Design of an Automatic Fish Sorting System on a Conveyor based on Machine Vision

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Abstract—In the industrial sector, automatic sorting systems are used to increase production output. This paper describes research conducted on the design of an automatic fish sorting system on machine vision-based conveyors. The approach of applying a stereo camera as a vision sensor designed to become a vision machine is applied to achieve this design goal. In addition, techniques based on stereo vision imaging were developed for the task of fish size identification. A machine-vision based system is used for fish sorting. Algorithms were developed to determine the length, width, and height of fish directly with fast, real-time online processing. This sorting technique applies to one species of fish. The design specifications of the vision system and camera capture device are also presented in this paper. The method of size-based fish product sorting is effective. Sorting by system can identify in either the top or side position. Real-time analysis is used by this system to deliver the necessary outcomes. The outcomes reach the sorting gate situated at the terminus of the conveyor belt system.

Indexed Terms—Design, Automatic fish sorting, Conveyor, Machine Vision

I. INTRODUCTION

Automation aims to make equipment, systems, or processes operate automatically so that they can replace the role of human labor. It has become a very important application for industry today to incorporate automation systems into the production process because it is cost-effective, efficient, and fast. For the advancement of automation, it is important to research the various ways in which an industrial process can be automated.

The decision about how an industrial system or process will be automated depends on the type of industrial system. The most difficult task in fish sorting activities is sorting on conveyors. The stages in the fish sorting process start with measuring the level of injury, measuring area, measuring volume, and sorting. Sorting fish is generally carried out on a fast-moving belt conveyor. This operation is very time-consuming and tends to produce stress and fatigue for the human operator. To overcome this condition, this system can be developed to include computers and sensors that can read fish and automatically sort them according to their final destination. The sensor here is in the form of stereovision, which gives the computer eyes. The integration of stereovision and computers will become machine vision. Machine vision functions like the eyes in the most important organ of the human body, where human abilities depend on their ability to see, differentiate, and separate objects. However, machine vision is still limited as an instrument. For the purpose of automatic fish sorting, machine vision must be integrated with a hardware structure consisting of a conveyor frame, conveyor, drive motor, gearbox, components of other supporting machine elements, instrumentation systems, and software.

The aim of this research is to design a fish sorting system that is on a belt conveyor with stereo-vision as a viewing sensor and integrated with a computer so that it becomes machine-vision. The design of automatic machine-vision based fish sorting on conveyors is a continuation of research that has been carried out by researchers. The research is measurement of injury levels in fish [1], 2D measurement of injury levels in fish using a modified K-means cluster algorithm based on the L*A*B* color space [2], area and volume measurements of real-time fish [3], and measuring the area and volume of fish on moving conveyors [4].

II. LITERATURE REVIEW

The efficiency and productivity of industrial processes and reducing the time and costs of industrial processes cannot be separated from industrial practitioners who are committed to improving automated systems. In the 1950s and 1960s, technicians and engineers had to perform physically challenging and time-consuming work to complete industrial processes. For this reason, it became necessary to develop devices that would make industrial processes more efficient, and this led to the development of modern controllers [5].

The mention of automation technology these days makes people think of industrial robots and computer controllers. However, automation technology began in industry in 1769 with the use of steam engines by James Watt. Steam engines were used to drive several machine tools and drain water from mines [6]. Henry Ford developed the first production line for the Model T in 1913.This resulted in increased productivity, as the time required to produce one car was reduced from seven hundred and fifty to ninety-three hours. This means eight cars can be produced at the same time to produce one car. Increased productivity allowed the price of the Model T car to fall, making it a consumer good for most of the population. Henry Ford's assembly line was based on Frederick Winslow Taylor's division of labor, in which a complex production process could be divided into smaller parts that even unskilled workers could perform [7]. The invention of sensors that can be integrated with computers makes it possible to perform complex tasks automatically. Stereo-vision as a visual sensor integrated with a computer will become machine-vision [8]. Zhifei X. et al. review the application of machine-vision to food detection from the hardware and software of machine-vision systems, introduce the current state of research on various forms of machine-vision, and provide insight into the challenges facing machine-vision systems [9]. Thi Vo et al. provide a review of the development of smart aquaculture and smart technology. The latest results and technology used for the development of smart aquaculture are using machine learning and machine vision [10]. However, machine vision is still limited as an instrument. For the purpose of automatic fish sorting, machine vision must be integrated with a hardware structure consisting of a conveyor frame, conveyor, drive motor, gearbox, components of other supporting machine elements, instrumentation systems, and software.

