

Lobster Growth Monitoring with AI-Based Computer Vision Using SVM and Neural Network

Suhendri¹, Ari Purno Wahyu Wibowo²

¹Program Studi Bisnis Digital – Politeknik Jatiluhur, Indonesia, ²Informatika, Universitas Widyatama, Indonesia

¹suhendri@polijati.ac.id, ²ari.purno@widyatama.ac.id



*Corresponding Author

Article History:

Submitted: 19-06-2025

Accepted: 23-06-2025

Published: 05-07-2025

Keywords:

Lobster; Computer Vision; Neural – Network; SVM; Artificial Intelligence.

Brilliance: Research of Artificial Intelligence is licensed under a Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0).

ABSTRACT

A modern agricultural and aquaculture technique today heavily relies on computer assistance. Computers aid in the analysis, identification, and regulation of feeding patterns, making the process more effective. For example, lobster farming is now predominantly conducted using pond-based methods, known as aquaculture, rather than sourcing lobsters from the wild. This is because lobsters are highly sensitive creatures, and failing to replicate their natural habitat can lead to crop failure. Several factors influence lobster farming conditions, including water quality, feed quantity, and lobster species. Another critical factor is disease outbreaks, which can spread rapidly due to the high lobster density in a single pond. Managing these conditions manually is impractical due to the large number of ponds and the need to replicate natural habitat conditions accurately. To address these challenges, a monitoring mechanism utilizing artificial intelligence (AI)-based image processing is implemented. AI methods can manipulate environmental conditions to closely resemble a lobster's natural habitat by monitoring pH levels, determining gender, and assessing health status. Data accuracy is ensured using two algorithmic approaches. Experimental results show that the application is designed as a GUI with simple features, making it user-friendly for farmers and the general public. This application was tested using a sample of 200 lobsters, achieving a data accuracy rate of 95% with the SVM algorithm and 85% with the Neural Network algorithm. The application can identify lobster species, size, and potential diseases affecting them.

INTRODUCTION

Lobsters are a type of marine animal that is widely cultivated and has high economic value. Currently, lobster farming is prevalent in coastal areas, particularly along the shores of Java and Sumatra. The price of lobster is quite expensive due to its high economic value and the costly, complex farming process that requires specialized skills. This differs from lobsters caught directly in the wild, which are typically fresher and more abundant. However, wild lobster harvesting is limited due to weather conditions, fluctuating yields, and regulatory restrictions designed to protect the ecosystem and ensure lobster sustainability.

Research on seafood traceability has become a crucial requirement for businesses and consumers to address concerns related to food safety, quality, and product substitution. The Southern Rock Lobster (SRL) industry has been proactive in investigating various tracking solutions to mitigate issues related to marine bio-toxins (Rosmawati, Sains, & 2019).

Currently, many lobsters are farmed in tanks or ponds using mass cultivation methods. However, this approach presents several challenges, as the artificial ponds must closely replicate the lobsters' natural habitat. Key conditions that need to be maintained include water quality, pH sensors, and water circulation. If these factors are not properly regulated, the lobsters' health may deteriorate, leading to mortality and crop failure.

Aside from these environmental factors, another critical issue is overcrowding in the ponds. Overpopulation can cause stress in lobsters, which negatively impacts the molting process—the shedding of the exoskeleton necessary for growth. If the pond is too crowded, molting lobsters may become prey for other lobsters, leading to stress and high mortality rates. Additionally, overcrowding results in food competition, creating an imbalance in nutrition distribution.

Previous studies on lobster farming have implemented electronic sensor technology to measure water pH and sanitation levels, ensuring conditions resemble their natural habitat. However, this method has limitations, as it does not effectively regulate pond density or track lobster growth. This research aims to develop a method for measuring lobster density and growth without disturbing their natural habitat by utilizing computer vision with image processing



techniques. These techniques, which have been widely used in industrial and healthcare sectors, are known for their high data accuracy.

