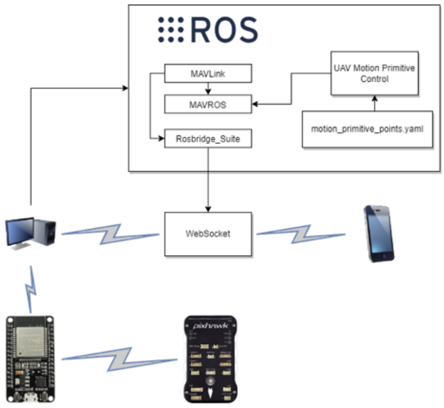


Fig. 1. System of Drone.

4. Result and Discussion

Figure 2 shows the prototype of maritime SAR operations.

Fig. 2. Prototype of maritime SAR operations.

Testing is done by inputting offboard, arm, then giving movement commands on each axis. The parameters seen in this test are changes in input to the interface control display, Quadcopter connection to ROS and connectivity between each package and nodes on the ROS used, Quadcopter movement and the accuracy of speed, altitude, position and orientation of the Quadcopter. These parameters can be seen through rqt which is a default node from ROS to display each data that comes out and enters the ROS database. The data presented through rqt can be in the form of graphs, diagrams or real-time data sent and received via ROS.

Connectivity on each ROS package and ROS Node that exchanges ROS Topics can be seen in Fig. 3. as in the image that shows connectivity in the ROS workspace functioning as desired. While in the motion primitive program that is run on the terminal console too, as long as there is no movement command or after the Quadcopter position has reached the target position, it will display ROS Info which shows the current target position value. On the terminal console, as well as physical observations of drone movements, there were no errors or warnings during testing.

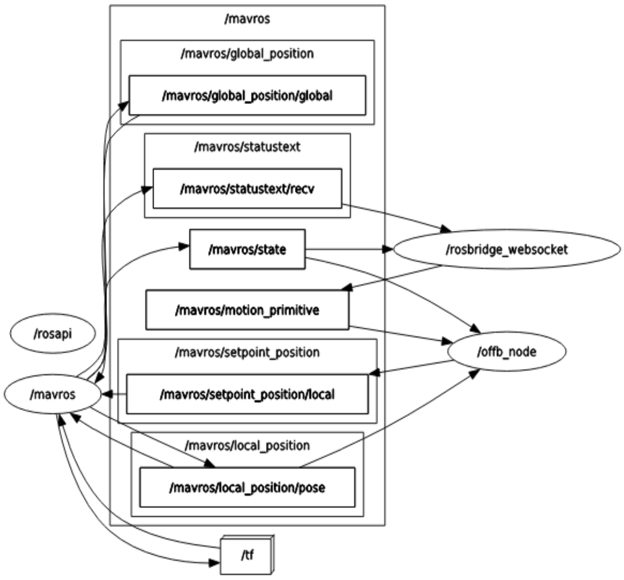
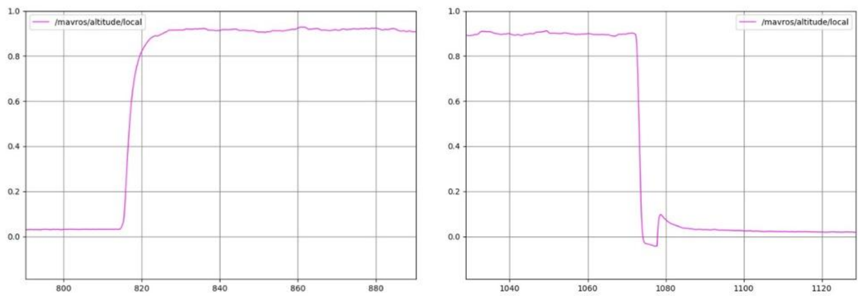


Fig. 3. The algorithm of drone diagram.

4.1. Distance

The final result of the testing on the Quadcopter is the statistical value of changes in altitude, position and speed on the Quadcopter which is shown in Figs. 4-8.



