TABLE OF CONTENTS

CHAPTER 1

1 Introduction

Nowaday's computers have been tremendously used in our daily work, as they can handle a large amount of data and computations more accurately and efficiently than humans. So the capabilities should be exploited to do more intelligent tasks with high accuracy. For examples recognition of patterns in images whether images are one dimensional or two dimensional images or signals can also be done by humans but while doing this tasks hundred times the accuracy shown by human being slows down. Take an example of human visual system in detecting and recognizing patterns. In our daily lives different kind of non linear images has been used for example human faces, cars, non linear signals etc. In our home also the electricity which is coming is not perfectly sinusoidal sometimes we get sag, swell etc.

The detection of these signals can easily find out, handwriting matching can also be done. Human beings can also recognize and detect these patterns but their accuracy is not that much efficient as done by computers. So one of the preliminary task are detections of different non linear patterns, objects, poses in images etc. This type of capability would have large number of applications.

The detection and recognition can be done with the help of detectors for example shift detector, HOG (histogram of gradient), Volterra series etc. In this project work HOG and volterra series is used to detect the signals. After detecting the signals it can be classified by various classifiers such as neural network, SVM (support vector machine) etc. In this thesis we used SVM classifiers. Earlier many researches have been done to detect linear as well as non linear patterns. The interest of such non linear detectors resides in its various types of applications such as power quality event detection, crowd control, video surveillance or automatic image indexing.

Detecting non linear one dimensional analog signal is a challenging matter as non linear signals adopt wide range of amplitude, frequency and other parameters

1.1 Motivation

With day-to-day development in artificial intelligent system, detection and recognition of non linear data is very essential in image processing research field. The value proposition for non linear data detection and recognition system varies depending on the end users as given below.

- To consumers
  - Safety & security(power quality event, detection of objects)
  - Time savings (error detection)
  - Better efficiency
- To business
  - Additional data from signals (warranty, usage)
  - Increased productivity of the device (or "price of survival")

Companies have started hiring non linear detection system. It becomes very difficult to detect a large number of patterns of any type for example one dimensional signal, data from video signals or two dimensional signals doing manually it will consist lot of manpower and money. Moreover certain features like real time non linear pattern detection may not be possible manually at times.

In order to solve all these issues, automatic non linear data recognition is used. Fleet hirer is interested in various details such as efficiency and accuracy of detection about the data, in real time. This real time detection helps the fleet hirer in managing and controls a particular pattern from a particular input signals or data. Also, this system helpful in preventing any misuse of signals in power quality event detection.

1.2 Objective

As the detection of the unique pattern is very much essential in our day to day life. So the main focus is to detect and recognition the patterns, so, our first aim to detect the derived pattern is detect with the help of HOG(Histogram of Oriented Gradients), as Naveen

Dalal made the algorithm to detect the pedestrian. So, we take the idea of Naveen Dalal and we used HOG to detect one dimensional pattern recognition.

We can also detect Non linear pattern with the help of the volterra series, volterra series creates the envelop around the non-linear pattern by that we can detect and recognize the derived pattern.

After the detection we used different classification to classify our pattern from example SVM (Support Vector machine), Neural Network etc.

The main objective of this work is

- To design and develop a small, portable and rugged embedded system that shall detect and recognize non linear patterns.
- To design a system with low power consumption, high reliability and good accuracy.
- To propose a smart computer vision system which gives accurate output in few seconds?

1.3 Scope of Work

In this work, the modification in the algorithm makes pattern more visible, and accurate even it can be done in one dimensional pattern also.

The work is mainly done for detection of Non-Linear patterns and recognition.

1. By using HOG (Histogram of Oriented Gradients)
2. By using volterra series

The image obtained from the camera is preprocessed and analyzed using an efficient algorithm. This algorithm shall aid in reducing the background noise, refining the image, This algorithm uses Artificial Neural Network (ANN) classifier or SVM to classify the detected image based on several features.

1.4 Resources

The following resources are used for detection and recognition of the pattern

1.4.1 Software

Windows & is used as a operating system having MATLAB version MATLAB2013a is used for the simulation of the image processing.

1.5 Organization of Report

The report is organized as follows

Chapter -1 gives overall view of the project work including introduction motivation, scope of work and objective.

Chapter-2 This chapter is all about the literature survey on Non-Linear pattern recognition.

Chapter-3 This chapter is all about detectors HOG

Chapter -4 This chapter is all about VOLTERRA SERIES.

Chapter-5 This chapter is based on the design methodology. This chapter gives detailed explanation of detection and recognition.

Chapter-6 MATLAB simulation results for image detection of non linear patterns are discussed.

Chapter-6 MATLAB simulation results for image detection of non linear patterns in power quality events.

Chapter-7 This chapter deals with the conclusion from the interpreted results and explores the future work for this technology.

2 CHAPTER 2

Literature Review

In this chapter various techniques of pattern detection and segmentation which are published in last year will be reviewed. The review focuses mainly on the different applications which are linked with the project.

It is categorized in three parts.

- Object hypotheses which means region of interest selection.
- Extraction (feature extraction)
- Verification (classification)

2.1 Region of interest selection (ROI)

In the context of pattern reorganization and estimation which means selection the subset of images for the set(pattern) or sample within the images. The simplest and tradition techniques to get initial pattern location hypotheses is the sliding window techniques, on which detector windows at various location and scale are shifted over the image.

This technique is formulated by N.Dalal and B.Triggs(2005), and P.sabzmeydami and G.Mori(2007) where a number of samples slided by fixed size of the windows which skip "some pixels" from "original pixels" to the last pixel. Although performance is far better and good, as the computation is time consuming. The reason of this is that the computation is too much complex for real time processing.

Hence there ways to optimize

- To couple the sliding windows approach with a classification cascades.
- This will provide us smaller cost and more efficient.
- Since the boosted classifiers and used to construct to reject many of the negative windows while detecting all positive windows.

In processing the better result came's from the first classifier and it gives input to the second classifier which adjusted to achieve a very high detection rates.

Result which given by first classifier to the second classifier transmits.

A negative output at the end of the classifiers leads to immediate fall of the sub-window. Therefore the cascade tries to reject as many negative samples as possible at the beginning stage. Finally the classifiers able to reduce the computation time.

2.2 Extraction methods

Pattern extraction is based on ROI, by using "spatial" and "temporal" cues.

For the categorization, the images or patterns are roughly divided into the "shape based method" and "feature based method". Both methods devoted the useful information which is used for solving the computation tasks.

2.2.1 Feature-based extraction method

Ideally this feature of patterns should generalize over the small variation in an object appearances, and action execution. At same point, representation of the features is discriminative to allow for classification to process. Some literatures about the feature representation is described as below as.

Feature representation is mainly divided into two categories.

- Global representation
- Local representation

Global representation

The calculation for global representation is based on a top down method when ROI is enclosed as a whole body. The representation of global features are taken from silhouettes, edges etc. these representation are powerful since they enclosed much information. However they depend mainly on the accurate location. These representations are sensitive to viewpoint and noise.