STUDI LITERATURE

Crayfish or crawfish, more commonly known as freshwater lobster (*Cherax quadricarinatus*), is a type of crustacean that closely resembles marine lobsters in size and body shape. This species has several advantages over saltwater lobsters, one of which is its ability to be cultivated using simpler techniques compared to tiger prawns and giant freshwater prawns. Additionally, its life cycle is less complex as it does not go through intricate larval stages such as nauplius, zoea, mysis, and post-larva (Hasan, INFOKUM, & 2021). Lobsters belong to the arthropod class and are among the most widely cultivated marine animals. In Indonesia, they hold significant economic value. Several types of lobsters are farmed in the country, with high-quality varieties commonly found in coastal regions, particularly in the waters around Bali, Sulawesi, and the Maluku Islands. Generally, lobsters inhabit shallow waters near coral reefs (Dan & 2020).

Water quality is a crucial factor that significantly affects the success of lobster farming. The water source is a vital aspect of freshwater lobster (*Cherax quadricarinatus*) cultivation, as lobsters not only require an adequate water supply but also high-quality water to ensure optimal growth (Nugroho, ..., & 2023). One of the advantages of freshwater lobsters is their resilience to stress and disease. As long as their dietary needs, water quality, and oxygen levels are met, they can grow and develop rapidly (Deni Johansyah, Foster, Maharani, Prakarsa, & Purnama, 2022). Maintaining water quality within the lobsters' tolerance range is essential for their survival, growth, and development.

The key water quality parameters measured include temperature, pH, and water clarity. The optimal temperature for growth ranges from 25°C to 30°C, with an ideal pH level between 5 and 8. Meanwhile, the optimal water clarity level falls within the range of 25 to 30 cm (Elmunsyah, ..., & 2019). With the wide variety of lobster types in Indonesia and their high economic value, an automatic identification tool is necessary. Each lobster has a unique and rich flavor influenced by its diet and habitat. Previous studies on lobster identification have utilized computerized systems with the help of computers, enabling the identification of all lobster species found in Indonesia. This system is developed as an application using computer vision methods to record various lobster variables, including species, color, size, and gender.

The data reading system operates using a matching method, comparing two lobster objects with similar shapes and characteristics (Allken, Rosen, ..., & 2021). These farmed animals have several advantages compared to saltwater lobsters, making them widely cultivated and highly valuable as a commodity. In previous studies, a monitoring system was deemed essential for collecting data and assessing the condition of lobsters. This research system utilizes IoT devices connected to a computer, ensuring that the collected data is highly useful for research activities and commercial purposes (Zou et al.). Another study stated that a lobster monitoring system plays a crucial role, as identifying and classifying lobsters helps in understanding their characteristics, species, and quality. With advancements in computer technology, a new monitoring system based on IoT has been developed. This technology can be applied for both research and commercial purposes. An IoT-based monitoring system is considered essential because it overcomes human limitations in effectively tracking the movement of freshwater lobsters (Cao, Zhao, Sun, Marine, & 2021).

The factors affecting freshwater lobster growth can be categorized into two types: internal and external factors. Internal factors originate from the lobster itself, such as the molting process, where the lobster must shed and replace its shell as part of its growth cycle. Meanwhile, external factors include environmental aspects, such as food availability and the quality of the water medium used (Ghazal, Munir, Agriculture, & 2024). Freshwater lobsters have been cultivated in Indonesia since the year 2000, with most of them being imported from Australia. A remote water quality monitoring method is used, where data variables are measured using pH sensors or turbidity sensors. The collected data is then analyzed using the Fuzzy Logic Sugeno algorithm, achieving an accuracy rate of 93.5% in this study (Noreils, 2024). Some monitoring techniques and research also utilize computer vision methods. With this approach, the monitoring system is used to measure accuracy by comparing the results with lobster data stored in a database. This method is implemented to assess lobster quality, ultimately enhancing their market value (Gomes & Leta, 2012).

Computer vision methods have also been employed to identify and track specific species, such as the Norway lobster (*Nephrops norvegicus*). The identification scheme involves marking the lobsters with black-and-white labels featuring geometric shapes in the center (e.g., hollow triangles, filled triangles, hollow circles, and filled circles) (Dowling, Dichmont, Haddon, ..., & 2015). Lobster farming previously relied on IoT-based tools, where data was collected from sensor inputs in an application. The sensor values were then used as variables that could be stored in a database. In this study, the sensor variable values were used to monitor the pH threshold. If the pH level exceeded the

normal threshold, the water pump would automatically activate to replace the water, ensuring that the pH level remained stable and returned to normal (Toé et al.).

