Remote Monitoring Weaving Machine

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Summary

This project was done with an external company Xiros plc and the overall aim of the project was to develop an automated system to monitor the product quality of weaving machine. Xiros is a leading medical device company dedicated to the design and manufacture of quality products. Previously, they have been monitoring the quality parameters by installing an Axis Camera on the site location and manually observing the product images from remote location. They wanted an automated system to monitor the product continuously and inform the user automatically via Email/SMS if the quality parameters fall out of standards.

Considering all the requirements, the final product involved a dedicated system connected with Local Area Network and having access to the axis camera. This remote monitoring system has been designed, implemented, tested and evaluated on various product images under different lighting conditions with a satisfying outcome. The project faced a number of technical and non-technical challenges. By the end of project, all the challenges had been overcame successfully and all of the project objectives had been met in a high standard.

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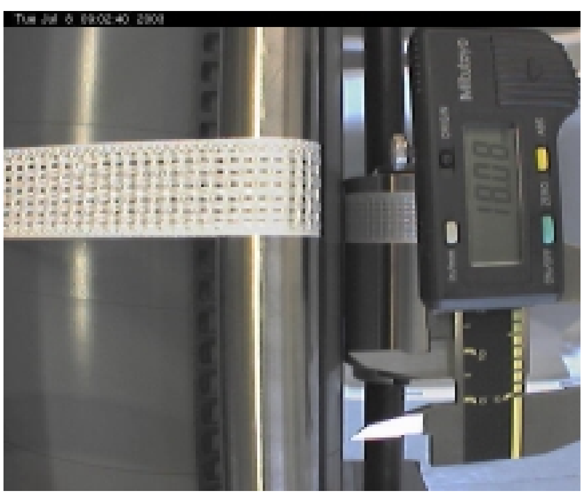
Contents

Chapter 1 Introduction

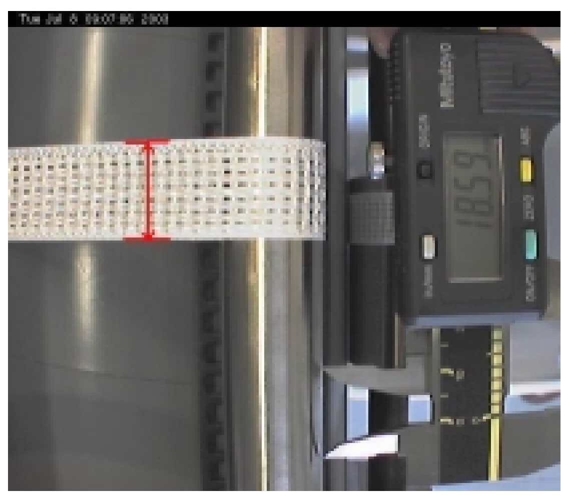
This report describes the building of a system for Xiros plc to automate monitoring of weaving machine product in respect of quality control. The final product involved a dedicated application that is supposed to run while the production is going on. The system needs access to the axis camera to capture product images consistently and also needs LAN to inform user via Email.

1.1 External Company and the Problem Statement

Xiros is a leading medical device company dedicated to the design and manufacture of quality products. To monitor the product quality, they had installed an Axis Camera on the weaving machine and the images *(shown in Fig 1.1)* captured were monitored manually from a remote location or office. This needed a dedicated manual effort to observe the images continuously and take action if the product quality does not seem according to standards. This way of monitoring was inefficient and there were more chances of error due to manual observation. Moreover it was not easy to find the defects in the product quality manually. One of the major defects, they were looking for, was width of the product i.e. white bandage tape. *Figure 1.1 (a)* shows the ideal width of tape and *(b)* More width (defected product).



(a) Ideal width of Weaving Product



(b) Defected Product with more width

Figure 1.1 White Bandage Tape

1.2 Aims and Objectives

The aim of this project was to build an automated system to monitor the product quality to remove the current manual processes. It should also inform the user automatically via Email/SMS if the quality parameters fall out of standards.

Overall Objectives:

- To research in computer vision techniques to process the images and monitor quality parameters such as overall appearance and dimensions of the product.
- To send immediate notification to operators at the main site, if there is a failure (i.e. product quality not according to the standards).
- Evaluation of the system

Minimum Requirements:

- The minimum requirements are to monitor the dimensions (width) of the bandage cloth *(shown in fig 1.1)* and if it falls outside the standards, i.e. if the width is more than the required parameter, system should inform the operator either by SMS or by email.

1.3 Key Challenges

There were many technical as well as non-technical challenges to be faced in order to make this project a success. Technical challenges include

- how to build a dedicated monitoring system for the product quality,
- the system should be robust enough to work in all environments and conditions,
- there should be no dependency of location or lighting assumptions while system is running,
- how to measure the width dynamically and if error occurs then how to send the notification immediately.

