CLASSIFICATION OF FISH DISEASES IN KARANTINA KELAUTAN DAN PERIKANAN BADAN KARANTINA IKAN, PENGENDALIAN MUTU DAN KEAMANAN HASIL PERIKANAN (BKIPM-KKP) KELAS II BANDUNG USING HIDDEN MARKOV MODEL

Salman Muhammad[1], Nelly Indriani W.[2]

[1,2] *Informatics Engineering Program*
Engineering and Computer Science Faculty Indonesia Computer University
Jl. Dipati Ukur No. 112-116 Bandung
E-mail : salman_bdg93@yahoo.com[1], indiwidi@gmail.com[2]

ABSTRACT

Fish is one of aquatic animals that are always in contact with the aquatic environment so easily infected with disease either pathogenic or non pathogenic type through the water. There are several factors that often lead to fish death i.e. the internal and external factors. BKIPM-KKP *often affect the review of the pengkaran-captivity in the West Java, and sometimes at the time of the review of such breeding experience difficulties at the time of classifying diseases suffered fish that exist in captivity, because to know the disease must pass through stages of laboratory* BKIPM-KKP *first and the results from the lab won't be out at that time also for the process of classification. On the basis of research through observation against the lab* BKIPM-KKP, *wawacara to the station and the laboratory, and data collection is needed to resolve the problem that is occurring, as well as some journals and other sources that are concerned about the classification using the Hidden Markov Model (*HMM*).*

*The image used is the result of a microscopic image of a good type .jpg or .PNG, where the image will be processed using image processing starting from grayscale, canny edge detection and extraction, the extraction stage through image after the next step, namely the process of classification using a Hidden Markov Model (*HMM*).*

After doing the test with the image obtained from the results of the microscopic method using Hidden Markov Model (HMM) that uses image processing process it self be enough to determine the characteristics of the image of fish diseases, resulting in a using only the image processing, the accuracy gained just 69% of the image data of 100 tested in the process of classification

Keywords: *Classification Of Fish Diseases, Diseases, Fish, Hidden Markov Models, Image Processing, laboratory,* BKIPM-KKP, *microscopic*

1. INTRODUCTION

1.1 Background

Fish is one of aquatic animals that are always in contact with the aquatic environment so easily infected with disease either pathogenic or non pathogenic type through the water. Fish diseases generally have two factors cause terjangkitnya disease i.e. internal and external factors. Internal factors or in IE, disruption of water that causes the immune system in fish declining, there is also disruption of genetic and metabolic. The external factor is interference from outside the outer nature of pathogens and non-pathogens. Factors ekternal the nature of pathogens [1.2] include viruses, parasites, bacteria, fungi and protozoa, a factor that is non-pathogen include temperature, pH, nutrients, and water quality, usually fish are often exposed to disease due to external factors. [3]

BKIPM-KKP often do a review of a captive-breeding region of West Java, and sometimes at the time of the review of the captivity, BKIPM-KKP often find breeding that has the problem of diseases of fish, BKIPM-KKP had difficulty due to know the disease should be included into the lab BKIPM-KKP and have to wait for days to perform the process of classification.

In the process of classification of fish diseases, traits that are used are pictures of fish diseases microscopic results obtained from the laboratory, so that the obtained image with good quality for use as data in the process of classification and classification process results of fish diseases, its accuracy will be searched to prove the classification process. So the result of the classification of fish diseases with good accuracy, in a fast enough can lower the rate of transmission of the disease against which ecosystems are being attacked by the disease.

The process of disease classification can be done by various methods. Artificial Intelligence (Artificial Intelligent). In this study, the method of classification of diseases from microscopic laboratory samples used is a Hidden Markov Model

(HMM). Hmm is a method often used in the process of recognition of DNA. In the last research research on health using a Hidden Markov Model (HMM) has ever done that is designing the introduction of blood disease [4]. The result is that blood disease can be recognized by using a Hidden Markov Model (HMM) with an accuracy of 60% to 82,76%.