Lobster production faces challenges due to high mortality rates caused by cannibalism. This behavior primarily occurs among juvenile lobsters and during the molting process, as molting lobsters release a distinct scent that attracts other lobsters, making them vulnerable to predation. One of the factors influencing molting frequency and cannibalism rates is water quality (Chen et al. n.d.). The availability of a reliable water source is crucial in freshwater lobster farming, as their survival depends on an adequate water supply with good quality to support optimal growth. Water quality is determined based on several parameters, including temperature, acidity level (pH), ammonia concentration, and turbidity levels (Marder, Physiol., & 2007, 2007). Human-assisted monitoring systems can be ineffective as they require a large number of experienced personnel. While this method is practical for managing small fish populations, it becomes a challenge when applied to large-scale fisheries. This can lead to prediction errors in data readings due to human error. More modern research employs computer-assisted monitoring using machine learning technology. Visual analysis significantly enhances data reading accuracy and enables the system to track large numbers of fish. This research method has been widely implemented in Norway between 2017 and 2018 (Wahyudi, Hermawan, & Chanas).

Studies on the stomatogastric nervous system in lobsters and crabs have provided valuable insights into cellular mechanisms and neural circuits that generate rhythmic motor patterns. The small number of neurons, which are easily identifiable, allows for the creation of connectivity diagrams among neurons within the stomatogastric ganglion (Vo, Scanlan, Control, & 2020). A similar study has been conducted to read and analyze crab data using cameras mounted on boats. The purpose of this research was to collect data on the health and growth of lobsters. The collected research data was then used to determine where the crabs grew and lived. Additionally, the study recorded water quality and pollution distribution in the surrounding waters. The computer vision method was utilized to identify and analyze lobster objects, with each lobster assigned a unique data record. Data reading accuracy was achieved using machine learning algorithms (Arco, ..., & 2016).

In monitoring and research involving cameras, the accuracy of data readings is affected by poor lighting conditions. To compensate for this limitation, the Phototaxis method was introduced to detect and analyze moving objects with high image sharpness (Lengka, Perairan, & 2013, 2013). Current research integrates computers with specific algorithmic methods to optimize detection and accuracy measurement processes. These methods become even more effective when combined with other computer techniques, such as computer vision. In the agricultural sector, for example, issues can be addressed by detecting and identifying plant diseases. The use of computer-assisted technology is expected to enhance agricultural productivity and ensure sustainable harvests over time (Zaky, Rahim, (JPP), & 2020). The influence of computer technology has had a significant impact on human civilization. The advancement of modern computers with AI capabilities enables them to simulate and manipulate human abilities, allowing them to analyze problems and provide recommendations or solutions in a manner similar to human reasoning. The predictive capabilities of computers in problem analysis rely on an approach known as machine learning (Astiyani, Humaira, & ...).

The implementation of computer vision methods in the livestock and agricultural sectors presents unique challenges, as computers are required to enhance both the quality and quantity of agricultural yields over the long term. The agricultural system itself consists of various types and, naturally, different problems. Therefore, sharp analysis and precise decision-making capabilities are needed to identify agricultural issues and find solutions using computer assistance. The data collected can serve as a decision support tool that influences actions or risk mitigation strategies (Susilo, Cahyana, ..., & 2024). Modern fisheries systems are now interconnected with extensive data and utilize computer assistance for stock management, fishery grading systems, and reporting in the form of forecasting. In broader applications, computers are used to prevent overfishing to maintain fish populations and their natural habitats (Tropis & 2011). Previous research on lobster farming employed IoT-based monitoring devices connected to pipelines. These IoT devices read real-time lobster data, track their development over specific periods, and store measurement results as data for further analysis in forecasting models (Muchtaron, 2021). A modern agricultural system capable of calculating and implementing a grading system is classified as modern agriculture and considered part of a large-scale industry. The YOLO algorithm is widely used for lobster data collection, including determining whether a lobster is male or female. Image processing techniques can analyze lobster texture and unique characteristics, transforming them into useful information. In this study, the data reading accuracy reached 97.23%. GPU-based measurements, combined with YOLO, classify lobster sizes into four categories: V3, V4, V3tiny, and V4tiny. Since real-time applications in marine environments require highly accurate readings, the system is further enhanced using the R-CNN algorithm (Garza de Yta, Davis, Rouse, Ghanawi, & Saoud, 2012).