There were different mechanisms available to solve these types of problem Deciding which technology would be applied for this specific problem was another challenge to the project. Apart from these technical challenges, non-technical challenges also existed. These include maintaining proper coordination with the external company and work according client requirements to provide customer satisfaction. The limited time constraint to solve the problem was also one of the major challenges.

1.4 Report Organisation

While developing this system, several stages have been passed through. This report is designed to cover all of these stages and is structured into three parts:

First: The first part shows problem statement and background research.

- Chapter 1 gives the introduction and explains the problem statement;
- Chapter 2 studies the literature review and background research for this project;

Second: The second part explains system's development process.

- Chapter 3 explains the system design and analysis;
- Chapter 4 discusses the system implementation;
- Chapter 5 shows the system testing and evaluation.

Third: The last is the conclusion part.

- Chapter 6 discusses the limitations and future improvements of this system;
- Chapter 7 concludes the project.

Chapter 2 Background Research and Technologies Review

Being a development project, the major background study comprised of deciding the tools and techniques to be used for building the system and deciding the steps in advance to solve the problem. This chapter describes all research methods and background study performed at various stages of development process.

2.1 Image Processing

First and foremost aim was to extract the region of interest (i.e. strip of cloth) from the whole image and then comes, further steps for measuring the width and finding the error. A literature and technologies review on the Image Processing was conducted to search the relevant algorithms. Number of algorithms and techniques were available to perform the task.

2.1.1 Hough Transform

Rudolf K. Bock [1] explained *"The Hough transform is a standard tool in image analysis that allows recognition of global patterns in an image space by recognition of local patterns (ideally a point) in a transformed parameter space."* The basic idea of this technique is to find curves like straight lines, polynomials, circles, etc., in a suitable parameter space. It is useful when patterns are digitised and/or the pictures are noisy. Its main use is in two dimensions to find, e.g. straight lines.

This approach can be applied in this concern, for looking two boundaries of the tape i.e. the upper and the lower one. Once these two straight lines are extracted, further width can be measured in between these lines. A track of width can be kept on real time over number of frames per period of time.

Problems anticipated in this approach:

- there are more than one straight lines in the image, so finding the required one is crucial;

- the (cross) pattern of cloth may also be a difficulty in finding straight lines
- and the border of the cloth is not exactly a straight line, so might not be a suitable approach in this particular case.

2.1.2 Background Subtraction

According to Z. Duric, H. Wechsler's paper [2], "*Background subtraction is performed by subtracting the colour channels and edge channels separately and then combining the results*". There are majorly teo types of background subtaction i.e. Colour based and Edge based.

Colour Based Subtraction

In the color subtraction phase, the current video frame is subtracted from the stored mean image. This is done for each color channel, which results in three different images. Next, a normalization step is performed for every channel using two thresholds, derived from the standard deviation images. Since change in any color channel can be an indicator of a foreground region, a maximum of the three images is taken. The higher the value of this maximum at a pixel, the more probable is that the pixel belongs to the foreground.

Edge Based Subtraction

In the edge subtraction phase, changes in both edges magnitude and edge direction are taken into account. Edges are often classified as foreground edges, occluded background edges, and background edges. Even in a static scene, changes occur frame-to-frame due to noise, camera jitter, and varying illumination. These factors are quite difficult to control. "*Therefore, to preserve the validity of our background model one has to update the mean images continuously*" [2].

If this approach were applied in this concern, then a background image (without white cloth strip) and a foreground image (with white cloth strip) would be needed. Once both of these images are available, the width between the boundaries of the cloth, i.e. the upper one and the lower one, could be measured and passed as parameter for further processing of the system.

Problems anticipated in this approach are:

- Variation in lighting conditions could be a crucial in implementing this approach.
- the (cross) pattern of cloth may also be a difficulty and has to be handled (by taking low resolution images)

2.1.3 Thresholding

Thresholding is a process of segmenting image into two levels. For example, given a grey level image, thresholding:

$$g(i,j) = \begin{cases} 1 & f(i,j) \geq T \\ 0 & f(i,j) < T \end{cases}$$

where **g(i, j)** is the pixel grey level at the position of **(i, j)** of the output image;
f(i, j) is the pixel grey level at the position of (i, j) of the input image;
T is grey level threshold.

Thresholding is very useful tool in image pre-processing and image sub-division. In the concerned case, white (bright) tape region can be extracted from the captured images due to significant change in contrast in-between background and the bright tape. Hence, this approach seemed more relevant and simple to perform the task, but there were some challenges to be faced:

- Grey level of tape and background vary over a period of time;
- Grey level of tape and background may become similar;
- Objects other than tape within the image have similar or same grey level.