Local representation

It describes the observation as a collection of a local patches and descriptors. The calculation of this representation obtained from bottom to top. Local patches will be computed around these points. After that all these patches are concatenation together. This type of representation is mainly focused on correlation between the patches. The merit of this local representation is that it is less sensitive to noise. This is the main reason that it can help in extraction of patterns.

Combination of both feature vectors can be used in this algorithm. The different kinds of techniques has been discussed which are used in the various application for the several feature representations. One of the popular techniques called Haar wavelet which had been introduced by P.Vila and M.Jones [2001]. Haar wavelet uses local filter to operate on the pixel intensities. The no adaptive feature of the wavelet is widely used in the representation of the local intensity differences at various instances, scales and orientation.

Due to overlapping of a spatial filter shifts; better redundant representation is produced by this filter. The solution of this redundant representation uses mechanisms for the proper selection of the subset features out of the possible pattern features. Previously, the operation of the subset of a feature selection of the patterns is designed manually by incorporating past knowledge about the geometric configuration of the non linear patterns.(Adaboost) have been mainly used for the automatic feature selection of the patterns. The automatic feature extraction of a subset of "non-adaptive features" has been considered as one of the optimizing feature for the classification.

The particular configurations of these spatial features are another style of optimization. The Codebook feature is one of the local intensity-based, feature patches which extracted interesting points around the image (S.Agarwal et al. [2004]). At first, a built in "vocabulary" of parts can be used in representation of objects in the target class.17 extracts information-rich paths from patterns of the images. These similar patches are grouped together and become as a single part. Based on the representation of the

extracted feature vectors of images include informations about the presence and geometric relation with “codebook patches”. Local edge structure is the feature extraction which focuses on discontinuities present in the non linear pattern brightness function. It computes the value of normalized gradient orientation histogram (HOG) over local image blocks. They are used in (HOG), for example N.Dalal and B.Triggs [2005]. Initially, gradient orientation of histograms was computed to use on local image blocks on a single fixed scale. Compared with the fixed size blocks, the later research includes variable-size blocks by (Q.Zhu et al. [2006]) or uses covariance matrix descriptor which increases robustness toward light changes (O.Tuzel et al. [2007]).

Others have designed a local shape filters that incorporate the spatial configurations of salient edge like structure. On contrary, local shape filters when combine with the spatial configuration of the salient edge structures designed for the process of multi-scale feature. The Multi-scale features mainly based on horizontal as well as vertical interactions of the dominant gradient orientation. Multi-scale feature is of two types, “edgelets” and “shapelet”. For capturing edge structures, sets of edgelets features have been designed for the representation of local line and curve segments. shapelet features has been assembled from oriented gradient responses. The combination of spatial feature and time feature has been proposed for capturing human motion by (N.Dalal et al. [2006]). There are many research activities in these fields.

2.2.2 Shape-based Extraction Method

The following paragraphs provide literature, concepts and the techniques used to understand the shapes models in recent years. In computer vision, the shapes can be termed as a collection of all corresponding corner points and characteristic surface configuration of a contour. Why those shape models are used here? The reason is that the non linear pattern recognition is based on feature extraction is affected by surroundings image. The shape model which is used in the research work would not consider the large variations in patterns or images appearance due to lighting, clothing etc. This method has been used for detecting of images. In this thesis work has been done for one dimensional, three dimensional models are omitted.

For the first category, models the shape feature densely or globally over the patterns. There are various features which includes Harr wavelet features, histogram of oriented gradients. For global shape model

- It tolerates few degrees of occlusions.
- It captures articulations having large number of samples.

The global shape models requires training a single and strong classifiers, they are easier than part based approaches. In part based approach each part has to be trained separately and an addition classifier are used to train. But the advantage of this part based model it can detect quickly and accurately. Shape model approach can be shown as discrete or continuous.

2.2.3 Shape and texture models

Shape and texture model information is combined with parametric appearance model. The approach of building models involving a separate statistical model for intensity and shape variations. A linear model is built by shape normalizing for examples guided by sparse and dense correspondences. The fitting of the statistical models requires combination of shape and texture parameter by using methods like iterative error minimization schemes. To reduce the complexity of finding the parameter, the relationship of fitting error and the models associated with it can be learned from various examples as shown by Edwards et al. [1998].

2.3 Classifiers

Classifier plays an important role in pattern recognition. The goal of classifier is used to classify some characteristics to identify which classes the belong. The classifiers classify the desired patterns based on the value of characteristics. Their main motive is to determine a decision boundary between pattern classes. If the input patterns are non linear patterns then neural network can be implemented with the help of the linear functions in the feature space. In order to get good results of decision boundary, the best way is used to minimizing the error level that is reducing mean squared error. For the

nonlinear features multilayer neural networks has applied within the hidden network layer. In this way various responses are generated for one spatial scale.

In single spaced scale computations was replicated and it increases to four different scales. The desired response is given by doubling the standard deviations. After each complex cell pyramid structure map is shown. This architecture is used to combine the feature extraction and classify within a single model.

AdaBoost is used for feature selection of various patterns. The selected features are used to build strong classifiers which are combination of selected weak classifiers. Weights are set equally. Weak classifiers involving a threshold of a single feature. Adaboost is used separately in each layer to construct strong classifiers which is guided by the users or it depends on the user performance criteria. During training errors is estimated in each layers produced by the previous layers. Than cascaded of whole makes more complex detectors. This method can be used for obtaining high processing speed of the cascade method approach, usually a few feature evaluations in beginning of the cascade layers requires to reject quickly non desired patterns.

Support vector machine is another classifier used widely in this pattern detection task. It minimizes the edge of linear hyperplane and tries to find out best separation between the patterns. The application of Linear SVM (support vector machine) has been used with various features sets. There is another type of SVM which is non linear uses polynomial and radial basis function to map the sample to get the higher dimensional space. Hence the performance will get boost up. But the main disadvantage of this method is that it increases computation costs and memory.

SVM is a widely used method when we used it with HOG (histogram of oriented gradients). SVM constructs hyperplane in N-dimension. It separates the data in two categories. Mainly SVM model uses sigmoid or linear function. It is same as when it is implemented in two layers .When kernel function is used support vector machine can be applied to polynomial, weights of a network has been found out by quadratic programming problem. The aim of SVM modelling is to separates clusters of vectors.

The one category of the desired variable is on the one side and the other category of the vectors on another side. The vectors distribute on plane. The simplest application work in two dimensional spaces. A classification is performed, when the data is having two categories and these are two known and continuous values. The SVM analysis separates the cases based on their target values. Generally high dimensional and irregular vectors are present which cannot be divided by those SVM which are linear so the separation has been done with the help of the non linear curves.