Data analysis in the study utilized the Confusion Matrix method, which categorizes test results into four general conditions: TP (True Positive), TN (True Negative), FP (False Positive), and FN (False Negative). Based on these four conditions, Recall, Specificity, Precision, Accuracy, and F1 Score values were calculated. From 16 tests involving 16 lobsters weighing 60-190 grams each, the results showed 25 TP cases, 109 TN cases, 11 FP cases, and 15 FN cases. These values yielded a Recall of 0.625 (62.50%), Specificity of 0.9083 (90.83%), Precision of 0.6944 (69.44%), Accuracy of 0.8375 (83.75%), and an F1 Score of 0.6579 (65.79%). Observations and testing of the detection system and application using magnetic sensors were evaluated based on Accuracy, which resulted in a score of 83.75% (Kusuma, Nugroho, Teknologi, & 2023).

METHODS

The lobster monitoring system using this method involves several specialized stages. This method operates with the assistance of cameras connected to hardware devices. In previous research, this approach utilized electronic tools or IoT devices to measure water quality, pH sensors, and feeding processes. Meanwhile, IoT devices were also used to track lobster growth and conduct identification processes, including measuring lobster size, detecting color changes, and assessing lobster health conditions. To further develop this monitoring method, a dataset collection technique is required to serve as comparative data. The volume of comparative data significantly affects the accuracy of data readings. This data analysis process employs two algorithmic methods: Support Vector Machine (SVM) and neural networks.

Lobster monitoring using Artificial Intelligence (AI) is an innovative computer-assisted method designed to observe and analyze fish behavior as well as aquatic environmental conditions. The primary goal of this method is to enable visual monitoring without disrupting the lobster's natural habitat. The main stages of this image processing technique include collecting, analyzing, and interpreting large-scale data. The collected lobster data is divided into two categories: training data and testing data, both of which must undergo several key stages, as outlined below:

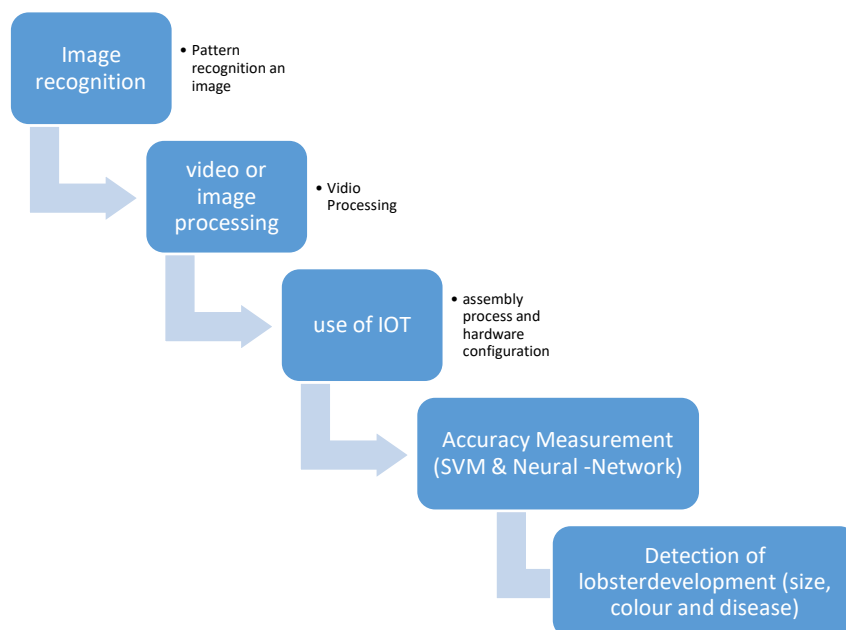


Figure 1: Stages Of The Lobster Monitoring System Using Image Processing and AI Techniques

Image Recognition

Technique: In this lobster monitoring method, the author uses an underwater camera installed directly at the bottom of the pond or above the aquaculture tank. The use of underwater cameras or drones captures images or videos, which are then analyzed using AI-based image recognition algorithms. Before using the camera, a calibration process is performed to adjust sharpness, pixel resolution, and camera placement height.