(a) **(b)**

Fig. 4. (a) Setpoint increased, (b) Setpoint decreased.

In testing the program with the height parameter command on the IMU based on the graph in the image, the height approaching the target can be achieved in less than 1 second with an error value of 10%. On the up and down setpoint graphs, both show relatively the same time even though when descending there is a gravitational pull that accelerates the descent of the Quadcopter. This happens because the acceleration settings in ROS have been made the same between the up and down setpoints.

4.2. Orientation

The final test results listed in the orientation graph (Fig. 5) show stable results. Each orientation movement, the four axes x, y, z and w show rapid value changes, and the errors are also only slightly visible.

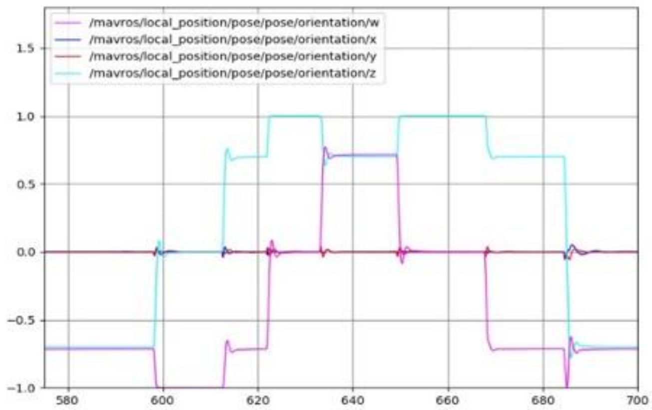


Fig. 5. Orientation graph.

4.3. PID for control position

Figure 6 shows the position output graph without using PID. The response of each X, Y or Z axis to changes in the setpoint looks unstable or the quadcopter is never still because there is continuous movement on each axis.

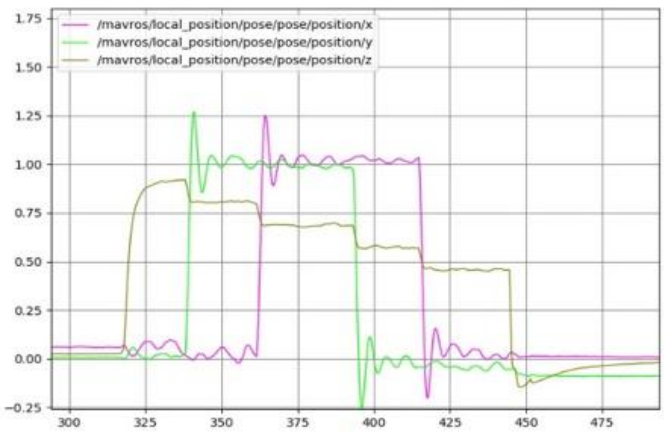


Fig. 6. Position without PID.

After the first PID tuning on the controller, the position of the quadcopter on each axis is seen to be more stable, but the response speed to its setpoint until stable is seen at an average of 20 seconds. It can also be seen from the graph that the position on the Z axis has a large error. This value is not yet optimal, so PID tuning can still be done once more to maximize it.

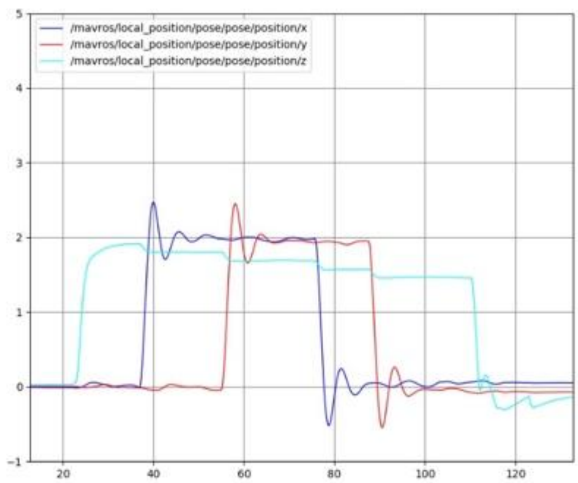


Fig. 7. First tuning position.