Based on the description of the problem above, then on this final project research reports take the topic of " CLASSIFICATION OF FISH DISEASES IN KARANTINA KELAUTAN DAN PERIKANAN BADAN KARANTINA IKAN, PENGENDALIAN MUTU DAN KEAMANAN HASIL PERIKANAN (BKIPM-KKP) KELAS II BANDUNG USING HIDDEN MARKOV MODEL".

1.2 Purpose and Objective

The purpose of this research is how to implement the methods of the Hidden Markov Model (HMM) is in the process of classifying the results of microscopic fish diseases laboratory, BKIPM-KKP-.

While the goals to be achieved from this research is to find out whether fish diseases can be classified using Hidden Markov Model (HMM) and knowing how much accuracy in the classification process of the fish disease case study BKIPM-KKP.

1.1 Patologi Parasi Protozoa

Unisellular are organisms protozoa (unicellular) very small microscopic and has a complex structure which is used for movement, adhesions, and shield cover. This parasite has several groups that are on the fish. This parasite can reproduce in the body of the host. The Protozoan has at least 7 phylum which is parasitic on fish, namely: Phylum Amoebozoa, Phylum Ciliophora, Apicomplexa phylum, the Phylum Microspora, Phylum Myxozoa.

Among the fresh water parasite, Ichthiophthirius multifillis has caused many problems in the cultivation of freshwater fish. On the conditions of cultivation of certain Protozoan species, can cause diseases that result in high mortality resulted in considerable economic loss on fresh water fish as well as fish of sea water. [6]

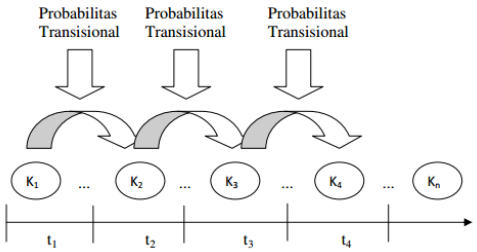
1.3 Extraction

Ektraksi features or featur extraction is a hallmark of the retrieval/feature from a later value obtained will be analyzed for the next process. featur extraction is done by calculating the number of dots or pixels that are found in any checking, where checking is carried out in various directions on checking of coordinates kartesial tracing of the digital image is analyzed.

1.4 Markov Chain

Markov chains is a mathematical technique used to do modelling a wide range of systems and business processes. This technique can be used to estimate changes in the future in the dynamic variables on the basis of changes of the dynamic variables at time lalau. This technique can be used also to analyze the kejadia events in the upcoming times mathematically.

Markov Chain models (Markov Chains) found by a Russia named Andrey Markov in 1906: "for each time t, when the Genesis was the earlier incident and the whole of $K_{t(j)}$... , $K_{t(j-n)}$ that occurs from the process are known, the probability that the entire incident will come *Kt(j)* depends only on the incidence of $K_{t(j-1)}$ and does not depend on previous events i.e. $K_{t(j-2)}$, $K_{t(j-3)}$,..., $K_{t(j-n)}$. ".



Fiture 1. Markov Chain

1.5 Hidden Markov Model

Hidden Markov Model (HMM) is a probability model describing the relationship between the statistical observation sequence O and the order of the state S are not observed to "hidden". [12]

Thre are 4 procedur HMM that could be used in the real, I,e, [10]:

a. forward procedure

Assuming the variabel forward $\alpha_t(i)$ at the time to-*t* and *state* to-*i* defined.. α_t (i) = P $(O_1,O_2,...,O_T,$ $q_t=i$ | $\lambda)$. Function forward opportunities can be solved for N state and T symbol in observation inductively with the following steps:

a) Inisialisasi, $\alpha_t(i) = \pi_i b_i(O_1)$,

$1 \leq i \leq N$ (2.12)

b) Induksi, $\alpha_{t+1}(j) = \left[\sum_{i=1}^{N} \alpha_t(i)\alpha_{ij}\right] b_j(Oi+_1)$,

$1 \leq t \leq$ T-1; $1 \leq$ j $\leq$N (2.13)

c) Terminasi,

$P(O|\lambda) = \sum_{i=1}^{N} \alpha_T(i)$ (2.14)

Calculation of forward based on trellis diagram patterns +. There are N points of each time slot on the pattern, all possible row state are merged as much as N points regardless of the length of the row of observation. At time *t*=1, calculated value $O_1(i)$, $1 \leq i \leq N$. At time t = 2, 3, ..., T, αt values calculation is only required $\alpha_t(j)$ where $1 \leq j \leq N$.

