IMPLEMENTATION OF HIDDEN MARKOV MODEL AND GABOR FILTER TO DETECT PUBLIC VEHICLE VIOLATIONS

Kukuh Setiawan

Teknik Informatika – Universitas Komputer Indonesia
Jl. Dipatiukur 112-114 Bandung
Email : kukusetiawan@email.unikom.ac.id

ABSTRACT

The number of traffic violations from year to year has increased. It is known from analysis and evaluation data of traffic offences there is a rise in 2015, traffic violations committed riders if compared with the period in 2014. Then the relation to this research, that recognize the type of offence by way of a Hidden Markov Model as classification methods and Gabor Filter in image processing based on the problems presented. Things to note in knowing violation, infringement upon a signpost to classify the image around the vehicle. And within the boundaries of the problem observed research focus to signs "don't enter" and "don't turn back". So the offense that was the Foundation of the research using methods to be able to generate conclusions this type of offence. When encountered with such a pattern of that signs, then direction violations can be detected from the classification of the extraction of the characteristics at the time of image preprocessing stage. Then the methods used to detect violations of the image Hidden Markov Model in the process of classification and image of Gabor Filters as one way the preprocessing image. By implementing these methods are intended to be able to meet the need to detect the violations committed by the vehicle. The results of this research in the form of data classification training which is used to detect data testing, and produce an output type of offence intended. And testing of K-Fold Cross Validation using data obtained 82, average accuracy value 70.31% correct classification and 29.69% invalid.

Keywords : *Gabor filter, Hidden Markov Models, image classification, image processing, violation of vehicle.*

1. INTRODUCTION

Traffic regulations made in the public interest with the goal of creating order in the drive, because the rules are obeyed, it will create a comfortable atmosphere while using traffic facilities. But still, there are those who commit the offense, and the amount of vehicle traffic violations from year to year increase. It was known from the data analysis and evaluation of traffic violations in 2015, there is a rise in the number of traffic violations committed rider when compared with the period in 2014. [1] And in the city of Bandung in one week alone there were an average of 1200 docket last violation cross on trial. [2]

In terms of this study, which detects the image processing vehicle violations that will be a study to determine the types of violations that occur based on the issues presented. Things to consider in knowing violation of an object is a vehicle and symbol signs in the vicinity. Violations that will be used as a research method to produce conclusions of violations. When encountered signs with patterns such as banned "Don't Enter" or forbidden "turning toward" the offense can be detected using pattern recognition. The method used to detect the image of this offense, namely Hidden Markov Model as image classification and Gabor filter as one image preprocessing, by implementing these methods are intended to be able to meet the needs of detected offenses committed by vehicles.

Regarding the Hidden Markov Model (HMM) is a method that can determine patterns of violations of the vehicle based on probability, it can be analyzed that the vehicle has a traffic violation. Or sequence feature extraction matrix formed image preprocessing results will be stored in the database as a value classification and HMM working hides another image that does not fit in the database image edge detection value of training with a given state, so it will detect the violation in question. [3]

Then explained that the Hidden Markov Model (HMM) is a probability model that describes the statistical relationship between the sequence of observations and order state which is not observed "hidden" or hidden. [4] In HMM, the state is not seen directly, but its output is dependent on the circumstances the look is in this case a matrix of extraction. And to make image classification, the need for preprocessing stage beforehand that lets me switch condition where if the original image data or noise can still be done testing. And in previous studies on the noise detection code such as the

signature pattern recognition HMM only has an average of 43.35% CER with the explanation that the smaller the CER (Character Error Rate), the better the resulting accuracy, while the introduction of handwritten letters and numbers achieve an accuracy of 74%. That means the introduction of the resulting better than the preprocessing. [4] In the end to assist in refining the HMM weakness then the need for other methods mangkus in the image preprocessing stage before image classification.