If the clusters cannot be completely separated, then a third predictor variable is added, its value will be used in third dimension and points can be plotted in three dimension cube. Here points in 3-D can be separated by 2-D. According to this rule of SVM predictor value is added with the data points in an N-Dimensional space, and a (N-1) dimensional plane can separate them. The decision function is non linear function of the data that's the reason of non linear hyperplane is used for separation. A variety of kernels is used in many researchers' topics. A few kernels considered for having good performance in many applications for example linear, polynomial, and sigmoid

2.4 Volterra series

Volterra series is mainly done for the non linear systems detection. Volterra kernels are estimated with the help of the volterra kernels by using first and second order volterra series. As linear patterns are easily solved with the help of the matrix algebra and various transforms such as Laplace transform. But the main problem is that most systems are non linear so linearism is essential to get better response .The volterra series is the powerful tool for the detection of non linear patterns.

A volterra series is used to represent a non linear system having memory.

CHAPTER 3

3 Histogram of oriented gradients

In this chapter, the feature is extracted with the help of the histogram of oriented gradients (HOG).This method gives the normalized value of the histograms of gradients of the image. Pre-processing is done to reduce the effects of illumination after this gradient of image is computed.

After finding the gradient, the gradient vectors binned together according to the orientations. Concatenation of the all bins is then sending for normalization. Feature vector is extracted for each block. The following sections give the details of the steps carried out in HOG algorithm.

3.1 Preprocessing

Preprocessing is initially used to reduce the noise coming in the image. The reduction is compulsory otherwise it will give false output of the gradient vectors. Preprocessing is mainly done with the help of the filters by convolving the image with the filter noise will get reduced.

Multiplication of image with the filter can also be called as a kernel or mask. The multiplication or convolving the image is simply sliding the filter over the image. To reduce noise various filters are used such as Gaussian filters etc

3.2 Gradient computation

In order to get the accurate shape and appearance gradient computation is useful. This is the primary step in calculation feature extraction of the image. This function is based on calculating the derivatives of each function. $\partial f / \partial x$ And $\partial f / \partial y$ at each and every pixel coordinate is calculated.

To find the edge detection of the image magnitude is calculated. To find out the magnitude the following equation is used.

$$\text{Magnitude} = [Gx^2 + Gy^2] \qquad \text{Equation (3.1)}$$

Next task is to find out the direction of the vectors after gradient is calculated by

$\tan^{-1} \emptyset$ Where $\emptyset = \frac{Gy}{Gx}$ Equation (3.2)

For the derivative mask, the gradient computation is done with the help of the spatial filters. There are two types of derivative masks 3*3 Sobel operators and the other is 2*2 Roberts cross operators. The one dimensional masks represented by centred [-1 0 1] and uncentered [-1 1].Robert cross operator is shown below in figure (3.1)

-1	0
0	-1

0	-1
-1	0

Figure 3.1: Robert cross operators

There is another kind of operators known as sober operators for gradient estimation are shown below in figure 3.2.

-1	-2	-1
0	0	0
1	2	1

-1	0	1
-2	0	2
-1	0	1

Figure 3.2: Sober operations

Original image is shown in figure 3.3 (a) then gradients is estimated with the help of above expression in x direction as well as y direction. After finding the gradients in both

the directions then resultant magnitude will be calculated. Gradient in x as well y direction is shown in figure 3.3(b) and 3.3(c). Resultant magnitude is shown in

figure3.3 (d) and the orientation of gradient is calculated by trigonometry expressions explained above in fig3.3 (e)

Figure (3.3a)

Figure (3.3b)

Figure (3.3c)

Figure (3.3d)

Figure (3.3e)

The images come out after gradient which expresses the boundaries of the penguins.

3.3 Orientation binning

In the HOG analysis weighted magnitude and binning orientation plays a key role. In each pixel gradient of a magnitude and orientations is calculated. Each pixel having a weighted magnitude is represented in histogram channels (bins).The magnitudes are concatenated into bins. The region over this accumulation is said to be cell. The bins contain the angles from 0 degrees to 180 degrees. Chooses of good orientation produces better results or better detection of patterns. The performance can be increased by increasing the number of bins. For calculating the weight of each pixel gradient is calculated. Then all the pixels are concatenated and histogram is formed.

3.4 Normalization

Generally there are various types of variations in the images such as illumination, background and foreground contrast and brightness. It varies the gradient strength over a wide range. Without applying normalization result is not that much accurate. So the normalization is necessary to get desired result. Below figures shows the normalization result.

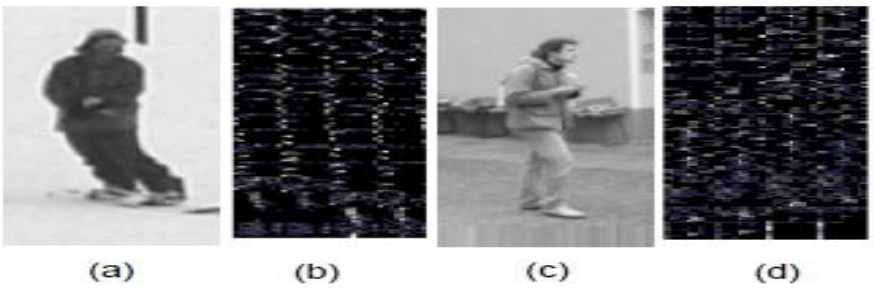


Figure 3.4: normalization

There are various methods to perform normalization techniques.

$$L2-norm: \quad \nu \rightarrow \nu/\sqrt{||\nu||_2^2+\epsilon^2}$$
$$L1-norm: \quad \nu \rightarrow \nu/(||\nu||_1+\epsilon)$$
$$L1-sqrt: \quad \nu \rightarrow \nu/\sqrt{||\nu||_1+\epsilon}$$

Equation (3.3)

By using these equations normalization is performed where v is the vector corresponding to the histogram of the block after combining $\dot{I}$ is a small constant. After calculation above equation we get the normalized featured vector of HOG. Another method for the normalization techniques can be achieved through Newton raphson iterative methods.