The purpose of installing the camera is to identify the types and species of lobsters in the pond, count the number of lobsters, and detect their behavior in their natural habitat. For data analysis, the author utilizes algorithms such as **Convolutional Neural Networks (CNN)** and **Support Vector Machine (SVM)**. These algorithms are widely used to detect lobster movement in ponds or deep-sea environments, enabling real-time monitoring of their health and growth.



Video Processing

Technique: Using deep learning algorithms to analyze videos recorded by underwater cameras. The purpose of using deep learning is to capture the behavior of lobsters in the pond to ensure it aligns with their natural habitat. If any unusual movement is detected, the system will automatically perform an identification process by re-evaluating lobster density, including factors such as color, size, gender, and pH levels.

Use of Internet of Things (IoT)

Technique: In addition to using image processing detection methods, another supporting method involves installing electronic sensors in the water (e.g., temperature sensors, pH sensors, dissolved oxygen sensors). These sensors are connected to an AI-based system to analyze environmental conditions and lobster behavior. Abnormal behavior is often linked to pH measurement data that does not match the lobster's natural habitat. The system also provides predictive data on potential stress or diseases, especially during the molting process.

Example application: Providing AI-based analytics to predict when fish or lobsters may experience stress or illness based on environmental data patterns.

Predictive Modeling and Machine Learning

Technique: Machine learning algorithms are used to predict fish movement patterns, growth rates, and factors affecting their health.

Objective: To predict when and where fish will appear and evaluate potential population changes based on historical data.

Application Example: Predicting fish catch yields or the health of fish populations in the near future based on existing data.

Monitoring and Lobster Disease Detection

Technique: In this method, research is conducted by collecting data on lobsters that will be used as samples. The selected lobster samples must meet specific criteria, including size, species, color, and habitat. AI methods can be used to detect fish diseases by analyzing images or videos of infected fish.

Objective: Early detection of fish diseases that can spread rapidly and harm the aquaculture industry. With this system, lobsters in the pond will be separated if they are identified as infected with diseases or pests, preventing the spread to other lobsters through a quarantine method.

Feed Optimization with AI

Technique: Using AI algorithms to regulate feed distribution based on the needs of individual or groups of lobsters, ensuring that the amount of feed provided matches the exact quantity and portion required. Without this method, excessive feed could be produced, polluting water quality. If left unmanaged, this condition could negatively impact the lobster habitat, leading to poisoning. Excess feed will increase ammonia levels in the water, making it toxic. In addition to optimizing feed distribution, this algorithm also measures lobster growth, allowing those ready for harvest to be separated immediately.

RESULTS

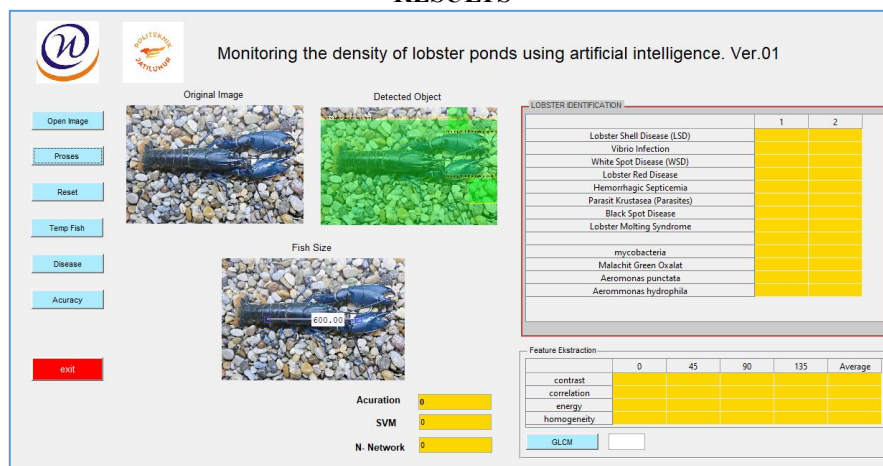


Figure 2. GUI Display of Lobster Growth Measurement Application

In **Figure 2** above, the system testing results using the computer vision method are shown. This method is used to measure the quality of the lobster's shell, which affects its reproduction and, consequently, its overall health. The

health assessment is conducted visually, ensuring that the growth of active and moving lobsters in the pond remains undisturbed.

