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.

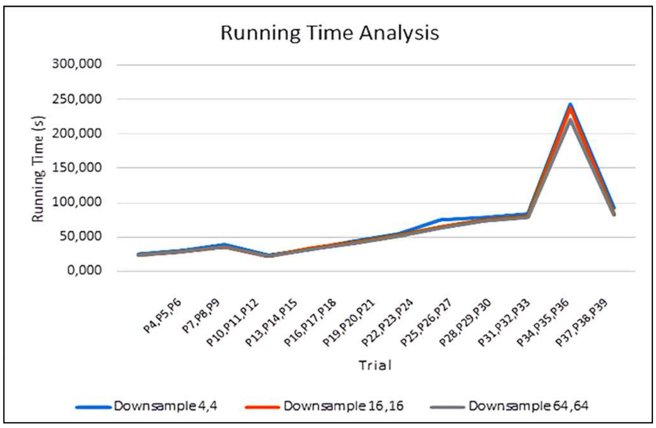

Fig. 4 Line Graph of Running Time Analysis

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.

ACKNOWLEDGMENT

Profound thanks are due to the Department of Computer Science, Faculty of Mathematics and Natural Science, Lampung University.

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