The fish processing industry requires technological solutions that focus on processing automation to increase production as well as reduce processing time and costs [11]–[17]. Processing automation means making the process work automatically [18]. Automatic fish sorting starts with measuring the level of injury, measuring the surface area and volume of the fish, and sorting[19], [20]. This is an important step in the entire process in the fish processing industry. With the availability of image processing methods and stereo vision as measuring instruments, automation of the fish processing industry process can be carried out through the application of new techniques by developing machine-vision-based automatic sorting methods [21]. The first step that must be taken for automatic sorting of objects using machine vision is image segmentation of the object. Furthermore, measuring the surface area and volume of fish on a moving conveyor in real-time is based on stereovision. The final step is automatic sorting on a moving conveyor.

The main objective of this research is to design a fish sorting system on a conveyor belt with stereo vision as a vision sensor and integrate it with a computer so that it becomes machine vision. In this work, the researcher proposes designing an automatic fish sorting method with machine vision as an instrumentation system that is used as feedback for the automatic system. The design was carried out based on a real-time method of measuring the size of fish on a moving conveyor based on stereovision.

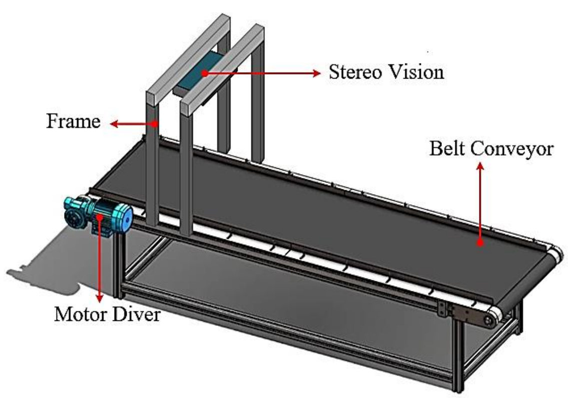
Another strong reason for research on designing automatic fish sorting systems for industrial processes is that Indonesia is rich in biodiversity, including fish. Fish are excellent for economic growth if managed well. The fish management industrial process is one of them. In the fish management industry, there is a very important processing component, namely sensor instruments, which need to be engineered to increase process efficiency, namely machine vision. The fish management industry requires a sorting method, which is an important part of processing. The methods resulting from this research can be used to develop automation for industrial management processes. Furthermore, the development of automation for sorting fruit products, the design of automation for fish sorting activities on Internet of Things (IoT)-based conveyors, and goods-moving robots.

III. MATERIALS AND METHODS

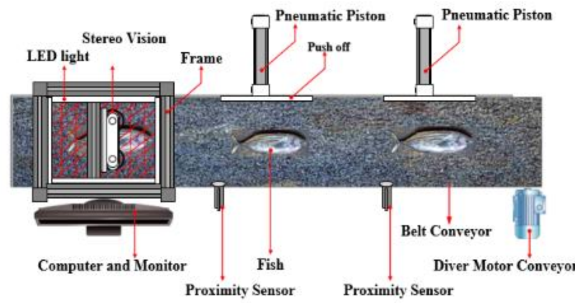
3.1. Design a Belt Conveyor Drive Mechanism.

This part describes the structure design for the sorting system in a belt conveyor. Fig. 1 shows the concept of fish sorting on a moving conveying system. The hardware structure comprises a computing device and a monitor, a stereo-vision, an LED light source, a conveyor system, an electrical motor, and a frame. Every experiment is run on a PC with an Intel CoreTM i3-3220 @ 3.3GHz CPU and 8 GB of RAM running Windows 10 64-bit.

Among the components is the position of the fish entering the measurement area on the part of the frame where stereo vision is installed. In this section, the fish is measured to determine its dimensions. Next, the fish, whose dimensions have been obtained, moves past the proximity sensor. The first proximity sensor and the first pneumatic piston for sorting larger fish sizes. The second proximity sensor and the second pneumatic piston for sorting smaller fish sizes and injury fish.



(a)



(b)

Figure 1. The concept of fish sorting: (a). isometric view structure model of belt conveyor; (b). top-view structure model of belt conveyor

3.2. Design a Machine Vision Based Automatic Sorting Prototype Device.

Two webcams are arranged into a stereo camera, as shown in Fig. 2, and used as stereo-vision in automatic measurement method. Stereo-vision instrumentation is useful for determining fish coordinates. This stereo-vision can detect depth, track motion, and perform real-time fish detection.

