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Implementation of Gabor Filter for *Carassius Auratus*'s Identification

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***Abstract*— Carassius Auratus, otherwise known as goldfish, is one of the most popular ornamental fish. Goldfish have many variations, such as differences in body shape, colors, size, and fins. Identifying goldfish manually is difficult to do. This is due to several species that have similar anatomy, so automatic fish identification is needed. This research aims to identify three species of goldfish, such as Fantail, Oranda, and Ranchu. Gabor filter was applied to extract the features of goldfish. Gabor filter consists of several steps, including parameter initialization, Gabor kernels, Gabor convolution, feature point. The parameters used were frequency, orientation, and kernel's size. Gabor kernel was formed based on initialized parameters. The convolution process was produced by adding up the multiplication of 256x256 pixel goldfish's images and Gabor kernels. The results of the convolution process were normalized to produce a feature vector matrix. A probability neural network was used to classify the goldfish. Probability Neural Network is a supervised network that finds its natural use in decision making and classification problems. This research used 216 of goldfish's images. Seventy-two images were used for each species. The optimal parameters in this study were kernel size (5,5), frequency (3), orientation (5), and downsample (16,16), with accuracy up to 100%. Parameters of the frequency, orientation, kernel size, and downsample affect the level of accuracy. The greater the parameter value used, the more variations in feature vectors are obtained. Still, if too many variations of the feature vector cause redundancy data, it causes the classification process to be inefficient.**

***Keywords*— Extraction feature; gabor filter; goldfish identification; pattern recognition; probability neural network.**

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I. INTRODUCTION

The ornamental fish trade is currently a multibillion-dollar industry in more than 125 countries. Ornamental fish involved over 2500 species. 60% of them are freshwater fish species. [1]. Ornamental fish's global export increased from US$177.7 million in 2000 to US$337,3 million in 2016. Global imports of ornamental fish also increased from US$247.9 million in 2000 to US$ 275,2 million in 2016 [2]. The global market was dominated by 30 freshwater fish species, such as neon tetra, goldfish, livebearers, angelfish, discus, and zebra danio [1].

Goldfish is one of the popular fresh ornament fish and most commonly kept aquarium fish [3]. Goldfish is the first place in 24 Top Sellers Freshwater Ornamental Fish in the Netherlands and second place in 25 Top Sellers Freshwater Ornamental Fish in the USA [4]. The most popular ornament fish in India is goldfish. Second, to goldfish in preference are other livebearers such as guppy, molly, platy, and swordtail [5]. In Indonesia, 90% of the ornamental fish market is controlled by Tulungagung Regency. The top seller of Freshwater Ornamental Fish in Tulungagung Regency is goldfish [6].

Goldfish has several species that are almost similar, so that many ordinary people cannot recognize the goldfish species. Fish identification systems are needed to help ornamental fish's enthusiasm or ordinary people recognize their species. Goldfish's error identification will cause money loss, so this system was made to recognize goldfish.

The genetic algorithms were combined with tabu search and back-propagation based on the color signature, extraction shape, and color texture to classified the 24 fish families into 8 dangerous (poisonous) families and 16 non-dangerous families [7]. This research used 500 fish's images. Three hundred fifty images were used for the training, and 150 images were used for the testing. The highest recognition rate of this research is 87 % with the Metaheuristic-Backpropagation classifier.

The generic fish was classified into four dangerous families, four poisonous families, and 16 non-poisonous families using a hybrid metaheuristic with a back-propagation algorithm (GAGD-BPC) [8]. This research used 300 fish's images. Two hundred twenty images were used for the training, and 100 images were used for the testing. The recognition rate of this research iss 83.32%.

The generic fish was classified into 8 families of dangerous fish (predatory or poisonous) and 16 families of non-dangerous fish (garden and food fish's family) with MA-B classifier and back-propagation algorithm [9]. Fish images could be recognized by the texture, statistical measurements, and anchor points. This research used 400 fish's images. Two hundred fifty images were used for the training, and 150 images were used for the testing—the recognition rate of this research is 82.25%.