Each calculation requires the previous value as much as N from $\alpha_{t-1}(i)$ because

each N points may only be connected with N points on the time slot before.

b. *backward procedure*

By the same token, variable backward $\beta_t(i)$ at the time to-t and state to-i $\beta_t(i)$ defined $\beta_t(i) = P(O_{t+1}, O_{t+2}, ..., O_T, qt = i \mid \lambda)$. Backward procedure used to calculate $P(O|\lambda)$ to retreat from maximum observation time, t = T until the time of the initial observation t = 1. Procedure steps backward are as follows:

a) Inisialisasi, $\beta_T(i) = 1$; $1 \leq i \leq N$ (2.15)

b) Induksi, $\beta_t(i) = \sum_{j=1}^{N} a_{ij} b_j(O_i + 1)\, \beta_t + 1(j)$, $t = T-1, T-2, ..., 1$ (2.16)

Initializing $\beta_T(i) = 1$ for all values of i. To get the state to the-i and-t time to row an observation at time t + 1, then assumed all possible state j at time t + 1, to get a transition from i to j, and rows of aij observation o_{t+1} state to-j, $b_j(O_{t+1})$. Then the calculated part observation of state j, $\beta_{t+1}(j)$.

c. *forward – backward procedure*

A combination of forward and backward procedures can be used to get the value of $P(O|\lambda)$. The odds are on state to-i time to-t of N state before time t-1 can be calculated with the function of the opportunity forward $\alpha_t(i)$. While the odds of a transition from state i to state j towards the tee-time t + 1 and take an observation symbol on a state j is $a_{ij}b_j(O_{t+1})$. The function used to calculate backward opportunities opportunities the appearance of rows of symbols of observation from time t to.

Mathematically reckoning $P(O|\lambda)$ use forward-backward procedure can be expressed as follows:

$P(O|\lambda) = \left[\sum_{i=1}^{N}\left[\sum_{j=1}^{N} \alpha_1(i) a_{ij}.\, b_j(O_i + 1)\right]\beta_t + 1(j)\right]$

$P(O|\lambda) = \sum_{i=1}^{N} \alpha_t(i)\, \beta_t(i)$ (2.17)

Keterangan :

$\alpha_t(i)$: the result of observation procedures forward termination stage.

$\beta_t(i)$: the result of observation of procedure termination stage backward.

d. *viterbi procedure*

On viterbi algorithm, the maximum odds is on the state to-i time to-t, which previously had been completed the row state $q=\{q1, q2, ..., qt-1\}$, if given a row an observation O and a model of the λ dinotasikan with $\delta_t(i)$.

$\delta t\ (i) = \max P[q_1 q_2 ... q_{t-1}, q_t = i, O_1 O_2 ... O_T \mid \lambda]$ (2.19)

To get the row of observation required sequence of arguments for each t and j. This is done via a function array $\psi_t(j)$. More procedures of viterbi algorithm is as follows:

1) Inisialisasi, $\delta_1(i) = \pi_i\, b_i\ (o_1)$, $1 \leq i \leq N$; $\psi_1(i) = 0$ (2.20)

2) Rekursi, $\delta_1(j) = \max_{1 \leq i \leq N}\left[\delta_{t-1}(i) a_{ij}\right] b_j(o_t), 2 \leq t \leq T; 1 \leq j \leq N$

$\psi_t\ (j) = \arg \max_{1 \leq i \leq N}\left[\delta_{t-1}(i) a_{ij}\right], 2 \leq t \leq T; 1 \leq j \leq N$ (2.21)