Concerning Gabor filter is a method with object recognition which can be defined as the process of determining the identification of the object. This method can detect any dots produced with high accuracy [5] [6] The image before entering them into a database, the image will first be processed using the method of preprocessing and one of them is Gabor FIlter. Gabor convolution calculation filter will produce a specific value called Gabor jet responses to achieve thresholding.

It is necessary both methods with different functionalities that Gabor filter to enhance the preprocessing stage and HMM to generate classification.

1.1 Gabor Filter

As the filter is used Gabor 2D filter kernel obtained by modulating a sine wave at a frequency 2D and specific orientation with Gaussian envelope. Basic equation Gabor filter kernel function 2D equation shown in the following equation:

$$\begin{bmatrix} x_{\theta n} \\ y_{\theta n} \end{bmatrix} = \begin{bmatrix} \sin\theta_n & \cos\theta_n \\ -\cos\theta_n & \sin\theta_n \end{bmatrix} \cdot \begin{bmatrix} x \\ y \end{bmatrix} \quad (1)$$

Then σ_x and σ_y is the standard deviation of the Gaussian envelope dimensions x and y. λ and θn is the wavelength and orientation of the 2-D sine wave. The deployment of the Gaussian envelope is defined in the form of a sine wave λ.. Rotation of x - y by angle produce θ_n Gabor filter at orientation. Here is an equation calculating the standard deviation:

$$\sigma_x = \sigma$$
$$\sigma_y = \frac{\sigma}{\gamma}$$
$$\sigma^2{}_x = \sigma^2$$
$$\sigma^2{}_y = \sigma/\gamma^2 \quad (2)$$

The default parameters used to calculate Gabor filters can be found in the documentation accord library.[12]

Orientation θn = 0.6

Gaussian Variance Sigma = 2

Aspect Ratio Gamma = 0.3

Kernel Size fx=3

Wave length λ = 4

As in calculating the final result can be performed on Gabor value equation formula (3):

$$a = 1 / (2 . PI . \sigma_x . \sigma_Y) \, Exp(-0.5 . (x^2{}_{\theta n}/\sigma^2{}_x + y^2{}_{\theta n}/\sigma^2{}_y))$$
$$c = Cos(2.0 . PI . fx . x_{\theta n} / 2)$$
$$Gabor(-1,-1) = a . c \quad (3)$$

If all Gabor filters with a variation of the wavelength (λ) and orientation (θ_n) is applied at a certain point (x, y), then obtained a lot of response filter to the point, for example: use four wavelengths (λ = 3, 5, 7, 10) and eight orientation, it will produce thirty-two response filter for each image point that dikonvolusikan the filters.

1.2 *Hidden Markov Model*

Hidden Markov Model or better known as the Hidden Markov Model (HMM) is a statistical model of a system that is assumed to be a process of Markov with a parameter that is not known, and the challenge is to determine the parameters of the hidden (state) of parameters that can be observed (observer). The parameters set can then be used for further analysis, for example for pattern recognition applications (Pattern Recognition). A HMM can be considered as a dynamic Bayesian Network simplest.

In general Markov models (Vanilla / Visible Markov Model), its state can be observed directly, therefore the probability of the state transition (state) being the only parameter. Inside the hidden Markov model, its state can't be observed directly, but can be observed are the variables that are affected by the state. Each state has a probability distribution over the tokens output that may arise. Therefore, a series of tokens generated by HMM gives some information about the sequence of state-state. [4]

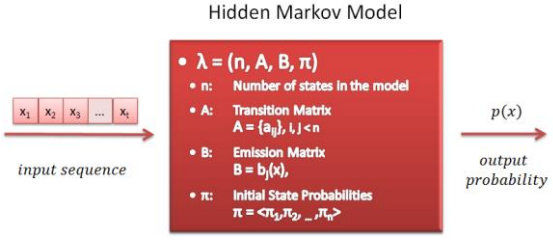


Figure 1 HMM Model

1.2.1 *Markov Chain*

Markov chains (Markov Chains) is a mathematical technique that is commonly used to perform modeling (modeling) a wide variety of business systems and processes. This technique can be used to estimate changes in the future in a dynamic variables on the basis of the changes of the dynamic variables in time plainly. This technique can be used also for analyzing events in the future times mathematically.