The faces are identified using the eigenface method and Gabor filter [10]. This research looked for the optimum point of the kernel's frequency, orientation, and size to reach the highest accuracy. Faces94 was used to test the method. The optimum point to recognize the face were frequency (3), orientation (5), and kernel size (5.5), and the accuracy up to 100%.

Faces are identified using Gabor feature extraction and additional methods such as GDA, PCA, LDA, and KPCA [11]. The database used was FERET and BANCA. The accuracy rate reached 97.5% with FERET and 94.04% with BANCA. This paper implemented Gabor filter as a feature extractor to recognized goldfish's species such as Fantail, Oranda, and Ranchu and find the most optimum parameters of kernel size (x, y), frequency (f), and orientation (θ) to reach the highest accuracy for goldfish's identification.

II. MATERIAL AND METHOD

A. Goldfish

Carassius auratus, known as goldfish, are ornamental fish with variations in size, fin configuration, body shape, and coloration. They have forward-facing mouths with pharyngeal teeth, a v-shaped caudal fin. The dorsal fin is long and a hard serrated spine at the dorsal and anal fins' origin. Goldfish are a popular ornamental fish because of their color (deep orange). They also have color variations such as black, a rare blue, red, grey, silver, and white. Goldfish grow more in the warmer seasons than in the colder seasons because their metabolic processes become faster in warmer waters than in cooler waters. They rely on ambient water temperature to stabilize their own internal temperature. Goldfish can hibernate during the winter in order to survive sub-freezing temperatures and go a substantial time without eating [12]. Ornamental fish lovers are attracted to more than 100 Carassius Auratus or goldfish's species. Some of the goldfish are listed as follows[13]:

1) Fantail: Fantail is also known as the western version of the Ryukin. Fantail has normal eyes, and some of them also have telescope-eyed. Most people describe Fantail as an egg-shaped fish. They have a quite slim body compared to other goldfish's species. Fantail has no hump's trace on its back, and its body not as deep as Ryukin. Fantail also has a variety of colors, including metallic self, variegated, and calico. Fantail has a few characteristics, such as have two caudal fins (twin-tailed) and two short anal fins. They are bred for the intensity of color, which should be deep orange or red because they have no showy finnage [13]. Fantail is the oldest varieties of goldfish known and the most common fancy variety available to the average ornamental fish lovers. This fish is the most popular, outselling all other goldfish's species. Fantail has a large double tail fin, which should be long and flowing. The most popular, most plentiful, and hardiest Fantail are solid orange metallic that grows very deep and bright with age. Nacreous Fantail is also available, and those with the most blues and blacks are considered to be among the most prized. Nacreous Fantail is not as hardy as their orange metallic cousins. This is one of the few fancy breeds that is durable and hardy enough for outdoor ponds. It is also the first fancy variety any hobbyist should own before moving into the more exotic breeds. A Fantail will grow to 3 to 6 inches in length with good care and has a life expectancy of somewhere between five and ten years [14].

2) Oranda: Oranda is a short-bodied high-backed fish with long paired fins or twin anals. Oranda has a dorsal fin that almost as high as their body. The Oranda has long flowing fins. Oranda has metallic or matte scales that resemble the appearance of the veil tail and their eyes are normal. Oranda is a goldfish type that has a characteristic berry-like bulge (raspberry) that wraps its head. These hood (also known as wen) usually grow in cranial, cover almost all parts of the head, except the eyes and mouth. Oranda that has fully divided caudal fins as long as or longer than the body is a high-quality fish [13].