3) Terminasi, $P^* = \max_{1 \leq i \leq N}[\delta_T(i)]$

$q^*_t = \arg \max_{1 \leq i \leq N}[\delta_T(i)]$ (2.22)

Backtracking, $q^*_t = \psi_{t+1}(q *_{t+1}), t = T-1, T-2, ... 1$ (2.23)

1.5 Image Processing

Digital image processing is a general term for various techniques of its existence to manipulate and modify the image in various ways. Each photo with a digital image of the form can be processed using specific software. The photo is an example of a two dimensional image can be processed easily. The basic principles in image processing: [5]

1. Increased brightness and contrast

Increased brightness and contrast is an improvement in the image of a changing image that has a value of brightness and a contrast value less value brightness and contrast values are better.

2. Noise Removal

Busting noise is noise cancelling process from an image with distortion or have noise.

3. Search the form object

Search the form object is a process for recognizing an object in an image using the specific approaches to get the value of the object.

Several types of image processing operations are as follows: [6]

1. Brightness modification

Change the value of keabuan or color from dark into light or vice versa changes the image too bright/pale became dark.

2. Contrast Enhancement

By increasing the contrast of an image then the point that tends to be more dark dark and light which tends to be more candid.

3. Negation

The operation to get the negative image

4. Grayscale

Image conversion is the process of with the actual color (true color) image keabuan (grayscale). Conversion of images into grayscale is done by taking the value of the pixels from one image input is then calculated using the following equation:

$$Grayscale = \frac{(R+G+B)}{3} \quad ...(5)$$

5. Thresholding

This operation is used to change the image scale with the format keabuan which has more than two

values into a binary image has only two values, namely 0 and 1.

6. Flipping

Reflection is the process of drawing the image to the form of the inverse of the image, such as when people are currently reflect.

7. Rotating

The rotation is the process of turning the coordinates of the image corresponds to the degree specified

8. Cropping

Cut the desired portion of an image

9. Pengskalaan (Scaling)

Change the size of the image becomes larger or smaller

10. Edge Detection

Edge detection is a process that generates the edges of objects in an image.

1.6 *Edge Detection*

Edge detection in an image is the process to obtain the edge of objects. Edge detection utilizing a drastic change in intensity on the boundary of two areas. Edge detection generally uses two kinds of detectors, i.e. the detector lines (Hy) and detector column (Hx).

Detection of edge is divided into two classes. The first is called first order edge detection, which works by using derivatives or first order differential. That is included in this group is the operator of Roberts, Prewitt and Sobel. While the two are called second order, which uses second-order derivatives. That includes the second order is the Laplacian of Gaussian (LoG). The following are operators of the edge detection in the process used on the research: [9]

Figure 2 the following are operators of the Sobel which are used in the process of edge detection which consists of a pair of size 3 x 3 kernel:

$$H_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \quad H_y = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

Fiture 2 Method Sobel

1.7 Normalization

Normalization is the process of changing the dimensions of the region of each character. In this process using Thresholding process, is one of the operations that are included in the operations of dots in digital image processing. This operation is used to change the image scale with the format keabuan belonging to the possibility of more value from 2 to a binary image has two values (0 and 1).

1.8 Accuracy

Accuracy is how close a number of results measurement of the number of actual (true value or reference value). Degree of accuracy is obtained by calculation in accordance with the following equation:

$$\text{Accuracy} = \frac{\sum \ value\ true}{\sum sample} \times 100\%$$

2. RESEARCH CONTENT

2.1 Analysis and System Design

Here is analysis and design from a system built:

2.1.1 Problem Analysis

On the basis of the problem which already obtained, it will be spelled out in more detail about the problems found in this research. These are issues that are found:

1. Using Hidden Markov Model (HMM) in this study of how these methods can be classifying fish diseases based on image from microscopic results.
2. The accuracy of the method of Hidden Markov Model of Markov Model (HMM).