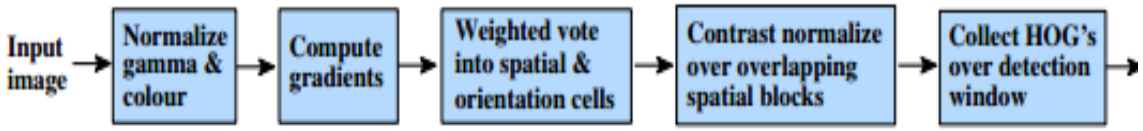


Figure (3.5): Flow chart representation of HOG

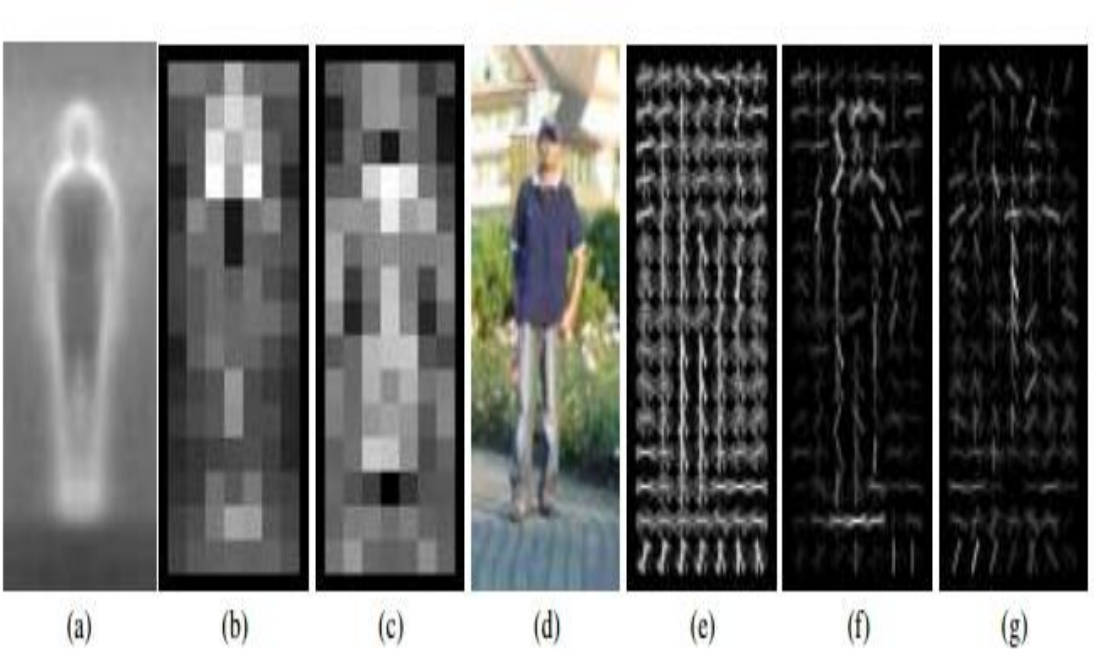


Figure (3.6): pictorial representation of HOG

CHAPTER 4

4 Volterra series

4.1 Volterra series

Volterra theory was developed by Vito volterra in 1881 .This theory is very essential in electrical or electronics engineering to find out the non linearity present in them so therefore can be used for modelling the signals having non linear behaviour. Volterra series is used to find out the non linearties present in input data. Volterra theory based on convolution of the signals which is often applied in LTI systems (Linear time invariant).This theory is based on any LTI systems which is time invariant can be modelled as an infinite sum of convolution of multidimensional integrals with increasing order. This is represented by series of integrals shown below and this series is said to be volterra series.

$$y(t) = \int_0^\infty h_1(\tau_1)x(t-\tau_1)d\tau_1 + \int_0^\infty\int_0^\infty h_2(\tau_1,\tau_2)x(t-\tau_1)x(t-\tau_2)d\tau_1 d\tau_2 + \ldots$$

$$+ \int_0^\infty \ldots \int_0^\infty h_n(\tau_1,\ldots,\tau_n)x(t-\tau_1)\ldots x(t-\tau_n)d\tau_1\ldots d\tau_n \,,$$

Equation (4.1)

Here x (t) represents the input data and y (t) represents the output system response. In this equation each integrals consists of volterra kernels. If only h1 is taken then the volterra kernel is linear and if all other h is taken then it will give non linear volterra kernels. This kernel represents the behavior of the system. Knowledge of these kernels tells the system response of any input. In the first term there are linear convolution integrals.

For the third order system, the first order gives the description about the mean of the input system response. All other orders which higher than the first tells about the variation around the first response or the variations about the mean calculated by the first response. If the input data is weekly non linear then the system response can be calculated easily by truncated volterra series. Weekly non linear means volterra series which is having order of 2 or 3.

All other higher order terms is tending to be zero. Volterra theory useful in areas where non linearity is more.

4.2 Volterra kernels

Volterra kernels are the important parameter in the volterra series just like a backbone of the body. All the important information is contained by the kernels any arbitrary input is given which predict system response. Volterra kernel is of two types linear and non linear basically depends on input data. The first order kernel h represents impulse response of the system. First order kernel gives the accurate system response for linear systems. Second order kernels is basically a two dimensional function of time. It represents the system response and it separates unit impulses shown at varying points in time.

Therefore the kernel represents the function of time and time lag. Similarly in kernels having three order degrees represents three dimensional functions of time and two time lags at distinct points. Three unit impulses are applied at three distinct points. These time lags in the non linear kernels represent the previous response of the systems.

Volterra series can be modelled in many ways by reordering in the equation. By doing this more than one kernel is used for the response of the system. Three different forms of kernels are used such as triangular, symmetric and regular. Symmetric kernels are mainly used.

$$h_2\,(T_1\,, T_2) = h_2(T_2, T_1)$$

Equation (4.2)

4.3 Memory functions

Volterra kernel represents the memory of the system. They measures relative influence of the past inputs on the current response. This memory is used to measure the non linearity because of this it is said to be as systems having memory. In the linear system memory is

defined by the impulse response of the system. After this volterra series expand for the non linearity with multidimensional impulse response.

4.4 Requirements of volterra series

Three conditions are necessary while defining volterra series:

- Volterra kernels input and output function must be real valued functions all over time.
- System should be causal.
- System should be time invariant.

For finding the volterra series volterra kernels input and output function should be real valued functions all over the time. The system used should be causal system means a system which does-not predict the future information and the last is the system should be time invariant this means it does-not get affected by time lag. Response should be same.

4.5 Volterra kernel identification method

The main task in the volterra series is to find out the kernels identification. As kernels is the basic necessity in the volterra series or to find out the system response. Volterra series can estimate both time and frequency response of the system. Mainly the work is done in the frequency response. Volterra kernels can be found out from the non linear identical responses from the experimental data.

CHAPTER 5

5 Design methodology used in detection and recognition of non linear patterns

In this thesis non linear patterns are detected and recognize with the help of the HOG. Suppose if there is a noise coming in signal, detection can easily be done by using this algorithm. Firstly a desired pattern is chosen from the whole patterns. For example, to detect the disturbance in this figure shown below.

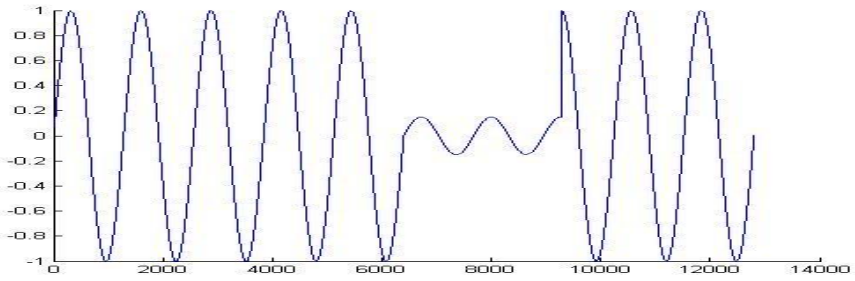


Figure (5.1): Input signal for detection of pattern

Apply HOG in this signal after applying HOG it will look like shown below.