3) Ranchu: Ranchu is bred in Japan. This goldfish has short, and the body is round. Ranchu has a broad head covered with generous head growth. Ranchu's caudal fin is double tail. Ranchu has no dorsal fins [13]. Ranchu is the simplest of all the Lionhead-type varieties. This fish is commonly called 'Maruko' in Japan, which means "round fish". This is a common name given to many fish, but the word seems most closely identified with this breed. It is a roundish, egg-shaped fish with no dorsal fin. Its back arches gracefully to the caudal peduncle, which points downward at approximately a 45-degree angle. The fins are usually short and include a dual caudal fin. The most appealing body's part on this fish is the head covered with a cap or hood. Many goldfish experts liken the bumpy, fleshy covering, which is neither hard nor soft, to a raspberry. On most specimens, the cap does not begin to appear until their second year, growing until the fish is a little over three years old. Ranchu also has varieties in color metallic and nacreous forms and color combinations of orange, red, yellow, silver, white, blue, violet, and black. Calico variations have the more blues and blacks; the more valuable the fish is thought to be. This fish has a life expectancy of approximately five to ten years and should be kept at a relatively constant temperature of 55°F to 65°F. Ranchu will grow to 3 inches. Diseases such as fungus are sometimes a problem, as these develop in the folds and crevices of the cap. This fish should be kept only by someone who has experience with goldfish and is not for the beginner [14].

Fig. 1 shows images of three goldfish's spesies, such as Fantail, Oranda, and Ranchu.

(a) (b) (c)

Fig. 1 Goldfish's species; (a) Fantail; (b) Oranda; (c) Ranchu;

B. Gabor Filter

The Gabor filters are self-similar. Gabor filter (G (x, y)) is a sinusoidal complex that combines with an envelope gaussian with a spatial domain. Gabor bank filter is a multi-channel filter generated from one mother wavelet by dilation and rotation that uses certain spatial frequencies. The orientation of sinusoidal and Gaussian spread towards x and (σx and σy). Gabor filter is similar to those of the human visual system and have been found to be particularly appropriate for texture representation and discrimination. Two-dimension Gabor filter is a function of Gaussian kernel that modulated by a sinusoidal plane wave in the spatial domain, defined as[15]:

$$G(x,y) = \frac{f^2}{\pi\gamma\eta}\exp(-(\alpha^2 x'^2 + \beta^2 y'^2)\exp(-(2\pi f x')) \quad (1)$$

Where:

$$x' = x\,cos\theta + y\,sin\theta \quad (2)$$

$$y' = -x\,sin\theta + y\,cos\theta \quad (3)$$

Each filter is in the shape of plane waves with frequency, restricted by a Gaussian envelope function with relative width α and β. A set of Gabor filters with variations of orientations and frequencies are required to extract useful features from an image:

$$f_{u=}f_{max}/\sqrt{2}^{u-1}, \text{ u = 0, 1, 2, ..., U-1} \quad (4)$$

$$\theta_v = \frac{v-1}{N}\pi, \text{ v= 0, 1, 2, ..., V-1} \quad (5)$$

fmax is the highest peak frequency. γ is the ratio between centre frequency and the sharpness of Gaussian major axis. η is the ratio between center frequency and the sharpness of Gaussian minor axis. U is the number of scales. V is the number of orientations [11].

Convolution is one of the filtering's processes that is often done in image processing. Convolution consists of two types, such as convolution one dimensional in the temporal or frequency domain and convolution two dimensional in the spatial domain. The convolution of two functions represents the amount of overlap between the two functions. The function of convolution defined as:

$$h(x) = f(x).g(x) = \sum_{\alpha=\infty}^{\infty} f(a).g(x-a) \quad (6)$$

In convolution operations Equation (6), g (x) is called a kernel of the convolution. g (x) is a window that is operated shifting to the input signal f (x), which in this case, the number of multiplications of the two functions at each point is the result of convolution that is entered with output h (x) [16].

C. Probabilistic Neural Network (PNN)

Probabilistic Neural Network (PNN) is one method that uses supervised learning based on a feed-forward network. Probabilistic Neural Network is an implementation of Kernel discriminate analysis. The algorithm has four main layers.

- The input layer is the first layer that contains n neurons, where each neuron represents one attribute.
- The second layer is the pattern layer. There are m neurons in this layer. m is the number of patterns or examples in training.
- The third layer is the summation layer that contains z neurons, where each neuron represents one output class.
- The output layer is the fourth layer that showed the results of classification [17].

III. RESULTS AND DISCUSSION

This research consists of several steps, including data acquisition, pre-processing, feature extraction, classification, and evaluation. Fig. 2 shows goldfish recognition's research steps.