2.1.2 Input Data Analysis

Enter the data required for this application is an image. The image can be a result of microscopic. The image used for this application format ' .jpg ' or ' .PNG ' with image size 80x80 pixels, the image will be the training data after processing the image. The image data to be entered in this will be divided into several types based on the results of the analysis carried out by the system, which will do the process of testing to determine the results of the classification table 1 Data Input

Table 1 Data Input

Parasit	Ciri-Ciri				Spesies	Tipe Prasite
	Filum	SubFilum	Class	Ordo		
1	Vermen	Platyhelminthes	Trematoda	Monogenea	Gyrodactylus sp.	Patogen
2	Vermes	Platyhelminthes	Trematoda	Monogenea	Dactylogyrus	Patogen
3	Protozoa	Ciliophora	Ciliata	Osteichthyes	Myxobolus sp.	Non-patogen
4	Arthopoda	-	Maxillopoda	Argulioida	Argulus	Patogen
5	Vermen	Platyhelminthes	Trematoda	Turbellaria	Temnocephala	Patogen
6	Protozoa	Ciliophora	Ciliata	Actinopterygi	Trichodina sp.	Non-patogen

2.1.3 Process Analysis

In general applications have some process in conducting an analysis of the image inserted into the application. Each process has its respective role to be able to recognize the images are included. Figure 3 can be seen in the following image:

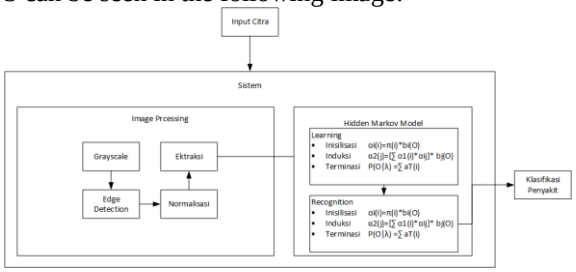


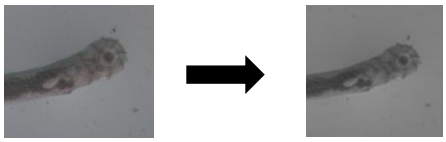
Figure 3 Process Analysis

2.1.4 Process image Processing

In this process there are several image processing process is needed on the simulation to be built starting from grayscaling, edge detection, normalization, and extraction.

2.1.4.1 Grayscale

The process of graycale is a normal image processing (RGB) image into grayscale. Conversion of images into grayscale is done by taking the value of the pixels from one image input is then calculated using the following equation, is the image of the results process grayscaling.



Fiture 4 Grayscale

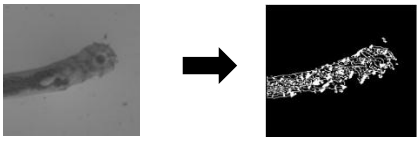
2.1.4.2 Edge Detection

In this process the image used is a colorful image grayscale. Edge detection process is run using prewitt prewitt, a method of using two measuring 3 x 3 matrix, i.e. a matrix of Gx and Gy. The second matrix is used to calculate the difference in color on pixels that are being calculated by the surrounding pixels horizontally and vertically. Gx matrix used to calculate the matrix horizontally and Gy are the matrix vertically. Figure 7 the following are operators of the prewitt edge detection process is used at:

$$H_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \quad H_y = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

Fiture5 Operator Sobel

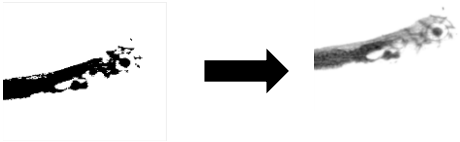
following are the results of image edge detection using prewitt:



Fiture 6 Edge Detection

2.1.4.3 Thresholding

In this process using Thresholding process, which is pixel-pikse separation process of berdasrkan degrees kebuan is smaller than the value of the limit. Pixels that have a degree of keabuan is smaller than the specified limit bilai shall be given a value of 0, whereas anilai which has a greater degree of keabuan and the limit will be converted into value 1. This method is used to convert the image data into binary data with the goal of keeping the next process easier:



Fiture 7 Thresolding

2.1.4.4 Extraction

Extraction or feature extraction is the process by which sample-sample of diseases that have been through the process of image processing. Figure 8 is an image that is used to process next.