Because of the above ambiguities, determining a single global threshold is the crucial problem. To overcome this problem, research has been done on the available algorithms to find adaptive threshold and variable threshold, that is, to divide the image into sub-images and apply different threshold on each sub-image. But it also needs some prior knowledge about the image, which is again not feasible here in this case.

Automated Methods for Finding Thresholds

To set a global threshold or to adapt a local threshold to an area, grey level histogram can be analysed to find two or more distinct modes—one for the foreground and one for the background. The histogram is a probability distribution:

$$p(g) = n_g/n$$

that is, the number of pixels n_g having the greyscale intensity g as a fraction of the total number of pixels n. There have been several methods researched to find adaptive threshold on the basis of above histogram:

- ***Known Distribution***

  This is based on the convention, that the concerned object is brighter than the background and occupies a certain fraction 1/p of the image, and the threshold can be set the by simply finding the intensity level such that the desired percentage of the image pixels are below this value. This is extracted from the cumulative histogram:

$$c(g) = \sum_{0}^{g} p(g)$$

  Set the threshold T such that $c(T) = 1/p$ or, if dark objects on a light background are of prime concern, then, $c(T) = 1 - 1/p$. This approach is more suitable due to the fact that the tape is brighter than the background *(see fig 1.1)***.**

- ***Finding Peaks and Valleys***

  There is one simple way to find a suitable threshold is to find each of the modes (local maxima) and then find the valley (minimum) between them. This method of thresholding is simple, but there are two main problems with it:

  a) The histogram may be noisy, thus causing many local minima and maxima. To overcome this, the histogram is usually smoothed before trying to find separate modes.

  b) The sum of two separate distributions, each with their own mode, may not produce a distribution with two distinct modes.

2.1.4 Edge-based Segmentation

Edge-based segmentation is one of the major methods to segment the image, which rely on edges found in an image by edge detecting operators such as Roberts, Sobel, and Laplacian. Once these operators have been applied on image, this results in edge marks on the image at the discontinuities in grey level, colour, texture, etc. Then the following processing steps combine edges into edge chains that correspond with borders in the image. This approach needs additional knowledge, about the segmented object, in advance.

2.1.5 Region-based Segmentation

Region Growing is one of the most popular methods of segmenting images. The logic behind this approach is segmenting the image on the basis of homogenous regions present in the image. Here homogeneous refers to all the pixels within the region containing similar grey levels. It may be started with a single or multiple pixel seeds. The connectivity of the pixel usually has two kinds: 4-connectivity and 8-connectivity. In the former one, the up, down, left and right pixels to the current pixel is examined. In the latter one, besides the above pixels, the 4 diagonal pixels are also added. If one meets the homogeneous criterion, it is added to the region. The region expands by absorbing more neighbour pixels and it stops growing until no more neighbour pixels satisfy the homogeneous criterion. Region growing techniques are generally better in noisy images where edges are extremely difficult to detect than edge-based techniques.

In the concerned case, again the (cross) pattern of the cloth is major obstacle in applying region-growing approach because it does not allow the region to grow within the whole tape area and there are chances of not image not being segmented properly.

2.2 Messaging via E-mail/SMS

Once the image is segmented and the variations in tape width are found, next step is to send an immediate notification to operators at the main site either by email or by SMS. Research shows that there are various methods/plug-in available to fire an email or SMS programmatically to a specific destination. The selection of the method/plug-in depends on the platform and the programming language used. Some of the existing tools are:

2.2.1 Email

The JavaMailTM API, a Java Standard Extension, is one of the most common applications programming interface library. It provides a strictly protocol-independent method of sending and receiving email. Java Mail's layered architecture allows the use of various message access protocols, like POP3 and IMAP, and message transfer protocols like SMTP. JavaMail interacts with message content through the JavaBeans Activation Framework (JAF). JAF provides a uniform way of determining message type and encapsulating it [3]. This library provides methods to send messages along with attachments using SMTP server. Sending attachment is a handy feature as when the product quality is not up to standards, a snapshot of the current frame might be required as an attachment file.

2.2.2 SMS

There are two major ways of firing SMS programmatically, one is by using third party APIs and other is using a dedicated mobile to the system. Both of these ways incur cost in their own ways. Using third party API costs per message basis or rental charges for using their libraries. Sending messages via dedicated mobile costs per message and depends on the network charges.

SMS Library (API) for java allows to send SMS (GSM) from the Java platform. It gives full control over the SMS including the UDH field so that EMS messages and images can be created and sent. It provides a pluggable transport layer that allows it to be used with a range of different SMS servers. It also gives full control to all parts of the SMS (UDH, UD, DCS...). This makes it possible to create all types of SMS messages, including picture messages and WAP push messages [4].