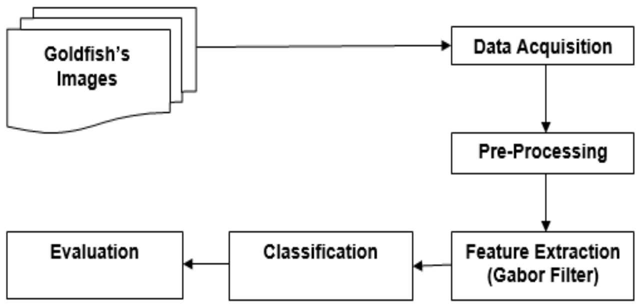

Fig. 2 Goldfish recognition's research steps

A. Data Acquisition

The first step was data acquisition. A digital camera took goldfish's images in moving images (video) with mp4 format. Then, the video was screenshot frame by frame to got goldfish's images in .jpg format. Results of data acquisition were goldfish's images with .jpg format and size 2912 x 5148 pixel. The total of goldfish's images was 216 images, 72 images for each species.

B. Pre-processing

The second step was pre-processing. This step consists of several processes like manual segmentation, resized images, and converted images to grayscale. Pre-processing results are segmented images with white background and resized images from 2912 x 5148 pixel to 256x256 pixel, and grayscaled images. Fig. 3 shows the results of data acquisition and pre-processing.

Fig. 3 Results of Data Acquisition and Pre-Processing

C. *Feature Extraction (Gabor Filter)*

The third step was the feature extraction. The feature extraction process in this study was carried out using Gabor filter. Gabor filter is a gaussian kernel function modulated by a sinusoidal plane wave. The filter has a real and imaginary component representing orthogonal directions. Gabor filters are commonly used in feature extraction methods. Gabor filter is a sinusoidal wave modulated by Gaussian function. Gabor filter is based on the frequency, orientation, and Gaussian kernel. With varying of these factors, a set of Gabor filter banks generate to be convoluted with the image to generate the corresponding features in a complex number. Feature extraction consists of several steps, including parameter initialization, Gabor kernel, Gabor convolution, feature point.

1) Parameter initialization: The first step was parameter initialization. The parameters used were frequency, orientation, and kernel's size. This study used 13 combinations of frequency, orientation, and kernel's size [10]. The downsample values used were (4.4), (16.16), and (64.64). Parameter combinations in this research were 13 x 3 downsample= 39 tests. Parameter combinations are shown in Table I.

TABLE I
COMBINATION OF TEST PARAMETERS

Trial	Frequency	Orientation	Filter Size	Downsample
P1	2	2	3x3	4.4
P2	2	2	3x3	16.16
P3	2	2	3x3	64.64
P4	2	3	3x3	4.4
P5	2	3	3x3	16.16
P6	2	3	3x3	64.64
P7	2	4	3x3	4.4
P8	2	4	3x3	16.16
P9	2	4	3x3	64.64
P10	2	5	3x3	4.4
P11	2	5	3x3	16.16
P12	2	5	3x3	64.64
P13	3	2	3x3	4.4
P14	3	2	3x3	16.16
P15	3	2	3x3	64.64
P16	3	3	3x3	4.4
P17	3	3	3x3	16.16
P18	3	3	3x3	64.64
P19	3	4	3x3	4.4
P20	3	4	3x3	16.16
P21	3	4	3x3	64.64
P22	3	5	3x3	4.4
P23	3	5	3x3	16.16
P24	3	5	3x3	64.64
P25	3	5	5x5	4.4
P26	3	5	5x5	16.16
P27	3	5	5x5	64.64
P28	3	5	7x7	4.4
P29	3	5	7x7	16.16
P30	3	5	7x7	64.64
P31	3	5	9x9	4.4
P32	3	5	9x9	16.16
P33	3	5	9x9	64.64
P34	3	5	39x39	4.4
P35	3	5	39x39	16.16
P36	3	5	39x39	64.64
P37	4	5	5x5	4.4
P38	4	5	5x5	16.16
P39	4	5	5x5	64.64