Fiture 8 *Extraction*

Extraction results can be seen in Figure 9 which is the result of a figure 8 as follows:Error! Reference source not found. Extraction results

2.1.5 Learning Process Learning Hidden Markov Model

Here are the steps that are performed in the process of learning Hidden Markov Model:

1. the image Data already extracted as A parameter.
2. Results of the parameter π is processed in order to find the parameter B.
3. Results of the parameter A will be used to explore the opportunities of the parameter π.
4. The results of the third parameter will be used to process the HMM training algorithm using HMM

2.1.6 Process Clasification Hidden Markov Model

The process of classification method of HMM using the same formula of calculation training on the learning process.

The following classification steps:

1. test Data calculated using data parameters of training who have already sought.
2. After obtaining the value of the likelihood procedure Viterbi is used to find the real kelas.

2.1.7 Analysis Requirements System Functionality

Here is a use case diagram from system:

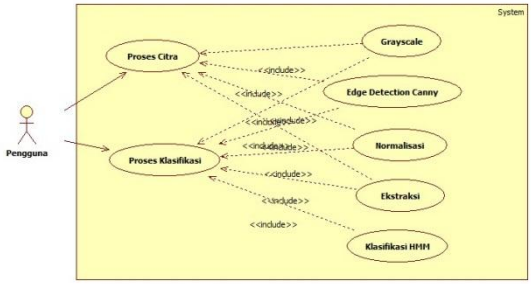


Figure 1 Use Case Diagram

2.2 Implementation and System Testing

The following will describe about implementation and testing of system.

2.2.1 Implementation Environment

Implementation environment is a specification of hardware and software which the system will be used. Here is the implementation environment:

1. Hardware

   Here is hardware spesification in developed this simulator:

   a. Processor : Intel Dual Core 2,0 GHz
   b. Memory : RAM DDR 3 1 GB
   c. Harddisk : 64 GB
   d. VGA 521Mb
   e. Monitor 14”
   f. Keyboard
   g. Mouse
   h. Scanner
2. Software

   Here is software used in developer simulator:

   a. Operating System : Microsoft Windows 7
   b. Visual Studio 2012

2.2.2 Interface Implementation

Here is interface implementation from implementation:

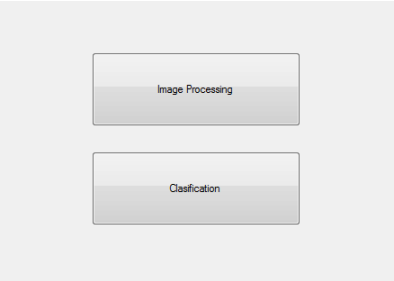


Figure 2 Interface Beranda

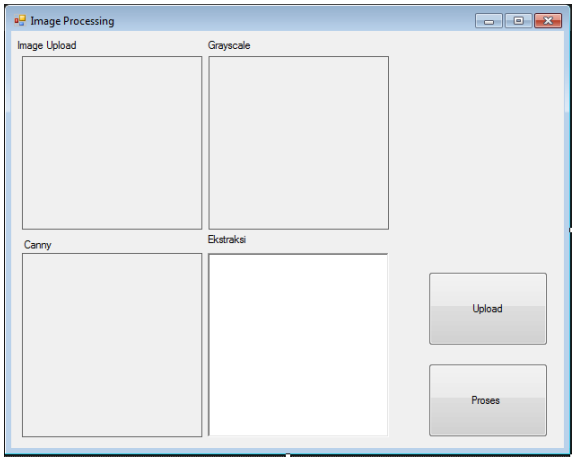


Figure 3 Interface Image processing

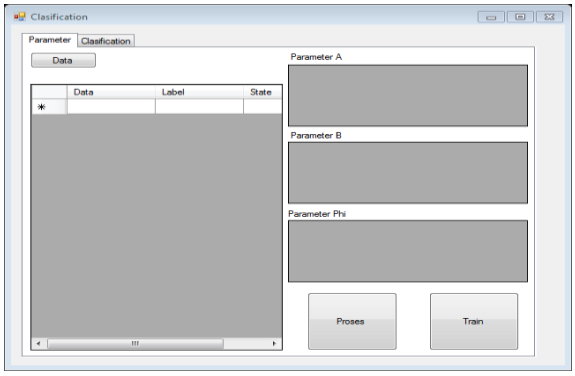


Figure 4 Interface training

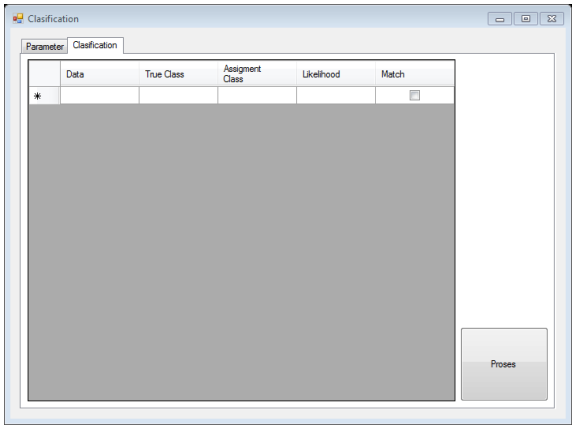


Figure 5 Interface klasifikasi

2.2.3 Testing

Here is the accuracy of the resulting from the process of testing the accuracy of data image 100 that have been tested using equation 8 different types of diseases:

$$Acuration = \frac{69}{100} \times 100\% = 69\%$$

3. CLOSING

3.1 Conclusion and Suggestion

Based on the results of the research, analysis, designing and manufacturing system simulator classifying fish diseases using methods of Hidden Markov Model (HMM) then the conclusion is a method of Hidden Markov Model (HMM) can be used to classify the disease image based on fish diseases result from mikrosopis, because the accuracy obtained already very good i.e. the accuracy of 69%.

From the results of research, analysis, design, manufacturing to testing, problems occurred at the time of image processing used to locate features of the image results from microscopic, resulting in a large number of image characteristics obtained from image processing, so the vector obtained will be equal to the number of earmarks that were obtained from the results of image processing. Then the suggestions to improve further research regarding the analysis of the Hidden Markov Model (HMM) for classifying fish diseases result from mikrosopis is because the data in the input image is very influential in the learning process, it is recommended to use a better image when first using the method to vector value mecari against the image that will be used as the data, whether the data training or test data in order to characterize the obtained not too much , thereby increasing the accuracy of the method of Hidden Markov Model (HMM).

REFERENCES

[1] Feliatra, "Identifikasi Bakteri Patogen (Vibrio Sp) di Perairan Nongso Batam Propinsi Riau," Jurnal Natur Indonesia II, vol. 1, pp. 28-33, 12 Juli 1999.

[2] A Hatmanti, R Nuchsin, and Y Darmayati, "Studi Penyakit Bakterial Pada Budidaya Ikan Kerapu dan Bakteri Penghambatnya di Perairan Teluk Lampung," Jurnal Akuakultur Indonesia, vol. 51-58, no. 7(1), 2008.

[3] Gusrina , Budidaya Ikan untuk SMK. Jakarta: Pusat Perbukuan Departemen Pendidikan, 2008.

[4] Afita Putri Lestari, Rencang Bangun Pengenalan Penyakit Darah Menggunakan Hidden Markov Model. Depok: Skripsi Fakultas Teknik Prgram Studi Teknik Elektro Fakultas Teknik Universitas Indonesia, 2008.

[5] Apoorva Mishra and Deepty Dubey, "A Comparative Study of Different Software," International Journal of Advance Research in, vol. 1, no. 5, p. 64, October 2013.