Markov Chain Model (Markov Chains) discovered by a Russian named Andrey Markov in 1906, namely: "For every time t, when the event is Kt and all previous events are $K_{t(j)}$... , $K_{t(j-n)}$ that occurs from a process is known, the probability of the whole incident to come Kt (j) only depends on the incidence of $K_{t(j-1)}$ and does not rely on previous events that $K_{t(j-2)}$, $K_{t(j-3)}$,..., $K_{t(j-n)}$.".

Markov chains (Markov Chains) when given the input state of the current state, the state will come is unpredictable and can be separated from the state in the past. That is, a description of the current state captures all the information that affects the evolution of a system in the future. In other words, the future condition addressed by using probability.

That is about markov chain an then movements of variables in future able to predictable according variables movements at the past. K_t4 influenced by events K_t3, K_t3 K_t2 influenced by events and so on which this change occurred because of the role of the transition probability (transition probability). Genesis K_t2 for example, will not affect the incidence of K_t4.

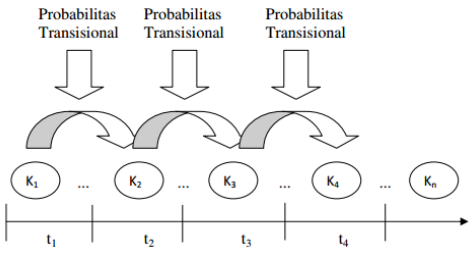


Figure 2 Markov Chains

Markov Chains helpful to calculate the probability of an event is observed that in general can be formulated as follows:

$$P(\sigma_i) = P(\sigma_t|\sigma_{t-1}, \sigma_{t-2}, \sigma_{t-3}, \dots, \sigma_{t-n}) \quad (4)$$

σ_t is the current state, and σ_t is the condition at a particular time associated with σ_t. While σ_ (t-i) is the condition before σ_t. Then it can be assumed that the right of the equation is invariant, ie, hypothesized in entire of system, the transition between the specific circumstances remained the same in its probabilistic relationships. Based on these assumptions, it can be the formation of a stet state transition probability between two states K_i and t_j:

Transition probability =

$$P(\sigma_t = K_t|\sigma_{t-1} = t_j), 1 \le i, j \le N \quad (5)$$

1.2.2 Parameter HMM

HMM mempunyai parameter-parameter distribusi sebagai berikut :

a. Probabilitas Transisi (A)

Parameter A merupakan parameter dengan ukuran MxM dengan M adalah jumlah state yang ada, parameter transisi dapat dituliskan dalam bentuk matriks seperti berikut:

$$A_{ij} = \begin{bmatrix} A_{11} & A_{12} & A_{13} & \cdots & A_{1n} \\ A_{21} & A_{22} & A_{23} & \cdots & A_{2n} \\ A_{31} & A_{32} & A_{33} & \cdots & A_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ A_{n1} & A_{n2} & A_{n3} & \cdots & A_{nn} \end{bmatrix}$$

$$A = \{a_{ij}\}, a_{ij} = P_r(x_{t+1} = q_j|x_t = q_i), 1 \le j, i \le N \quad (6)$$

b. Probability Of Observation (B)

Parameter B is an observation probability or likelihood state is the appearance of a state existing rows of the entire state. Parameter B in HMM written in matrix form column with MX1, where M is the sum of all existing state. Parameter B can be written in matrix form as follows:

$$B = \begin{bmatrix} b1 \\ b2 \\ b3 \\ \vdots \\ bn \end{bmatrix}$$

$$B = \{b_i\}, b_i(k) = P_r(O_t = V_k | x_t = q_i\ t) \quad (7)$$

c. Initial State Distribution (π)