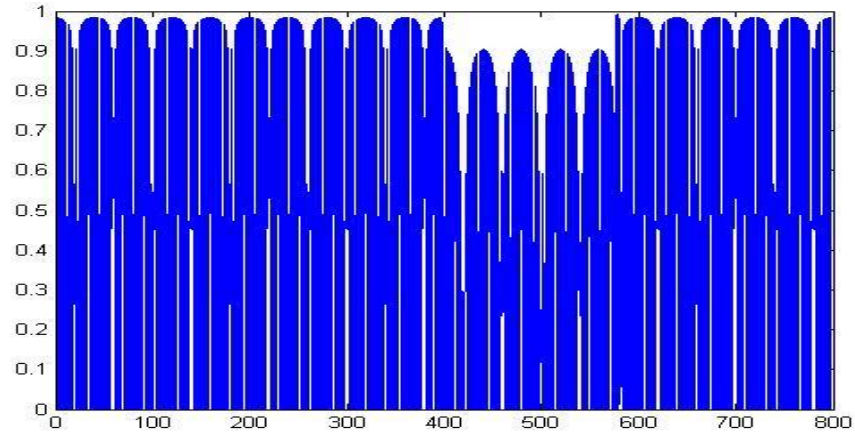


Figure (5.2): Input signal after applying HOG for detection of pattern

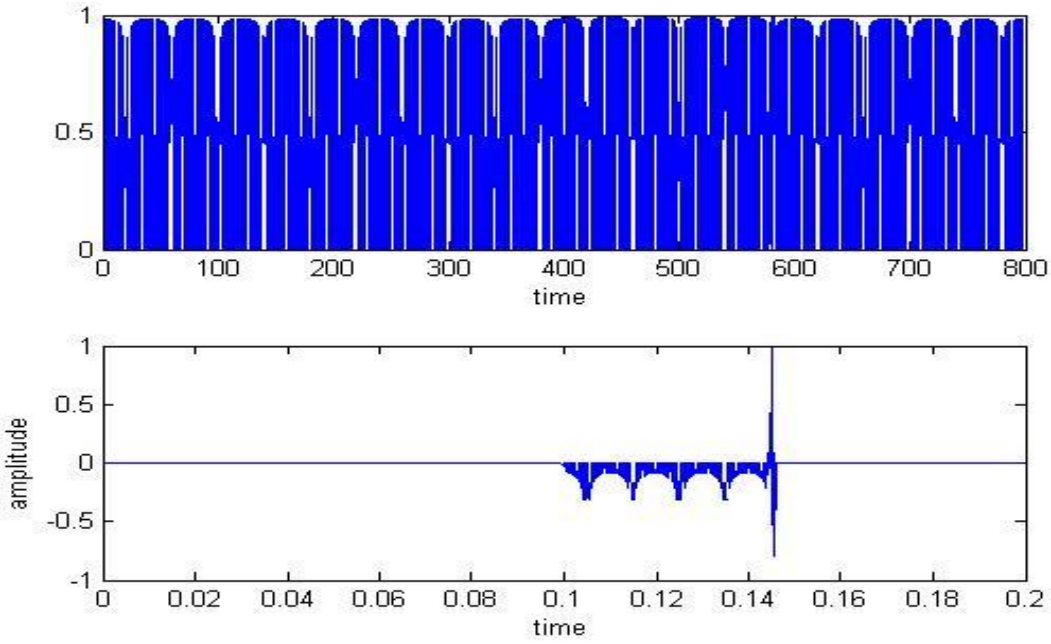


Figure (5.3): Detection of disturbances in input pattern

Comparison with signal after apply HOG and after detection. Accurate result is shown above and below figure after applying HOG.

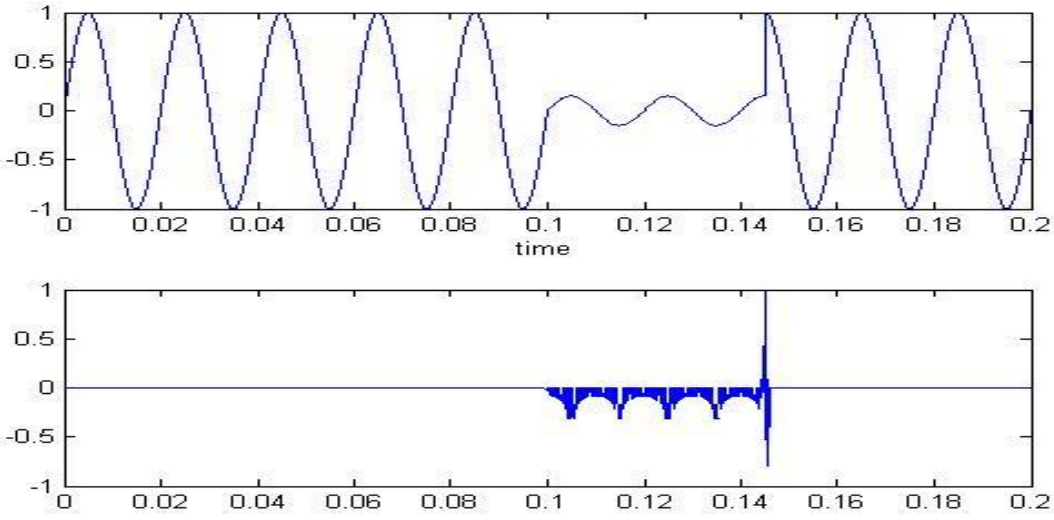


Figure (5.4): Detection and comparison of input signal and the output signal

By this way input pattern is detected at fixed time interval and output is good as comparison to all other detectors. This application of non linear pattern detection and recognition can be used in the detection of power quality events. As detection is very much necessary in electrical industries.

CHAPTER 6

6 Design methodology used in detection and recognition of non linear patterns in power quality

In this thesis a new method is used to detect the power quality events in time domain. Earlier various methods are used to detect the disturbances caused by applying non linear loads in the electrical signals. Power quality events like sag, interruptions, swell, harmonic, transient, notch, flicker, combination of sag and impulse, swell with interruptions, notches, spikes, spikes with impulse, etc signals are generated and it is very important to detect these signals. In this paper histogram of oriented gradients (HOG) method is used to detect the disturbances. In this method there is a less computation as comparison with wavelet transform, H-transform and Hilbert transform. Detection with the help of HOG gives better and accurate result in time domain with faster response.

6.1 Introduction

Detection and monitoring the power quality is a vital for recognizing the causes and various characteristics in power quality events causes due to increase in non linear electrical loads in industries, commercial as well as domestic applications. Distorted voltage waveform mainly depends on the current drawn by the non linear loads, switching activities etc. Distortion in voltage waveform causes odd behavior in control devices such as programmable logic controllers (PLC), electric drives, or in industries due to equipment breakdown in production line.

This problem can be eradicated by recording and analysis of power quality events and its statistical information. Accurate detection is necessary and useful for electrical engineer in solving the issues related to power quality events. With the incoming of signal processing researchers in power quality applications, they developed the algorithms based on the detection of power quality events for recording and analysis.

Earlier various methods are used for the detection of power quality events such as Fourier transforms (FT). Mostly the power quality disturbances are non stationary as well as non

periodic in nature and this can-not be possible by using Fourier transform. Limitation is mainly due to quick variations (transient phenomenon) in incoming signals, which is difficult to observe visually by this method. Short-time Fourier transform (STFT) is also used for the detection of these non linear patterns.