Figure 2. Stereo-vision device

Computer hardware as shown in Fig. 1(b) and algorithms are used in machine vision, often referred to as computer vision, to help machine analyze and comprehend visual data from their environment. Replicating human vision abilities is the main objective since it will enable machines to perceive, process, and decide on the basis of visual information. The main elements and guiding concepts of machine vision in fish sorting are integrated with automation and control systems.

3.3. Design an experiment on the effectiveness of the sorting system.

This stage will test the effectiveness of the automatic fish sorting design using machine vision. To carry out this test, the following things are done: First, the stereo camera is calibrated to properly correct the intrinsic parameters and distortion parameters. Second, real-time image segmentation of moving objects is carried out on the target view, and each image is classified and stored on the computer as an image library. Third, the stereo camera automatically identifies the target object by matching two contour views. Fourth, at two matching contour positions, the stereo camera measures the center of mass of the object and the size of the object. fifth, measurements for objects on the moving belt conveyor in real-time. Finally, the fish are sorted on a moving belt conveyor. The sorting is performed by choosing and classifying fish according to their size and the extent of fish injury.

The stereo-vision is the device used for video input. Hardware structures are designed in conjunction with software to group items in real-time. As observed on a conveyor in a fish handling line, objects are grouped together in the shape of fish. Open-source computer vision software with a Visual Studio compiler is used for picture processing and analysis.

Before use, the camera stereo is first calibrated. The goal of the calibration of stereo camera is to get both intrinsic and distortion characteristics. Objects are extracted from a graph-based image using feature extraction and real-time image segmentation. Contour detection, threshold, mathematical morphological change, and HSV color space are used to create these. In the end, dimensions of the fish, coordinates, and shapes are determined.

IV. RESULTS AND DISCUSSION

In order for the sorting algorithm to be executed using the suggested approach, specific hardware will be needed. The hardware systems include stereo vision, a camera interface system with the computer, a conveyor belt, a sensor, and a switching system.

The suit of software is required to enable the execution of the proposed fish sorting system. The software functions as an algorithm for separating fish images from the video captured by the camera, an algorithm for measuring the dimensions of the fish, and an algorithm to generate an appropriate control signal. Fig. 3 shows the fabrication result of the actual experimentation of the drive mechanism for the fish shorting process.

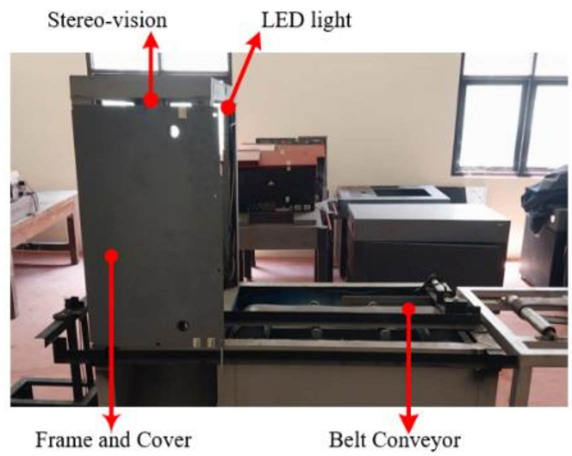


Figure 3. Actual fish shorting system.

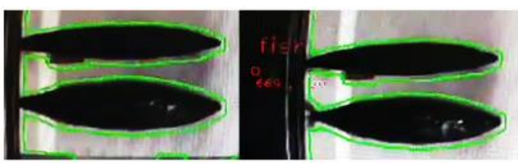
Camera intrinsic parameters are calibrated at a working distance of about 800 mm. The chessboard image is used as a calibration pattern, and an LCD monitor is used to display the image pattern. The calibration results of the left camera and right camera for stereo vision are obtained.

Results of the experiment to evaluate the efficacy of the machine vision-based automated fish sorting design are shown in Fig. 4. As illustrated in Fig. 4(a), the stereo vision begins with frame 1, and Fig. 4(b) depicts frame 2, which is the image captured on a moving conveyor that is larger than frame 1. The stereo camera is unable to discern the contours on these frames. The object is not visible in the measurement region in these frames. During the segmentation and object classification procedure, the tracking window has been set. Based on three-dimensional coordinates, the surface area of fish is measured using this tracking window. Frame 3 is the beginning of the object tracking, obtained by moving the panel more than frame 2, as indicated in Fig. 4(c). Frame 5 is the end of the tracking, obtained by moving the panel more than frame 4, as indicated in Fig. 4(e). A stereo camera is used to identify the outlines in Fig. 4(c). However, because the fish form does not completely cover the contour, there is no centroid or bounding box on the item. The closed contours can be gotten in Figs. 4(d)~(e). The centroid of the objects and bounding box are thus accessible. The frame position of the object during a 3D coordinate measurement is shown in Fig. 4(e). The bounding box functions to find the exact length, width, and height of the object for each object.