Parameter pi (π), referred to as the initial parameters, the probability of occurrence of a state in the beginning. Similarly, the B parameter, parameter π is also written in the form of a column matrix with the size of the MX1, where M is the number of their state, parameter π can be written in the following form:

$$\pi = \begin{bmatrix} \pi 1 \\ \pi 2 \\ \pi 3 \\ \vdots \\ \pi n \end{bmatrix}$$

$$\pi = \{\pi_i\}, \pi_i = P_r(x_0 = q_i) \quad (8)$$

While certain parameters HMM there are two, namely N and M:

N, the number of states the model. Notated finite set of possible states is Q = {q_1, ..., q_N} (9)
M, the number of observation symbols / state, discrete font size. Symbol observation relates to the physical output of the modeled system. Notated limited set of observations is probably the
V = {V_1, ..., V_M} (10)
HMM parameters are estimated based on the criteria of maximum likelihood (ML) and the Baum-Welch algorithm (EM = Expectation Modification).

1.2.3 HMM Problems

There are 3 basic human rights issue that must be solved for the model applied :

a. calculating $P = (O|\lambda)$ $O = O_1, O_2, \dots, O_T$ dan $\lambda = (A, B, \pi)$. (10)

Solution :
How common is commonly used to examine every possible state sequence along T N (number of observations). This is not possible because the calculation is less efficient. There are other procedures more simple and efficient is the use of forward procedure.

- *forward procedure*

forward $\alpha_t(i)$ at ke-*t* and *state* ke-*i* define with. $\alpha_t(i) = P(O_1,O_2,\dots,O_T, q_t=i \mid \lambda)$. Functions can be solved forward opportunities for the N T symbol observation state and inductively with the following steps:

○ Initialitation, $\alpha_t(i) = \pi_i b_i(O_1)$, $1 \le i \le N$ (11)

○ Induction, $\alpha_{t+1}(j) = \left[\sum_{i=1}^{N} \alpha_t(i)\alpha_{ij}\right] b_j(Oi+_1)$, $1 \le t \le T-1$; $1 \le j \le N$ (12)

○ Termination, $P(O|\lambda) = \sum_{i=1}^{N} \alpha\, T(i)$ (13)

The calculation of odds forward based on the pattern of trellis diagram. There are N points each time slot on the pattern, all possible row combined state as a point regardless of length N rows of observation. At the time t = 1, calculated the value of O1 (i), 1≤i≤N. At time t = 2,3, ..., T is only required calculation of the value αt (j) where 1 ≤j≤ N.

Each calculation requires as much as the previous value of αt N-1 (i) for each N point can only be connected to the N points on the previous time slot.

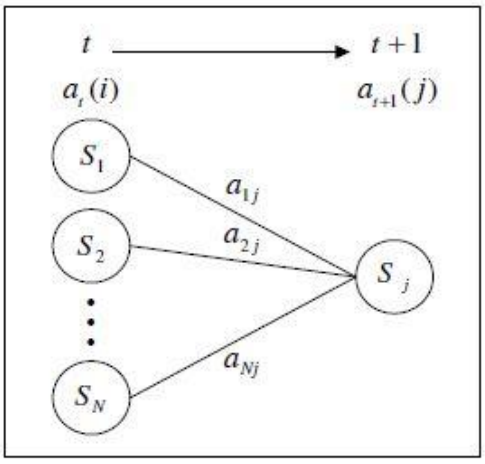


Figure 3 Serial of State

2. Research

2.1 Overview

The main objective of this thesis is to create applications that can perform the introduction of a traffic violation is prohibited "Don't Enter" and prohibited "reverse direction" in the vehicle. The process flow diagram modeling applications on the following picture:

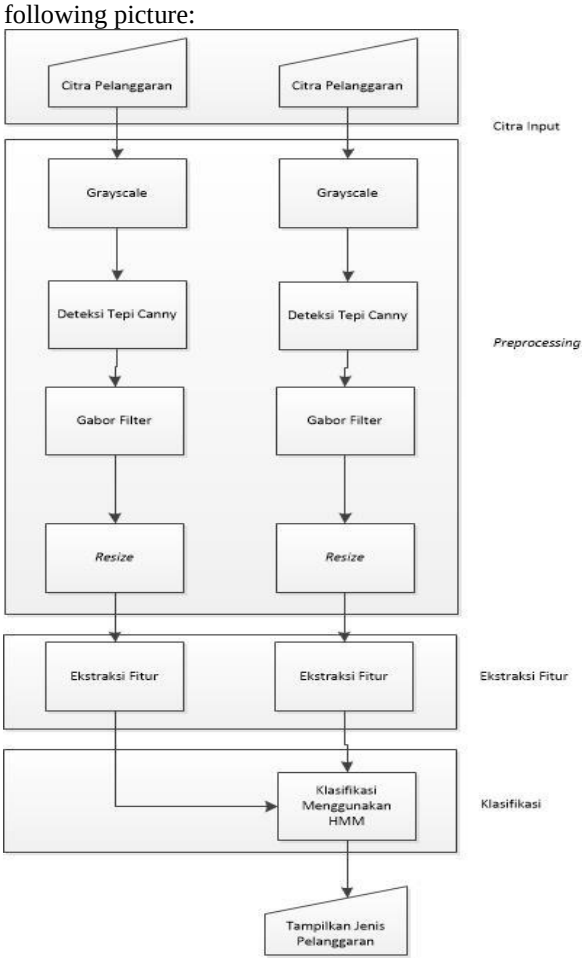


Figure 4 Flowchart of Application

In the modeling workflow application are described there are 4 (four) stages, namely the input image, preprocessing, feature extraction and classification. From each of these stages can be analyzed process is further from the input data in the form of the image of the violation, then into the preprocessing is to convert the image to grayscale, decisive edge detection Canny, filtering using Gabor filter and resize result of Gabor into 128x128. After that, look for the feature extraction to be included in the classification using HMM.

2.2 Input

Data input will be taken on this application is an image that is taken when a violation is prohibited "Don't Enter" and prohibited "reverse direction". So clearly the image of an offense, and in this study determines the identification of categories of offenses contained in the image.

Each process on image processing using pixel values of the image for calculation. Each pixel in the image is composed of three elements of basic colors namely Red (R), Green (G) and Blue (B), which is often called RGB, and each element has a value between 0-255 which became the code color depth of each of the elements , For example, the calculation of the processes of image processing, image used "vehicle violations" to do with the size varying input. The image of a violation can be seen as in the following picture:



Figure 5 Image Infringement prohibited "reverse direction"



Figure 6 Violations Prohibited "don't enter"

Of the input image size is different because of the dimensions of each image acquisition can be performed with a variety of tools that notabennya not have the same pixel size, it is necessary to resize the preprocessing to match the size of the image pixel dimensions. In this research will be conducted resize be 128x128 pixels.

2.3 Testing

Application testing is a stage that has the purpose to find flaws in the software being tested. The test aims to determine the software that made already meet the criteria in accordance with the purpose of designing and testing this software using black box testing. Black box testing focuses on functional requirements of the software, and also to the performance testing conducted to test the classification menghasil value.

Black box testing is used to determine the testing performed is divided into several scenarios. As seen below.

2.3.1 Scenario of Testing

Here is a test scenario as shown in the table below:

Testing Class	Process	Type
Images	Test input of image	*Blackbox*
Training data	Manage the data from image of train	*Blackbox*

2.3.2 Fungsional Scenario

Functional Scenario describes the functional testing of applications used. Here are the results of testing on the application:

Fungtional	activity	Testing	Conclusion
Grayscale	Change image to *grayscale*		[√] accept [ ] reject
Canny Edge Detection	Change grayscale to *canny* edge detection.		[√] accept [ ] reject
Gabor Filter	Canny to *gabor filter*.		[√] accept [ ] reject
Resize	Rezing to be 128x128 pixel.		[√] accept [ ] reject