This gives information in time domain and frequency domain. In this method two window functions is used to obtain good resolution and it increases the operations. This is the major drawback of this method. To overcome the limitations wavelet transform is used. In this multi resolutions are decomposed with the help of low pass and high pass filter.

This method gives better result as compare with the above methods but this method is also not that much efficient it also has some limitations such as incoming of low frequency components give low resolution, noise sensitivity, decomposing of frequency bands are fixed. S-transform is better and it is an extension of the WT (wavelet transform).It provides superior resolution. Various other methods are used such as stock well transform (ST), Time-Time transform, Hilbert transform, Kalmann filters etc are used for the detection of power quality events, which are non stationary signals.

A simple technique used for detection of events based on histogram of oriented gradient (HOG) is described in this paper. This method easily detects the events in the signal with faster rate with good accuracy and fewer computations, so it can be efficiently implemented as compare to the various time frequency analysis techniques. This method is capable to perform all real time power quality events such as voltage sag, voltage transient, etc. Earlier HOG is used for the detection of patterns in an image. In this thesis HOG is used to detect variations in the non stationary events

6.2 Power quality event detection

This proposed method for power quality event detection has four parts: preprocessing, gradient computation and binning orientation.

In this paper different types of events are considered as follows: voltage sag, voltage swell, voltage flicker, voltage interruptions, voltage swell with harmonics, sag with

harmonics, sag with impulse, swell with impulse and various other events. First, Preprocessing is done for these incoming events to reduce the noise with the help of the various filters,

After preprocessing gradient is computed for each pixel similarly after calculating gradient orientation can be find out.

After finding the orientation binning process is used and last is normalization method. In this thesis detection is done in MATLAB.

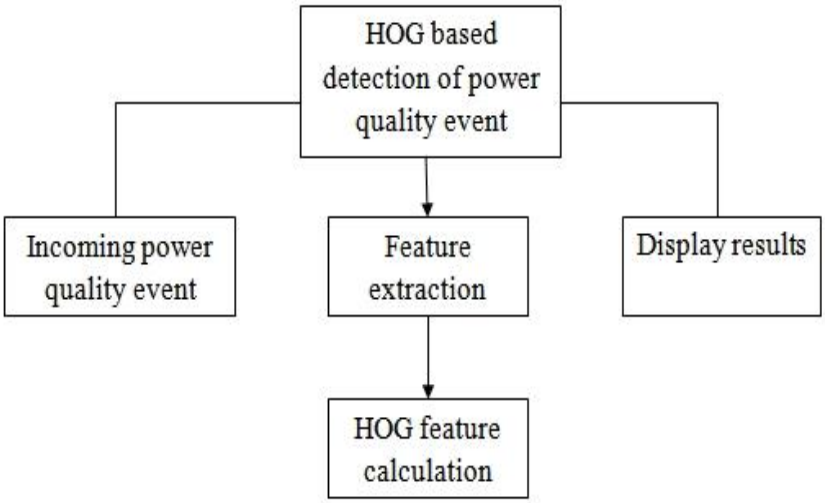


Figure (6.1) pictorial representation for feature based detection of events

In this above pictorial representation power signal is incoming and then feature is extracted with the help of the HOG by using preprocessing after that gradient is calculated and then binning process followed by normalization.

6.3 Algorithm of power quality event detection

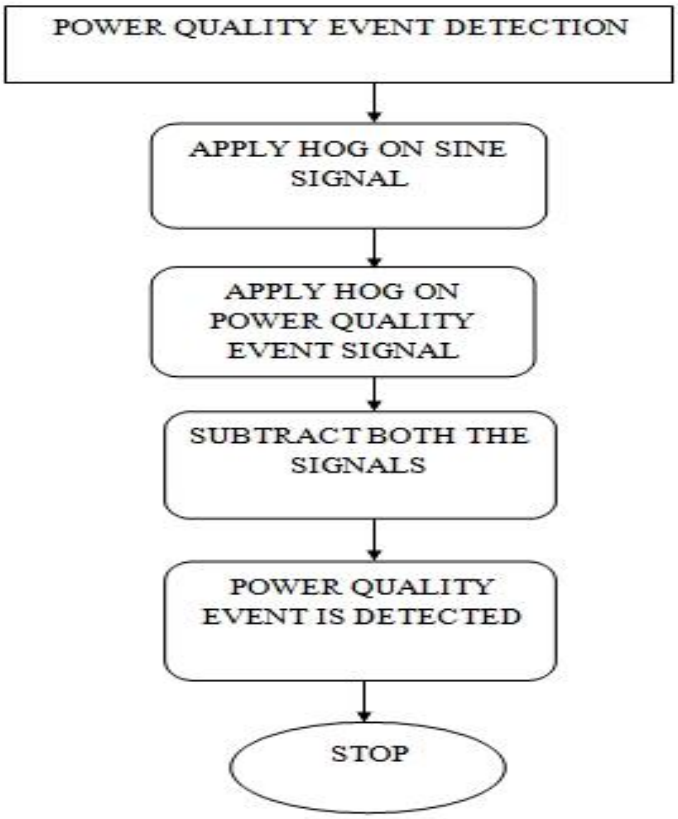


Figure (6.2) Algorithm representation of power quality event detection

In this above algorithm, first the HOG is applied on pure sine wave and then HOG is applied on incoming power quality event Then after subtracting both HOG event is detected and it can be further classified with the help of any other classifiers such as SVM, neural network classifier, etc. This algorithm is applicable for all the events whether sag, swell combination of sag and swell, interruptions, impulse with interruptions, flicker, sag with harmonics, swell with harmonics etc. This detection is shown with the help of MATLAB.