2) Gabor Kernel: Gabor kernels are formed from two components, such as gaussian envelope and sinusoidal waves. Results of the Gabor kernels is a complex number. A complex number is a combination of real parts and imaginary parts. The first step of Gabor Kernel is looking for fu and θv by using Equation (4) and Equation (5). The second step is looking for α and β. Defined $\gamma = \eta = \sqrt{2}$ [10]. The third step is to find the Gabor kernel with Equation (1). The frequency (f) and orientation (θ) will produce a three-dimensional (3D) array with sizes fxθ. The 3D array contains a two-dimensional (2D) array with the same size as the kernel size. For example, kernel size (3,3), frequency (2), and orientation (2), will produce a 3D array with sizes 2x2, which contains a 2D array with sizes 3x3. Example results of Gabor kernel are shown in Table II.

TABLE II
EXAMPLE RESULTS OF GABOR KERNEL

GaborArray{1,1}		
1	2	3
0.0585 + 0.0000i	0.0965 + 0.0000i	0.0585 + 0.0000i
0.0965 + 0.0000i	0.1592 + 0.0000i	0.0965 + 0.0000i
0.0585 - 0.0000i	0.0965 - 0.0000i	0.0585 - 0.0000i
GaborArray{1,2}		
1	2	3
0.0585 + 0.0000i	0.0965 - 0.0000i	0.0585 - 0.0000i
0.0965 + 0.0000i	0.1592 + 0.0000i	0.0965 - 0.0000i
0.0585 + 0.0000i	0.0965 + 0.0000i	0.0585 - 0.0000i
GaborArray{2,1}		
1	2	3
-0.0129 + 0.0465i	-0.0165 + 0.0597i	-0.0129 + 0.0465i
0.0620 + 0.0000i	0.0796 + 0.0000i	0.0620 + 0.0000i
-0.0129 - 0.0465i	-0.0165 - 0.0597i	-0.0129 - 0.0465i
GaborArray{2,2}		
1	2	3
-0.0129 + 0.0465i	0.0620 - 0.0000i	-0.0129 - 0.0465i
-0.0165 + 0.0597i	0.0796 + 0.0000i	-0.0165 - 0.0597i
-0.0129 + 0.0465i	0.0620 - 0.0000i	-0.0129 - 0.0465i

TABLE III
EXAMPLE RESULTS OF GABOR CONVOLVE

25	26
30.4767 + 0.3653i	30.4473 + 0.2590i
31.5094 + 5.8656i	31.6931 + 6.0184i

3) Gabor Covolve: The Gabor kernel is used for the convolution process. The convolution process is generated by summing the 256x256 pixel of goldfish's image with the kernel that has been formed in the Gabor kernel's process. Convolution operations are carried out by shifting the kernel pixel by pixel starting from the top-left position to the lower right position, often called the sliding window. The convolution process *begins by placing the kernel size mxn in the upper left corner of the 256x256 goldfish's image and then calculating* the convolution with Equation (6). Shift the kernel one pixel to the right, calculate the convolution with Equation (6). After the kernel shift to the right is done, the kernel is shifted one pixel down. Convolution's process starts again from the left side of the image. Table III shows an example of the results of Gabor convolve.

4) Feature Points: Gabor convolution results have two parts, the first is the real part, and the second is the imaginary part. The process of normalizing Gabor convolution converted the array, which was a complex double to double. The result of this normalization process is a 256x256 feature vector matrix consisting of double. The next process is to reduce the feature vector matrix due to the downsampling technique's normalization process. Downsampling is done by column and row. Features vectors of goldfish that originally consisted of 256x256 normalized pixels extracted using frequency(2) and orientation(2) will produce 262,144 feature vectors. If the downsampling value used is (4.4), then the feature vector is reduced and forms a feature vector with a size of 16384 for one image of goldfish. To avoid redundancy of data, feature vectors are reduced again by looking for maximum values so that the characteristic vector with size 1 x the number of goldfish images is obtained. The total of goldfish's dataset is 216 images, so that the overall feature vector is 1x216.

D. Classification

The classification process in this study used 36 test images. Each type of goldfish consists of 12 test images. The method used is the Probability Neural Network (PNN). The classification results are in the form of a confusion matrix. An example of confusion matrix P1 can be seen in Table IV.