2.3.3 Cases and Test Results

Based on the test plan has been finalized, it can be tested as described in the table below:

Result

Input	Activity	Observation	Conclusion
Image	detected "Don't Enter"	The apps show "Don't Enter" from input.	[√] accept [ ] reject
	detected "turn back"	Show "turn back" from input.	[√] accept [ ] reject

2.4 Pengujian Performansi

Performance testing is used to determine the accuracy of which is done using k-fold cross validation, with k values as much as 10 fold. Aiming to test the stability of accuracy when tested with the training data and test data are different. The use of a 10-fold is recommended as the best to fold the number of test validity. Tests conducted on methods of Hidden Markov Model (HMM). To test of the method of Hidden Markov Model (HMM) data that is used by 82 data is divided into two subsets with categories of violations "Do not Enter" and "reverse direction", and used in performance testing using iterations 50 times. The accuracy of the test scenario performasi fold cross validation method as follows:

a. Testing Result *Fold* 1

Assigned Class	Likelihood	Match
S	0,999900705020977	☐
S	0,99998621018447	☐
S	0,999999008132514	☐
S	0,999998340107268	☐
S	0,999956995233563	☐
S	0,9999981826972	☐
S	0,8294743178533	☐
P	0,948383153256537	☑
S	0,997309111024863	☐
S	0,999881150386368	☐
S	0,999991754716689	☐
S	0,999982706583785	☐
S	0,930941847374728	☐
S	0,998141541241458	☐
S	0,999999947473385	☐
S	0,999999996030738	☐
S	0,999999997396799	☐
S	0,999854151366954	☐
S	0,761191367573416	☐
P	0,996033790715403	☑
S	0,978296490589362	☐
P	0,727764947622747	☑

The test results are not correct in the classification results in a subset 1 is 20. So the value of accuracy in experiment fold 1, which is $\frac{2}{22} * 100\% = 9.09\%$.

b. Testing Result *Fold* 2

Assigned Class	Likelihood	Match
P	0,837644551917209	☑
P	0,830910270031823	☑
P	0,889592258925908	☑
P	0,999999999971863	☑
S	0,999097644025353	☐
P	0,813019440684304	☑
P	0,999948745862639	☑
P	0,99999999999261	☑
P	0,999999999988916	☑
P	0,999710927077499	☑
S	0,989999541174043	☐
P	0,999999910330307	☑
P	0,999999999367219	☑
P	0,987784454097558	☑
P	0,999997716911756	☑
P	0,999999999820318	☑
P	0,999999125993368	☑
P	0,99999999550954	☑
P	0,999911435220222	☑
P	0,999998478090411	☑
P	0,999999427704261	☑
P	0,999999684140043	☑

The test results are not correct in the classification results in a subset 2 is 2. So the value of accuracy in experiments fold 2 that is $\frac{20}{22} * 100\% = 90.9\ \%$.

c. Testing Result *Fold* 3

Assigned Class	Likelihood	Match
P	0,999999994247446	☑
P	0,999980847765273	☑
P	0,999999999986471	☑
P	0,99999999999784	☑
P	0,999995628832555	☑
P	0,999999996951999	☑
P	0,999999997486498	☑
P	0,999999962165646	☑
P	0,999999986028172	☑
P	0,999999999999943	☑
P	0,999999999995055	☑
P	0,999999999925308	☑
P	1	☑
P	1	☑
P	0,999999999995964	☑
P	1	☑
S	0,999999999999091	☑
S	0,99963751146435	☑
S	0,99999240193108	☑
S	0,99999866379481	☑
S	0,974570531262582	☑
S	0,999961914073503	☑

The test results are not correct in the classification results in a subset 3 is 0. So the value of accuracy in experiments is $\frac{22}{22} * 100\% = 100\ \%$.