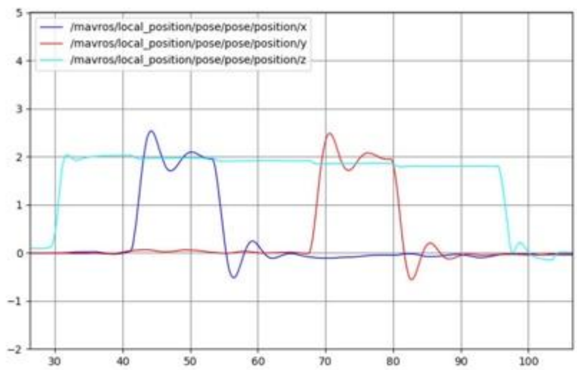


Fig. 8. Second tuning position.

In the final test of the position on each axis, after PID tuning was done once again, the position value on each axis only had a small error. Then the response speed to the average setpoint was only around 10 seconds. This proves that the use of PID in quadcopter control in this final project produces better output. The test results on the input, seen on the web interface, each button function and command can be operated and connected properly with the quadcopter. Likewise with the connectivity between each package, it can be seen from the terminal which shows that the package used has no warnings or errors.

Finally, the position graph shows that the position value when not using PID control has an average error of 0.055% which can be seen in the table. The position value at the time of the first PID tuning has an average error of 0.031% which can be seen in the table, with an initial time to stability of 20 seconds. The position value at the time of the first PID tuning has an average error of 0.024% which can be seen in the table, with an initial time to stability of 10 seconds. So, it is concluded that the use of PID can accelerate the response of the quadcopter to reach the position according to the setpoint, also reducing the error from the position based on it.

5. Conclusion

Based on the test results, implementing PID control on the quadcopter has proven effective in accelerating its response to reach the setpoint position while significantly reducing positional error. Compared to the non-PID condition, the first and second PID tunings reduced the average error to 0.031% and 0.024%, respectively, and shortened the stabilization time from 20 seconds to 10 seconds. These results indicate that a more precise control algorithm can improve the drone's accuracy and efficiency in reaching a designated point.

In the context of maritime SAR operations, where environmental instability and rapid deployment are key concerns, the ability of drones to respond quickly and maintain stable positioning is critical. Enhanced control precision enables drones to carry out specific rescue tasks more effectively, such as hovering precisely over a victim's location, maintaining visual lock for thermal imaging, or navigating to drop-off points for emergency supplies.

For developing drone algorithms in maritime SAR (Search and Rescue) operations, it is recommended to continue refining PID tuning or other control algorithms to achieve faster and more accurate response times in dynamic maritime environments. Utilizing adaptive control algorithms that can adjust parameters according to weather and sea wind conditions, along with integrating more advanced sensors, could also be considered to enhance the drone's stability and effectiveness in SAR emergency situations.

References

1. Mustafa, A.; Ebaid, A.; Omrani, H.; and McPhearson, T. (2021). A multi-objective Markov Chain Monte Carlo cellular automata model: Simulating multi-density urban expansion in NYC. *Computers*, *Environment and Urban Systems*, 87, 101602.
2. De Carvalho, L.L.; and Kogler, J.E. (2021). The enactive computational basis of cognition and the explanatory cognitive basis for computing. *Cognitive Systems Research*, 67, 96-103.
3. McLean, H.E.; Teel, T.L.; Bright, A.D.; Jaebker, L.M.; Tomecek, J.M.; Frank, M.G.; Connally, R.L.; Shwiff, S.A.; and Carlisle, K.M. (2021). Understanding tolerance for an invasive species: An investigation of hunter acceptance capacity for wild pigs (Sus scrofa) in Texas. *Journal of Environmental Management*, 285, 112143.
4. Morimura, S.; Zeng, X.; Noboru, N.; and Hosono, T. (2020). Changes to the microbial communities within groundwater in response to a large crustal earthquake in Kumamoto, southern Japan. *Journal of Hydrology*, 581, 124341.
5. Thota, S.K.; and Vahedifard, F. (2021). Stability analysis of unsaturated slopes under elevated temperatures. *Engineering Geology*, 293, 106317.
6. Chan, Y.T. (2020). Collaborative optimal carbon tax rate under economic and energy price shocks: A dynamic stochastic general equilibrium model approach. *Journal of Cleaner Production*, 256, 120452.
7. Feng, W.; Tang, J.; Yu, Y.; Song, J.; Zhao, N.; Chen, G.; Wong, K.-K.; and Chambers, J. (2020). UAV-enabled SWIPT in IoT networks for emergency communications. *IEEE Wireless Communications*, 27(5), 140-147.