TABLE IV
EXAMPLE OF CONFUSION MATRIX P1

	Fantail	Oranda	Ranchu
Fantail	12	0	0
Oranda	0	8	0
Ranchu	0	4	12

The confusion matrix of P1 (e.g., Table IV) shows that all Fantail and Ranchu images were correctly identified. Four Oranda(s) predicted as Ranchu. The overall classification results of goldfish's identification can be seen in Table V. The optimum parameters for goldfish identification using a Gabor Filter as a feature extraction method and Probability Neural Network as a classification method is P26. The combination of parameters used in P26 is kernel size (5.5), frequency (3), orientation (5), and downsample value (16.16). Parameters of frequency, orientation, kernel size and downsample affect the level of accuracy. The more significant parameter's value that is used, the more variations in feature vectors are obtained, but if there are too many feature vector variations, it will cause redundancy data, which causes the classification process to be inefficient.

TABLE V
CLASSIFICATION RESULTS

Test	Identified Images			Total
	Fantail	Oranda	Ranchu	
P1	12	8	12	32
P2	12	8	12	32
P3	12	0	11	23
P4	12	8	10	30
P5	12	9	12	33
P6	0	0	12	12
P7	12	11	11	34
P8	12	11	11	34
P9	12	6	7	25
P10	12	8	8	28
P11	12	9	4	25
P12	10	0	12	22
P13	12	8	12	32
P14	12	8	12	32
P15	12	2	11	25
P16	12	8	10	30
P17	12	9	12	33
P18	0	0	12	12
P19	12	10	8	6
P20	12	6	11	7
P21	0	0	12	12
P22	12	7	8	9
P23	12	7	10	7
P24	12	6	8	10
P25	10	8	6	10
P26	12	12	12	0
P27	1	1	12	11
P28	11	4	9	11
P29	12	9	12	3
P30	1	0	12	12
P31	11	5	8	11
P32	12	11	7	6
P33	1	0	11	13
P34	11	8	5	11
P35	12	11	8	5
P36	0	2	12	10
P37	10	8	6	10
P38	11	12	12	0
P39	1	1	12	11

E. Evaluation

The last step was the evaluation. Results from classification will be a parameter to get an accurate rate. The classification's results of P26 (Table II) show that the test images detected correctly amounted to 36 goldfish's images, consisting of 12 images for each species. Calculation of the evaluation is as follows:

$$Evaluation = \frac{TP+TN}{TP+TN+FP+FN} x\ 100\% \quad (7)$$

$$Evaluation = \frac{36}{36} x 100\% = 100\%$$

The highest evaluation in this research up to 100% in P26 with parameters frequency (3), orientation (5), kernel size (5.5), downsample (16,16). The lowest evaluation is found in P6, P18, P21, and P23, with accuracy values reach 33.333%. Details of the evaluation results of goldfish's identification that have been sorted based on the largest to smallest evaluation results can be seen in Table VI.

TABLE VI
RECOGNITION RATE

Trial	f	o	Filter Size	Downsample	Recognition Rate
P26	3	5	5x5	16.16	100%
P38	4	5	5x5	16.16	97.22%
P7	2	4	3x3	4.4	94.44%
P8	2	4	3x3	16.16	94.44%
P17	3	3	3x3	16.16	91.67%
P29	3	5	7x7	16.16	91.67%
P5	2	3	3x3	16.16	91.67%
P1	2	2	3x3	4.4	88.89%
P13	3	2	3x3	4.4	88.89%
P14	3	2	3x3	16.16	88.89%
P2	2	2	3x3	16.16	88.89%
P35	3	5	39x39	16.16	86.11%
P16	3	3	3x3	4.4	83.33%
P19	3	4	3x3	4.4	83.33%
P32	3	5	9x9	16.16	83.33%
P4	2	3	3x3	4.4	83.33%
P20	3	4	3x3	16.16	80.56%
P23	3	5	3x3	16.16	80.56%
P10	2	5	3x3	4.4	77.78%
P22	3	5	3x3	4.4	75%
P24	3	5	3x3	64.64	72.22%
P11	2	5	3x3	16.16	69.44%