[6] R Usman, Parasit dan Penyakit Ikan. Padang: Fakutas Perikanan dan Ilmu Kelautan Universitas Bung Hatta, 2007.

[7] Keith D Griffiths, Histopathology Services in Wales.: Nasional Pathology Programme, 2010.

[8] Putra D, Pengolahan Citra. Yogyakarta: Andi Offset, 2010.

[9] Cristopher Danil, "Edge Detection dengan Algoritma Canny," Deteksi Tepi.

[10] V B Rao and H V Rao, Neural Networks and Fuzzy Logic. New York: Management Information Source, 1993.

[11] Riyanto Sigit, Robotika Sensor dan Aktuator. Jakarta: Graha Ilmu, 2009.

[12] P Dymarski, Hidden Markov Model, Theory and Aplications. India: InTech, 2011.

[13] Robert G Fichman and Chris F Kemerer, "Object-Oriented and Conventional Analysis and Design Methodologies," Massachusetts Institute of Technology, vol. 92, pp. 0018-9162, 1992.

[14] Kiyofumi Tanaka, Embedded Systems - Theory and Design Methodology, Kiyofumi Tanaka ed.: InTech, March 02, 2012.

[15] Rany Zuriatna Utami, Made Budi Suksmadana, and Bulkis Kanata, "MENENTUKAN LUAS OBJEK CITRA DENGAN TEKNIK DETEKSI TEPI," Dielektrika, vol. 2, no. 2086-9487, pp. 1 :11 - 17, Februari 2015.

[16] Dwijanto, "Bab 7 Rantai Markov," Riset Operasi , vol. 7.

[17] Kadir A and Susanto A, Teori dan Aplikasi Pengolahan Citra. Yogyakarta: Andi Offset, 2013.

[18] Nugroho Bonafir, Membuat Aplikasi Sistem Pakar Dengan PHP dan Editor Dreamwever. Yogyakarta: Gava Media, 2009.

[19] S Maria Yulianti, Pengenalan Retina Dengan Hidden Markov Model. Depok: Departemen Teknik Elektro Fakultas Teknik Universitas Indonesia, 2008.

[20] Evi Andriani, Analisis dan Identifikasi Berbagai Penyakit Paru-Paru Dengan Metode Hidden Markov Model. Depok: Skripsi Fakultas Teknik Prgram Studi Teknik Elektro Fakultas Teknik Universitas Indonesia, 2009.

[21] Nisa Pandu Pertiwi, APLIKASI ALGORITMA VITERBI UNTUK MENENTUKAN BARISAN KEADAAN TERSEMBUNYI PADA HIDDEN MARKOV MODELS. Bandung: Universitas Perguruan Indonesia, 2011.

[22] Jia Li, Ami Najmi, and Robert M Gray, Image Classification by a Two Dimensional Hidden Markov Model.: The Pennsylvania State University , 2000.

[23] Firdaniza , Nurul Gusriani, and Akmal , "Hidden Markov Model," Trend Penelitian dan Pembelajaran Matematika di Era ICT, 24 Nopember 2006.

[24] Marc Mouret, Christine Solnon, and Christian Wolf, "Classification of images based on Hidden Markov Models," Classification of images based on Hidden Markov Models, vol. F-69622, p. CNRS, Februari 2005.

[25] Hanif Al Fatta, "Seminar Nasional Teknologi 2007 (SNT 2007) ," Konversi Format Citra RGB ke

Format Grayscale Menggunakan Visual Basic, pp. 1978-9777, 24 November 2007.
[26] Angela Irfani, Ratih Amelia, and Dyah Saptanti, "Algoritma Viterbi dalam Metode Hidden Markov Models pada Teknologi," Makalah Stmik, 2006.
[27] Muhammad Eko Budi Prasetyo, "Departemen Teknik Informatika, Institut Teknologi Bandung," Teori Dasar Hidden Markov Model, vol. 025, 2010.
[28] Howard Anton and Chris Rorres, Aljabar Linear Elementer, 8th ed., Amelia Safitri, Ed. Jakarta: Erlangga, 2005.