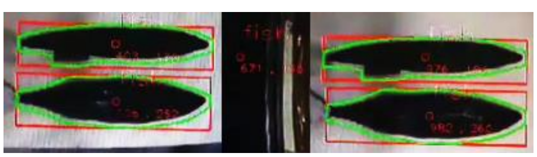
Table 1 shows the experimental results of the 2D image coordinates in the stereo-vision for up-view and side-view. This table shows the image centroids in pixels of the left camera, the right camera, and the stereo frame for top-view and side-view. From this value, the distance from the planes of the stereo-vision to the plane of the pixel can be obtained. The dimensions of four fish utilizing three-dimensional coordinate measurements for fish length, width, and height on a conveyor are displayed in Table 2.

a. Frame-1

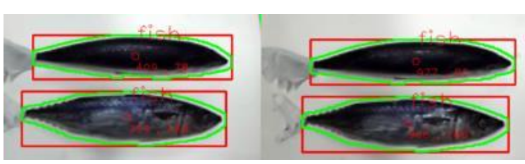
b. Frame-2



c. Frame-3



d. Frame-4



e. Frame-5

Figure 4. Experimental results evaluate the efficacy fish sorting design using stereo-vision

Table 1: Two-dimensional imaging coordinate of the center position for fish on a conveyor

Top-view the 2D coordinates of the center point (pixels).					
Left-side camera		Right-side camera		Stereo-vision camera	
X	Y	X	Y	X	Y
409	78	977	85	670	231
View-side the 2D coordinates of the center point (pixels).					
Left-side camera		Right-side camera		Stereo-vision camera	
X	Y	X	Y	X	Y
399	160	966	168	670	231

Table 2: The dimensions of four fish coordinate measurements for fish length, width, and height

Fish sample size (mm)			
No	Lenght	Height	Width
1	290	38.22	51.1
2	287	37.12	49.0
3	289	38.20	50.5
4	287	37.00	48.9

CONCLUSION

In this paper, an automatic sorting system is designed to sort fish based on size in real-time. The system can detect products at any position or orientation and determine the edge of the target product. The size of the fish as a templet is prepared by the processing system and changes as the size of the fish changes. It was found that processing time varies and is a function of the size of the shot and the volume of product detected. The main advantage of this fish sorting system is the ability to sort based on fish size in the form of length, width, or height.

The weaknesses that cause increased time and decreased detection accuracy is the low resolution of the camera used. Images taken on a moving conveyor cause errors in the sorting system due to image distortion, which the matching process requires sufficient time to detect. The limitation of this system is the need for appropriate lighting, which must be of appropriate intensity and distance from the moving conveyor to capture clear images. Also, the proposed design for sorting fish on a moving conveyor has limitations in stereo vision. The stereo vision used is two webcams with low resolution designed as a pair of stereo vision. This affects the sensitivity of the measurements for fish sorting. In addition, this method needs to be tested on various types of fish. Therefore, in future research, the author will develop this method using stereovision, which has high accuracy.

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REFERENCES

[1] M. T. Tran, H. H. Nguyen, J. Rantung, H. K. Kim, S. J. Oh, and S. B. Kim, "A New Approach of 2D Measurement of Injury Rate on Fish by a Modified K-means Clustering Algorithm Based on L*A*B* Color Space," *Lect. Notes Electr. Eng.*, vol. 465, pp. 324–333, 2017, doi: 10.1007/978-3-319-69814-4_32.

[2] M. T. Tran, J. Rantung, T. H. Nguyen, H. K. Kim, and S. B. Kim, "Measurement of injury rate on fish skin and performance comparison based on L*A*B* and HSV color spaces", doi: 10.1051/matecconf/201815902010.

[3] J. Rantung, F. P. Sappu, and Y. Tondok, "Real-time Measurement Method for Fish Surface Area and Volume Based on Stereo Vision," *Adv. Sci. Technol. Eng. Syst. J.*, vol. 6, no. 5, pp. 141–148, 2021, doi: 10.25046/aj060516.