6.4 Various power quality events

PQ Disturbance	Model	Parameter
Normal	$f(t) = A\sin(\omega t)$	Frequency = 50Hz A=1
Sag	$f(t) = A(1 - a(u(t - t_1) - u(t - t_2)))\sin(\omega t)$	$0.1 \le a \le 0.9$; $T \le t_2 - t_1 \le 9T$
Swell	$f(t) = A(1 + a(u(t - t_1) - u(t - t_2)))\sin(\omega t)$	$0.1 \le a \le 0.8$; $T \le t_2 - t_1 \le 9T$
Interruption	$f(t) = A(1 - a(t\sin(\omega t)$	$0.1 \le a \le 0.9$; $T \le t_2 - t_1 \le 9T$
Flicker	$f(t) = A(1 + \alpha_f \sin(\beta_f \omega t))\sin(\omega t)$	$\alpha_f = 0.1 - 0.2$ $\beta_f = 5 - 10\text{Hz}$
Harmonic	$f(t) = A(\alpha_1 . \sin(\omega t) + \alpha_3 \sin(3\omega t) + \alpha_5 . \sin(5\omega t) + \alpha_7 . \sin(7\omega t))$	$0.05 \le \alpha_3 \le 0.15$ $0.05 \le \alpha_5 \le 0.15$ $0.05 \le \alpha_7 \le 0.15$ $\sum \alpha_i^2 = 1$
Transient	$f(t) = A\sin(\omega t) + \alpha_{OSC} . \exp\left(-\left(\frac{t - t_1}{T_{OSC}}\right)\right) . \sin \omega_{nosc}(t - t_1))$	$T_{osc} = 0.008 - 0.04s$ $\omega_{nosc} = 100 - 400\text{Hz}$
Swell with Harmonic	$f(t) = A\left(1 + \alpha(u(t - t_1) - u(t - t_2))\right) . \alpha_1 \sin(\omega t) + \alpha_3 . \sin(3\,\omega t) + \alpha_5 . \sin(5\omega t) + \alpha_7 . \sin(7\omega t))$	$0.1 \le \alpha \le 0.8$ $T \le t_2 - t_1 \le 9T$ $0.05 \le \alpha_i \le 0.15$ $\sum \alpha_i^2 = 1$
Sag with harmonics	$f(t) = A(1 - a(u(t - t_1) - u(t - t_2)))$- $A(\alpha_1 . \sin(\omega t) + \alpha_3 \sin(3\omega t) + \alpha_5 . \sin(5\omega t) + \alpha_7 . \sin(7\omega t))$	$0.1 \le a \le 0.9$; $T \le t_2 - t_1 \le 9T$ $0.05 \le \alpha_3 \le 0.15$ $0.05 \le \alpha_5 \le 0.15$ $0.05 \le \alpha_7 \le 0.15$ $\sum \alpha_i^2 = 1$
Flicker with harmonics	$f(t) = A(1 + \alpha_f \sin(\beta_f \omega t))\sin(\omega t) . A(\alpha_1 . \sin(\omega t) + \alpha_3 \sin(3\omega t) + \alpha_5 . \sin(5\omega t) + \alpha_7 . \sin(7\omega t))$	$\alpha_f = 0.1 - 0.2$ $\beta_f = 5 - 10\text{Hz}$ $0.05 \le \alpha_3 \le 0.15$ $0.05 \le \alpha_5 \le 0.15$ $0.05 \le \alpha_7 \le 0.15$ $\sum \alpha_i^2 = 1$
Interruption with harmonics	$f(t) = A(1 - a(t\sin(\omega t) * A(\alpha_1 . \sin(\omega t) + \alpha_3 \sin(3\omega t) + \alpha_5 . \sin(5\omega t) + \alpha_7 . \sin(7\omega t))$	$0.1 \le a \le 0.9$; $T \le t_2 - t_1 \le 9T$ $0.05 \le \alpha_3 \le 0.15$ $0.05 \le \alpha_5 \le 0.15$ $0.05 \le \alpha_7 \le 0.15$ $\sum \alpha_i^2 = 1$
Notch	$f(t) = \sin(\omega t) - \text{sign}(\sin(\omega t)) * \sum k * (u(t - (t_1 + 0.02n))$- $(u(t - (t_2 - 0.02n)))$	$0.1 \le k \le 0.4, 0 \le t_1$ $t_2 \le 0.5T$, $0.01T \le t_2 - t_1 \le 0.05T$
spikes	$f(t) = \sin(\omega t) + \text{sign}(\sin(\omega t)) * \sum k * (u(t - (t_1 + 0.02n))$- $(u(t - (t_2 - 0.02n)))$	$0.1 \le k \le 0.4, 0 \le t_1$ $t_2 \le 0.5T$, $0.01T \le t_2 - t_1 \le 0.05T$