P15	3	2	3x3	64.64	69.44%
P9	2	4	3x3	64.64	69.44%
P25	3	5	5x5	4.4	66.67%
P28	3	5	7x7	4.4	66.67%
P31	3	5	9x9	4.4	66.67%
P34	3	5	39x39	4.4	66.67%
P37	4	5	5x5	4.4	66.67%
P3	2	2	3x3	64.64	63.89%
P12	2	5	3x3	64.64	61.11%
P27	3	5	5x5	64.64	38.89%
P36	3	5	39x39	64.64	38.89%
P39	4	5	5x5	64.64	38.89%
P30	3	5	7x7	64.64	36.11%
P18	3	3	3x3	64.64	33.33%
P21	3	4	3x3	64.64	33.33%
P33	3	5	9x9	64.64	33.33%
P6	2	3	3x3	64.64	33.33%

The downsample values used in this study are (4.4), (16,16), and (64,64). According to the downsample values, the running time evaluation can be seen in Table VII. Fig. 4 shows a line graph of the running time analysis.

TABLE VII
EVALUATION OF RUNNING TIME ACCORDING TO THE DOWNSAMPLE VALUES

Trial	Downsample		
	4,4	**16,16**	**64,64**
P1,P2,P3	17.428 s	17.472 s	17.147 s
P4,P5,P6	24.779 s	24.220 s	24.089 s
P7,P8,P9	30.835 s	29.199 s	29.330 s
P10,P11,P12	38.723 s	36.040 s	35.542 s
P13,P14,P15	23.754 s	22.832 s	22.443 s
P16,P17,P18	33.001 s	33.546 s	32.179 s
P19,P20,P21	44.035 s	42.698 s	40.300 s
P22,P23,P24	53.926 s	52.525 s	51.157 s
P25,P26,P27	76.056 s	65.294 s	63.119 s
P28,P29,P30	79.299 s	75.822 s	73.921 s
P31,P32,P33	83.227 s	80.079 s	78.940 s
P34,P35,P36	243.549 s	238.774 s	221.123 s
P37,P38,P39	93.012 s	84.155 s	82.473 s

The line graph of running time analysis (e.g., Fig. 4) explains that the results of the fastest running time were in P1, with kernel size parameters (3,3), frequency (2), orientation (2), and downsample values (64,64). The slowest running time was in P34 with kernel size parameters (39.39), frequency (3), orientation (5), and downsample values (4.4). The greater the downsample value used, the smaller the running time needed. The greater the parameter size of the kernel size, frequency, orientation, and downsample value, the greater the running time needed.

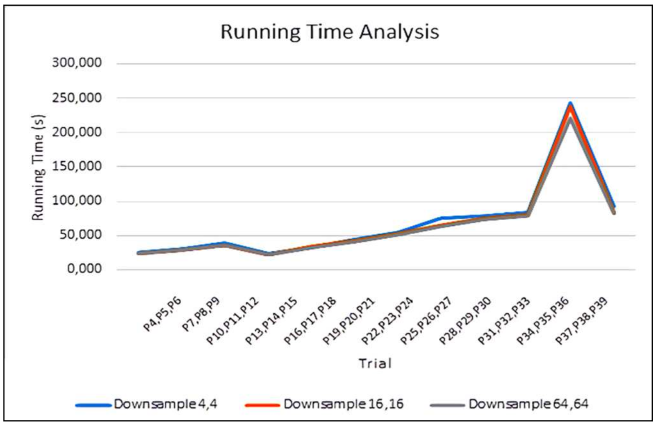

Fig. 4 Line Graph of Running Time Analysis

IV. CONCLUSIONS

This research obtained that the Gabor filter was successfully applied to identify goldfish. Goldfish's recognition rate is up to 100% with optimal parameters such as kernel size (5,5), frequency (3), orientation (5), and downsample value (16,16) with accuracy up to 100%. For future work, it is recommended to make a comparison with other feature extractors and classifiers.

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