[4] 병룡이, Q. Bao Truong, V. Huy Pham, 김형석 Byung-Ryong Lee, and H.-S. Kim, "Automatic Thresholding Selection for Image Segmentation Based on Genetic Algorithm," vol. 17, no. 6, pp. 587–595, 2011, doi: 10.5302/J.ICROS.2011.17.6.587.

[5] S. Stankovski, G. Ostojic, I. Baranovski, S. Tegeltija, and V. Smirnov, "Robust automation with PLC/PAC and edge controllers," in *IFAC-PapersOnLine*, 2022. doi: 10.1016/j.ifacol.2022.06.052.

[6] M. Callejas-Cuervo, A. X. González-Cely, and T. Bastos-Filho, "Control systems and electronic instrumentation applied to autonomy in wheelchair mobility: The state of the art," *Sensors (Switzerland)*, vol. 20, no. 21. 2020. doi: 10.3390/s20216326.

[7] M. Chui, J. Manyika, and M. Miremadi, "Four fundamentals of workplace automation," *McKinsey Quarterly*, no. 1. 2016.

[8] O. Sergiyenko, V. Tyrsa, W. Flores-Fuentes, J. Rodriguez-Quiñonez, and P. Mercorelli, "Machine vision sensors," *Journal of Sensors*, vol. 2018. 2018. doi: 10.1155/2018/3202761.

[9] Z. Xiao, J. Wang, L. Han, S. Guo, and Q. Cui, "Application of Machine Vision System in Food Detection," *Frontiers in Nutrition*, vol. 9. 2022. doi: 10.3389/fnut.2022.888245.

[10] T. T. E. Vo, H. Ko, J. H. Huh, and Y. Kim, "Overview of smart aquaculture system: Focusing on applications of machine learning and computer vision," *Electronics (Switzerland)*, vol. 10, no. 22. 2021. doi: 10.3390/electronics10222882.

[11] V. I. Komlatsky, T. A. Podoinitsyna, V. V. Verkhoturov, and Y. A. Kozub, "Automation technologies for fish processing and production of fish products," in *Journal of Physics: Conference Series*, 2019. doi: 10.1088/1742-6596/1399/4/044050.

[12] A. Hassoun *et al.*, "Seafood Processing, Preservation, and Analytical Techniques in the Age of Industry 4.0," *Applied Sciences (Switzerland)*, vol. 12, no. 3. 2022. doi: 10.3390/app12031703.

[13] W. Liu *et al.*, "Cutting Techniques in the Fish Industry: A Critical Review," *Foods*, vol. 11, no. 20. 2022. doi: 10.3390/foods11203206.

[14] J. Fu, Y. He, and F. Cheng, "Intelligent Cutting in Fish Processing: Efficient, High-quality, and Safe Production of Fish Products," *Food and Bioprocess Technology*. 2023. doi: 10.1007/s11947-023-03163-5.

[15] A. L. Ronzhin and A. I. Savel'ev, "Artificial Intelligence Systems for Solving Problems of Agro-Industrial Complex Digitalization and Robotization," *Agric. Mach. Technol.*, vol. 16, no. 2, 2022, doi: 10.22314/2073-7599-2022-16-2-22-29.

[16] J. O. Buljo and T. B. Gjerstad, "Robotics and automation in seafood processing," in *Robotics and Automation in the Food Industry: Current and Future Technologies*, 2012. doi: 10.1533/9780857095763.2.354.

[17] P. J. Wallin, "Robotics in meat, fish and poultry processing," *Trends Food Sci. Technol.*, vol. 4, no. 9, 1993, doi: 10.1016/0924-2244(93)90084-n.

[18] A. Courey, "The Future Of Customer Service: Artificial Intelligence," *Data Driven Invest.*, 2020.

[19] M. Mueller, J. Pander, and J. Geist, "Evaluation of external fish injury caused by hydropower plants based on a novel field-based protocol," *Fish. Manag. Ecol.*, vol. 24, no. 3, 2017, doi: 10.1111/fme.12229.

[20] P. Koukouvinis and J. Anagnostopoulos, "State of the Art in Designing Fish-Friendly Turbines: Concepts and Performance Indicators," *Energies*, vol. 16, no. 6. 2023. doi: 10.3390/en16062661.

[21] N. A. Ubina, S. C. Cheng, C. C. Chang, S. Y. Cai, H. Y. Lan, and H. Y. Lu, "Intelligent Underwater Stereo Camera Design for Fish Metric Estimation Using Reliable Object Matching," *IEEE Access*, vol. 10, 2022, doi: 10.1109/ACCESS.2022.3185753.