Table (6.1) List of power quality event

6.5 Results to detect power quality events

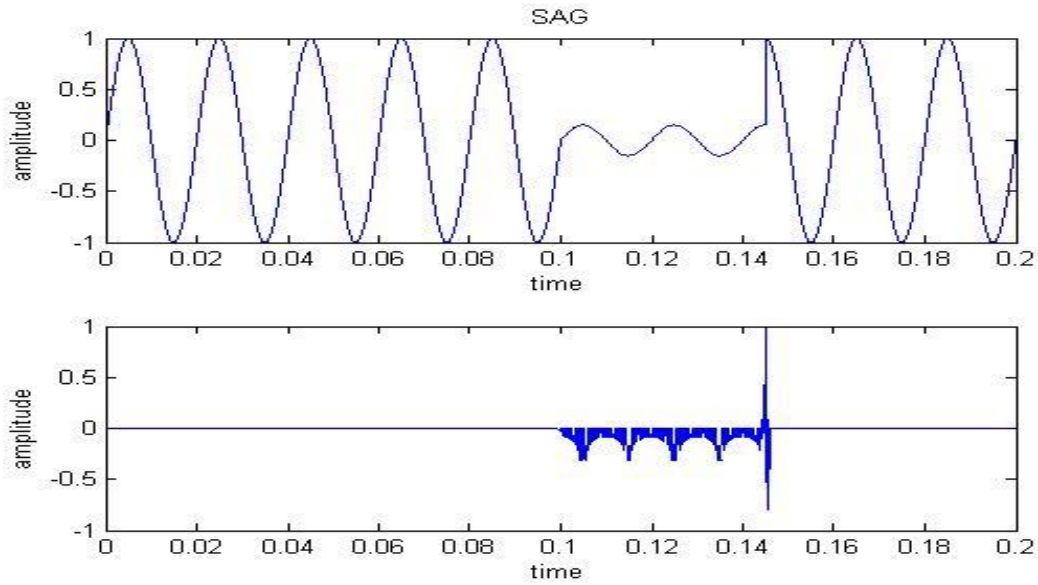


Figure (6.3): Detect the disturbance in the incoming signal

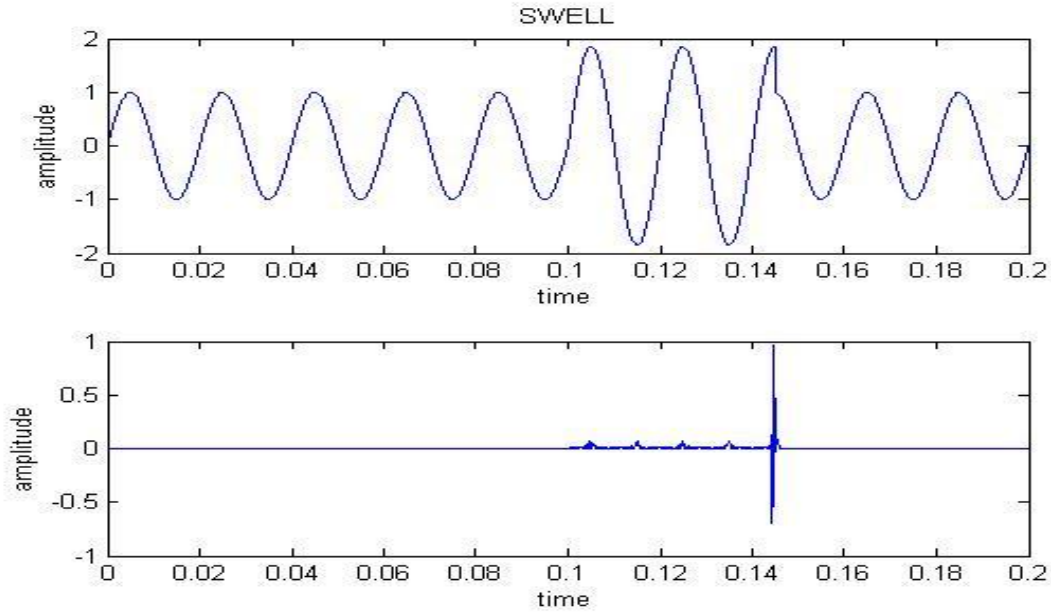
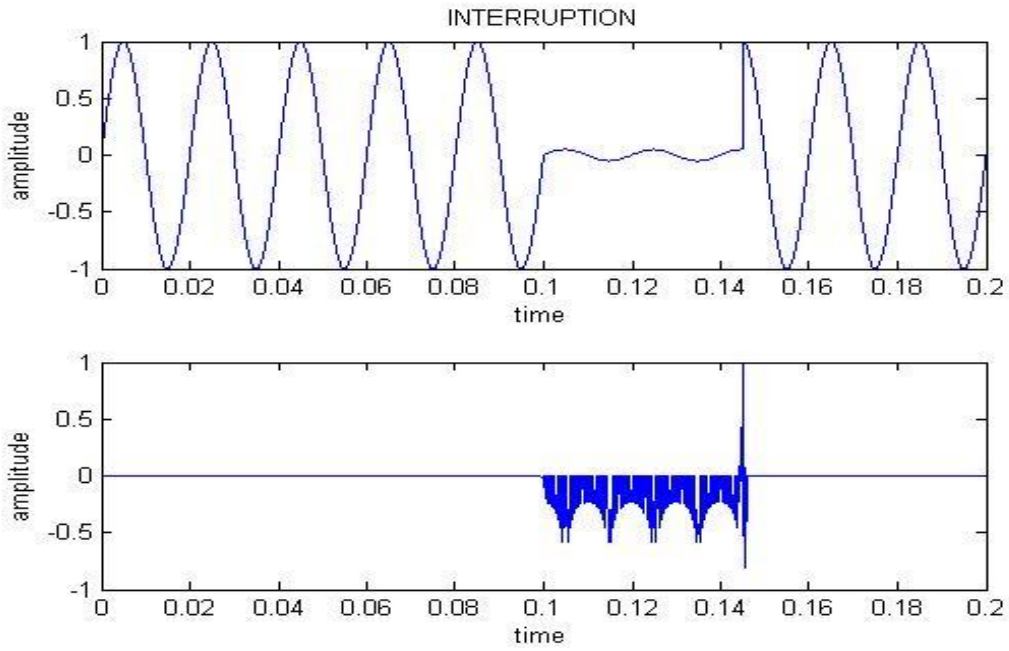


Figure (6.4): Detect the disturbance in the incoming signal at that particular time

As shown in above figures there are various events which detect the noise or disturbance in the incoming signals. It is useful in many purposes because detection is very much essential in the industries. This can be used to detect defects in clothes pieces, where ever there is any defect in clothes it will check it out as it is difficult for a person to give higher accuracy. So with the help of this application this can be used in cotton mills etc.



There is another example shown above which detect the disturbances after detecting the disturbances recognition is very much easier and simpler. This can also help sometimes in calculating approximate time at which detection occurs. After calculating approximate time the person who is looking the defect get to know easily at which time the defect will occur and can be rectify easily.

CHAPTER 7

7 Conclusion and future work

7.1 Conclusion

This era is an era of intelligence computations. The world is rapidly going towards intelligent and accurate systems. Therefore to get such systems where there is more accuracy detection is necessary if the detection used in this work is done then result would be better than before.

Earlier many researches are done to detect the one dimensional patterns with the help of S-Transform, Wavelet Transform, Short time Fourier transform, and many more but as seen all these HOG gives best results among them.

Therefore, in this thesis we had used HOG as a detector for detecting non linear patterns

7.2 Future Work

In this thesis HOG is used for detecting non linear patterns, many other detectors can also be used for detection such as volterra series. Volterra series detects whole pattern and then HOG can be applied which will give better performance than before work.

This can be used further in detecting:

- Cloth mills
- More non linear pattern detection
- In electronics industry

8 List of publications

[1] Rajiv Kapoor, Gunjan Rajput, “generation of electrical energies from ravaged sources of energy” presented in international journal organised by MECIT on 17 may 2105.

[2]Rajiv Kapoor, Gunjan Rajput, “Logic gates realization using spiking neural network and Vedic maths-A comprehensive study” presented in international journal organised by MECIT on 17 may 2105.

BIBILOGRAPHY

[1] https://en.wikipedia.org/wiki/Histogram_of_oriented_gradients

[2] http://users.utcluj.ro/~raluca/prs/prs_lab_05e.pdf

[3]https://www.scss.tcd.ie/Gerard.Lacey/Gerard_Lacey_Homepage/CS4053_Course_files/Lecture%20009%20HOG-HOF.pdf

[4] http://vis.uky.edu/~dnister/Teaching/CS684Fall2005/HOG.pdf

[5] Miller, R. K., *Nonlinear Volterra Integral Equations*, W. A. Benjamin, Inc., Philippines, 1971.

[6]http://luthuli.cs.uiuc.edu/~daf/courses/ComputerVisionTutorial2012/EdgesOrientationHOGSIFT-2012.pdf

[7] http://bengal.missouri.edu/~duanye/cs8690/lecture-notes/HoG.pdf

[8] https://en.wikipedia.org/wiki/Volterra_series

[9] http://www.scholarpedia.org/article/Volterra_and_Wiener_series

[10]http://ir.nmu.org.ua/bitstream/handle/123456789/114414/b5f16d4f2835d2ef315c26d36fb223ef.pdf?sequence=1

[11] N.Wiener, *Nonlinear Problems in Random Theory*, MIT Press, 1966.

[12] Reisenthel, P. H., "Prediction of Unsteady Aerodynamic Forces Via Nonlinear Kernel Identification," Langley International Forum on Aeroelasticity and Structural Dynamics, Williamsburg, VA, June 1999

[13] Rugh, W. J., *Nonlinear System Theory – The Volterra / Wiener Approach*, The Johns Hopkins University Press, Baltimore, 1981.

[14] Schetzen, M., *The Volterra and Wiener Theories of Nonlinear Systems*, John Wiley & Sons, New York, 1980.

[15] Vidyasagar, M., *Nonlinear Systems Analysis*, Prentice-Hall, Inc., New Jersey, 1978.

[16] The 6th International Power Electronics Drive Systems and Technologies Conference (PEDSTC2015) 3-4 February 2015, Shahid Beheshti University, Tehran, Iran

[17] 2014 IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES)

[18] 978-1-4244-8782-0/11/$26.00 ©2011 IEEE