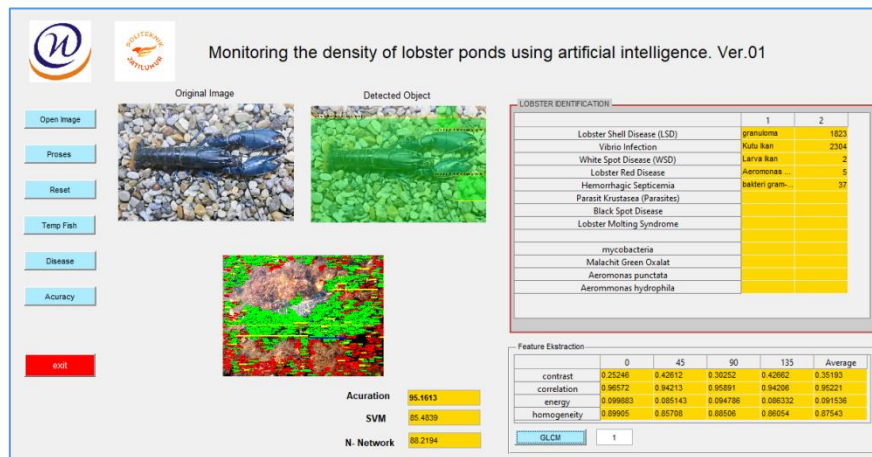


Figure 2. Lobster Disease Detection Display

In **Figure 3** above, the process of lobster identification using feature extraction is shown. This method is used to record and analyze diseases affecting lobsters. Any abnormal color changes that deviate from the original texture data are compared by the algorithm with healthy lobsters. In this method, the pattern-matching system records the number of similarities and differences in each dataset.



Figure 4 . Lobster Density Monitoring System in a Single Pond [5]

In **Figure 4**, the results of monitoring the lobster density in the pond, also known as aquaponics, are shown. This method automatically detects the size and growth of lobsters. The computer-based visual measurement system is useful for indirectly counting the number of lobsters, whether during feeding or while measuring their size.

With the aid of a computer, this measurement system can operate in real-time without disrupting the lobster ecosystem. In previous measurement and monitoring methods, lobsters were manually lifted from the water and measured using a measuring tape. This approach disturbed lobsters undergoing shell molting, potentially causing stress, unsuccessful molting, and even death.

In this test, the author conducted experiments on several lobster samples, converting their size measurements from centimeters to millimeters

Table 1. Lobster Growth Testing Using Computer Vision Method

No	Description	Size mm	Size cm	Accuraction
1.	Lobster 01	1226,3	12 cm	95%
2.	Lobster 02	1379.2	13.cm	92%
3.	Lobster 03	1702.4	17.cm	93%
4.	Lobster 04	1287.3	12.cm	95%
5.	Lobster 05	1245.4	12.cm	90%
6.	Lobster 06	1228.2	12.cm	95%
7.	Lobster 07	1652.3	16,5 cm	92%
..	...	...	...	...

Table 1 presents the results of testing 100 lobster samples. In this test, the samples are classified as adult lobsters, with sizes ranging between 12-17 cm. The data reading accuracy was determined using the SVM (Support Vector Machine) algorithm, which classifies the samples based on the available training data. To facilitate accuracy measurement, it was combined with a neural network algorithm that detects the presence of disease in lobsters, as this algorithm can identify the causes of disease by comparing parameters such as changes in color, shape, and size. This identification is achieved by comparing the data of diseased lobsters with that of healthy ones, using the highest accuracy values to ensure an accurate disease diagnosis process for the lobsters.

DISCUSSION

From the results of the study, the author concludes that the implementation and monitoring of lobsters with the aid of computer vision and AI is feasible. The application can display the number and density of lobsters in the containment pond. In this study, 200 lobster samples were randomly collected. The application uses the GLCM method for measurement, and the lobsters are automatically measured using computer vision, with results ranging from 10 to 17 cm, which falls under the category of adult lobsters. For accuracy, the author employed two types of algorithms—SVM and Neural Network—with accuracies above 95%. This application is user-friendly and does not disturb the ecosystem. The GUI-based design allows users to visually inspect the lobster images and view the size data. Additionally, the application is capable of displaying diseases affecting lobsters, whether impacting their shell or skin, and it serves as a decision-making tool to determine whether the lobsters should be sold or quarantined if infected by water-borne or viral diseases.