8. Chandran, I.; and Vipin, K. (2024). Multi-UAV networks for disaster monitoring: Challenges and opportunities from a network perspective. *Drone Systems and Applications*, 12, 1-28.
9. Khoirunnisa, H.; Adi, F.S.; Mulyadewi, A.; Sukarno, S.A.; Erdani, Y.; and Anggraeni, P. (2023). Implementation of IR Lock on Poledrone (Polman Drone Education) for precision landing with ROS. *Proceedings of the* 2023 *IEEE* 15th *International Conference on Computational Intelligence and Communication Networks* (*CICN*), Bangkok, Thailand, 584-590.
10. Khalil, A.; Nasser, W.S.; Osman, T.A.; Toprak, M.S.; Muhammed, M.; and Uheida, A. (2019). Surface modified polyacrylonitrile nanofibers by TiO_2/MWCNT for photodegradation of organic dyes and pharmaceutical drugs under visible light irradiation. *Environmental Research*, 179, 108788.
11. Iob, P.; Frau, L.; Danieli, P.; Olivieri, L.; and Bettanini, C. (2020). Avalanche rescue with autonomous drones. *Proceedings of the* 2020 *IEEE* 7th *International Workshop on Metrology for AeroSpace* (*MetroAeroSpace*), Pisa, Italy, 319-324.
12. Farsath, K.R.; Jitha, K.; Marwan, V.K.M.; Jouhar, A.M.A.; Farseen, K.P.M.; and Musrifa, K.A. (2024). AI-enhanced unmanned aerial vehicles for search and rescue operations. *Proceedings of the* 2024 5th *International Conference on Innovative Trends in Information Technology* (*ICITIIT*), Kottayam, India, 1-10.
13. Wang, C.-A.; Xu, D.; Gao, J.-P.; Tan, J.-Y.; and Zhou, Z.-Q. (2021). Numerical study of surface thermal signatures of lee waves excited by moving underwater sphere at low Froude number. *Ocean Engineering*, 235, 109314.
14. Xing, J.; Zhang, Y.; Li, B.; Cao, Z.; Zhan, C.; Liu, Y.; Hao, M.; and Jiang, Z. (2024). Terrestrial oil spills recognition based on small samples from UAV multispectral images. *IEEE Sensors Journal*, 24(22), 37786-37799.
15. Bushnaq, O.M.; Mishra, D.; Natalizio, E.; and Akyildiz, I.F. (2022). *Unmanned aerial vehicles* (*UAVs*) *for disaster management*. In Denizli, A.; Alencar, M.S.; Nguyen, T.A.; and Motaung, D.E. (Eds.), *Nanotechnology-Based Smart Remote Sensing Networks for Disaster Prevention*. Elsevier, Amsterdam, Netherlands.
16. Khoirunnisa, H.; Pancono, S.; Anggraeni, P.; Handayani, M.R.; and Arif, R.A.D. (2024). Image processing on a master of multi-quadcopter for optimizing area boundary monitoring system. *Proceedings of the* 2024 14th *International Conference on Electrical Engineering* (*ICEENG*), 237-242, Cairo, Egypt.