Hasil Percobaan *Fold* 4

S	0,961108850710227	☑
S	0,999992649967748	☑
S	0,999679218928233	☑
S	0,96752973713067	☑
S	0,999987077591462	☑
S	0,999999137873177	☑
S	0,999402861017684	☑
S	0,999999971755756	☑
S	0,999998398119861	☑
S	0,886950927309348	☑
P	0,620852593272065	☐
S	0,57147815804708	☑
S	0,999148234832538	☑
S	0,999475568992577	☑
P	0,957059516996981	☐
P	0,712536826097485	☐

Hasil test yang tidak benar dalam hasil klasifikasi pada subset 4 yaitu 3. Sehingga nilai akurasi dalam percobaan *fold* 1 yaitu $\frac{13}{16} * 100\% = 81.25\%$.

Accuration Result

Fold	Accuration
Fold 1	50%
Fold 2	30%
Fold 3	40%
Fold 4	30%
Average Of Accuration	$\frac{9.09\% + 90.9\% + 100\% + 81.25\%}{4} = 70.31\%$

Of testing C-Fold Cross Validation uses 82 data got an average accuracy value of 70.31% correct classification and 29.69% wrong. Factors causing the lack validan in classifying using Hidden Markov Model (HMM) because it depends on the traits that are used as training data.

3. Conclusion

Conclusions from the study entitled: "Implementation of Hidden Markov Model method and Gabor Filter To Detect Vehicle Traffic Violations" is as follows:

1. Research on offense vehicle image processing can be used to detect the image of the type of offense the vehicle is prohibited "Do not Enter" and "reverse direction".
2. Method Hidden Markov Models can be applied in the process of determining the classification of the type of offense "reverse direction" and "Do not Enter" made vehicle on vehicle violations image processing with accuracy results average 70.31% correct classification.

4. LITERATUR

[1] Website Resmi Korps Lalu Lintas POLRI. 2015. http://lantas.polri.go.id.

[2] Website Resmi Pemerintahan Jawa Barat. 2015. http://www.jabarprov.go.id.

[3] D Sudian, Arman dan P Priambodo. "Aplikasi Pengenalan Wajah (*Face Recognition*) Menggunakan Metode Hidden Markov Model (HMM)". Teknik Elektro, UI.

[4] E Yuwitaning, B Hidayat dan N Andini. "Implementasi Metode Hidden Markov Model Untuk Deteksi Tulisan Tangan". Teknik Elektro, Universitas Telkom.

[5] H Kekre and V Bharadi. 2010. "*Gabor Filter Based Feature Vector for Dynamic Signature Recognition.*".

[6] D Murugan, S Arumugam, K Rajalakshmi dan Manish. 2010. "*Performance Evaluation of Face Recognition Using Gabor Filter, Log Gabor Filter and Disctere Wavelet Transform*".

[7] Sepritahara. 2012. "Aplikasi Pengenalan Wajah (*Face Recognition*) Menggunakan Metode Hidden Markov Model (HMM)". Skripsi. Jakarta: Fakultas Teknik, Universitas Indonesia.

[8] A Margono, I Gunawan dan R Lim. 2004. "Pelacakan dan Pengenalan Wajah Menggunakan Metode Embedded Hidden Markov Models".

[9] A Agung, Fazmah A Yulianto dan W Maharani. 2011. "Pengenalan Wajah Menggunakan Psedo-2D Hidden Markov Model".

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

[11] A Khandual, G Baciu *and* N Rout. 2013. "*Colorimetric Preprocessing o*

f Digital Colour Image".

[12] *Gabor Filter Imaging Filter*. 2015. http://accord-framework.net/docs/html/T_Accord_Imaging_Filters_GaborFilter.htm.

[13] *Canny Edge Detector Class.* 2015. http://www.aforgenet.com/framework/docs/html/e08cae30-7a37-db9f-cede-05cf6521343f.htm

[14] P Mishra, R Chatterjee *and* V Mahapatra. 2010. "*Texture Gabor Filter Using Gabor Filter and Wavelets*".