CONCLUSION

From the experimental results above, the lobster monitoring system can be easily utilized and implemented. This application serves as a tool for recording and analyzing the condition of lobsters, ensuring it aligns with their natural habitat. Data measurements are taken in real time over a 24-hour period, which offers several advantages—namely, the movement and behavior of lobsters are captured and stored in a database. This information, in turn, influences the feeding patterns by regulating lobster density based on the available feed, thereby making the feeding process more effective and efficient.

The monitoring system in this study is implemented in two distinct stages: electronic sensing and image processing. This unique combination entails that electronic sensors provide information regarding the water's pH conditions, which affects the amount of feed given, while the image processing method offers analysis on whether the lobsters are diseased or healthy. The monitoring application is built as a GUI, making it accessible to general users, where lobster data appears along with their sizes and the types of diseases affecting them.

For assessing accuracy and data readings, the study employed two algorithm methods—SVM and Neural Network. SVM was used to determine the accuracy of lobster classification, whereas the Neural Network was responsible for identifying the type of disease affecting the lobsters. For future research, to further improve accuracy and capture new types of diseases affecting lobsters, it is necessary to conduct additional measurements and expand the dataset. This will add more parameters and variables concerning disease types, ultimately making the application smarter and more accurate.

REFERENCES

- Albaab, M. R., & Purbaningtyas, R. (2024). Website Monitoring Pinter Terintegrasi Berbasis IoT pada Budidaya. *Jurnal Aplikasi Teknologi Informasi dan Manajemen*, 4, 1-18.
- Ali, M. (2021). KLASIFIKASI KUALITAS AIR PADA BUDIDAYA LOBSTER AIR TAWAR MENGGUNAKAN METODE NAÏVE BAYES. *Repository Universitas Nahdlatul Ulama Sunan Giri Bojonegoro*.
- Allken, V.; Rosen, S.; Handegard, N.O.; Malde, K. A. (2021). A deep learning-based method to identify and count pelagic and mesopelagic fishes from trawl camera images. *ICES*, 78, 3780–3792.
- Arco, G. d., & Antonio, J. (2016). Using ORB (Oriented FAST and Rotated BRIEF), BoW and SVM to identify and track tagged Norway lobster *Nephrops norvegicus*. *SARTI*(March), 50-52.
- Astiyani, W. P., Humaira, F., Febriani, V. T., Akbarurasyid, M., & Prama, E. A. (2024). NILAI PARAMETER KUALITAS AIR PADA PEMELIHARAAN LOBSTER AIR TAWAR (*Cherax quadricarinatus*). *Jurnal Ilmiah Kelautan dan Perikanan*, 6, 1.
- Bagas Prasetyo Nugroho, Ahmad Fahrudi Setiawan, Deddy Rudhistiar. (2023). SISTEM MONITORING DAN CONTROLLING ALAT PENGURAS AIR OTOMATIS PADA KOLAM LOBSTER BERBASIS IOT. *JATI (Jurnal Mahasiswa Teknik Informatika)*, 7(1).
- Bob Foster, Vani Maharani, Graha Prakarsa, Susan Purnama. (2022). Improving the Value of Lobster Selling with Grading Method Using Machine Vision Technology. *Linguistics and Culture Review*.

- C. K. Sastradipraja. (2020). "SISTEM PEMANTAUAN KESEHATAN LOBSTER (LHMS) MENGGUNAKAN MACHINE LEARNING . *JURSISTEKNI*, 2(1), 1-9.
- Cao, S.; Zhao, D.; Sun, Y.; Ruan, C. (Mar. Sci. 2021). Learning-based low-illumination image enhancer for underwater live crab detection. . *ICES J.* , 78, 979–993.
- Chen, X.; Zhang, Y.; Li, D.; Duan, Q. (2023). Chinese Mitten Crab Detection and Gender Classification Method Based on Gmnet-Yolov4. *Comput. Electron. Agric.* 2023, 214, 108318.
- Fishery and Aquaculture Economics and Policy Division. Guidelines for the Routine Collection of Capture Fishery. (n.d.). *Data; FAO Fisheries Technical Paper*. ROME .
- Hakkun Elmunsyah , Feri Kurniawan , Prima yams Fathurrachman , Putri Ayu Anggreini ,Yogi Dwi Mahandi. (2018). Automated Lobster Cultivation Monitoring System Based on Embedded System and Internet of Things: TALOPIN . *Advances in Social Science, Education and Humanities Research*, 242.
- How computer vision is changing agriculture in.* (2023). Retrieved from <https://voxel51.com/blog/how-computer-vision-is-changing-agriculture-in-2023/> Accessed
- Lengka, K., Kolopita, M., & Asma, S. (2013). Teknik Budidaya Lobster (*Cherax quadricarinatus*) Air Tawar di Balai Budidaya Air Tawar. *Budidaya Perairan*, 1, 15-21.
- Lesmana, D., Robin, MZ, N., & Milla, A. N. (2022). EVALUATION OF PRODUCTION PERFORMANCE OF FRESHWATER CRAYFISH *Cherax quadricarinatus* WITH DIFFERENT FEEDING RATE. *Jurnal Mina Sains*, 8(Oktober), 101-106.
- Marder, E., & Bucher, D. (2007). Understanding circuit dynamics using the stomatogastric nervous system of lobsters and crabs. *PubMed*, 69(February), 291-316.
- Rosmawatia, Mulyanaa, and M. A. Rafib,. (2019). Pertumbuhan dan Kelangsungan Hidup Benih Lobster Air Tawar (*Cherax quadricarinatus*) Yang Diberi Pakan Buatan Berbahan Baku Tepung Keong Mas (*Pomacea* sp). *J. Mina Sains* , 31-41.
- (2024). *Shakey the Robot*. DARPA, 2024. . darpa.mil/about-us/timeline/shakey-the-robot Accessed.
- Sipriana, S. T. (2011). KUALITAS AIR PADA KOLAM LOBSTER AIR TAWAR (*Cherax quadricarinatus*) DI BBAT TATELU. *Jurnal Perikanan dan Kelautan Tropis*, vii(Desember), 3.
- Sumaira Ghazal ; Arslan Munir ; Waqar S. Qureshi ;. (2024). Computer vision in smart agriculture and precision farming: Techniques and applications. *Artificial Intelligence in Agriculture*, 13, 64-83.
- Susilo, A., Cahyana, Y., PuspitaLestari, S. A., & Rohana, T. (2024). Implementasi Alat Ukur Suhu Dan PH Air Untuk Budidaya Lobster Dengan Algoritma Fuzzy Logic Berbasis IoT. *Jurnal Teknik Informatika dan Sistem Informasi*, 4(Desember), 1-10.
- Toé, S.G.D.; Neal, M.; Hold, N.; Heney, C.; Turner, R.; Mccoy, E.; Iftikhar, M.; Tiddeman, B. (2023). Automated video-based capture of crustacean fisheries data using low-power hardware. *SENSOR*.
- Vo, S. A., Scanlan, J., & Turner, P. (2020). An application of Convolutional Neural Network to lobster grading in the Southern Rock Lobster supply chain. *Elsevier*, 113.
- Wahyudi, A., Hermawan, M., & Chanos, H. T.-C. (2025). THE USE OF A MAGNETIC SENSOR TO DETECT LOBSTER (*Panulirus* spp.) CATCHES ON THE LABORATORY SCALE. *ejournal-balitbang.kkp.go.id*.
- Yasir Hasan , Kristian Siregar . (2021). COMPUTER VISION IDENTIFICATION OF SPECIES, SEX, AND AGE OF INDONESIAN MARINE LOBSTERS. *JURNAL INFOKUM*, 9(2).
- Zaky, K. A., Rahim, A. R., & Aminin. (2020). JENIS SHELTER YANG BERBEDA TERHADAP PERTUMBUHAN DAN SINTASAN LOBSTER AIR TAWAR RED CLAW (*Cherax quadricarinatus*). *Jurnal Perikanan Pantura*, 3(1).
- Zou, Z.; Chen, K.; Shi, Z.; Guo, Y.; Ye, J. (2023). Object detection in 20 years: A survey. . *IEEE*.