Chapter 3 System Analysis and Design

This chapter illustrates the software development process model utilized in the project. Later, it discusses the architectural design of the system, which has been considered as the basis for further implementation.

3.1 Software Development Life cycle

This section focuses on the waterfall life [5] cycle, which can be considered as representations of traditional model of software development. Waterfall model is a well-defined development process in which one phase has to be finished before the next phase.

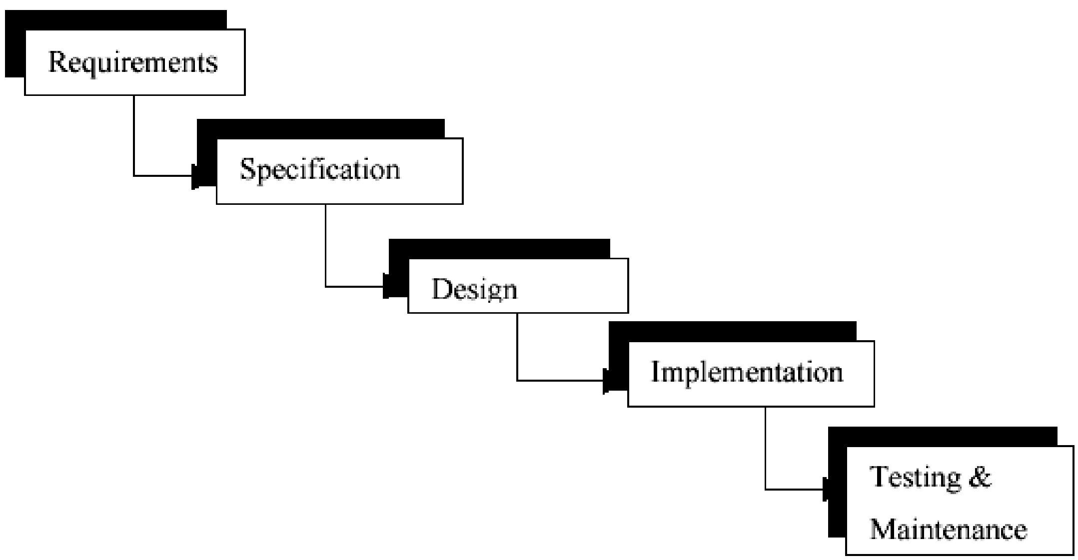


Figure 3.1 - Waterfall life cycle model

This model can be used if the requirements are well understood and defined. It enables an individual to break a large complicated project into small component of steps. In this approach, development proceeds from requirements analysis through specification, design, implementation, testing and maintenance *(see Figure 3.1).* The linear sequential model is designed for straight-line development. This approach assumes that a complete system will be delivered after the linear sequence is completed.

The fundamental issue with this approach is that it increases risk forward in time. It is neither too easy nor is it economical to make changes to the original plan once the design has been carried out. Hence there is a need of proper project planning before undertaking a large project.

Waterfall model has been chosen for the project due to the fact that the requirements for the project are clearly defined in advance and does not change very often. To overcome the disadvantage of "increases risk forward in time" in this approach, project schedule has been made flexible enough to cope with more than one iteration of life cycle, if the initial system fails to achieve the objectives. During the system development, considerable amount of time has been given to each of the five phases. The process also had to go through requirements analysis, system design and implementation.

3.2 System Design

According to the problem statement and system requirements (Chapter 1), this project was divided in two major phases. First phase, finds the width of the tape and second, analyse the width measurements over a period of time and inform the user if error occurs. One of these modules is Image Processing, which deals with algorithms and techniques to measure the tape width and second is Messaging Service, which takes care of sending message. These modules would have several functions to perform the specific task. Rest of this chapter discusses the design and workflow of both modules.

Phase 1- Image Processing	**Phase 2 – Analysis and Messaging**
• Access images from Camera	• Width Measure Analysis
• Select Region of Interest (in image)	• Alarm Mechanism
• Apply Image Filtering Algorithms	• Sending E-mail
• Segmenting Image (thresholding)	• Sending SMS
• Measuring Tape width	

Figure 3.2 System Phases

3.2.1 Phase I - Image Processing

Computer vision techniques are used to complete the first phase of system. This includes several steps, right from capturing the images to measuring the product quality dimensions (tape width). The overall design and workflow for this phase had been discussed in advance, which was capturing still frame (image) from camera; cropping the image to region of interest; converting image to grey scale; applying gaussian filter; segmenting the image; and finally measuring the width. *(see Fig 3.2.1)*. These image-processing methods would be applied on each new frame, consistently captured from camera (as infinite number iterations).

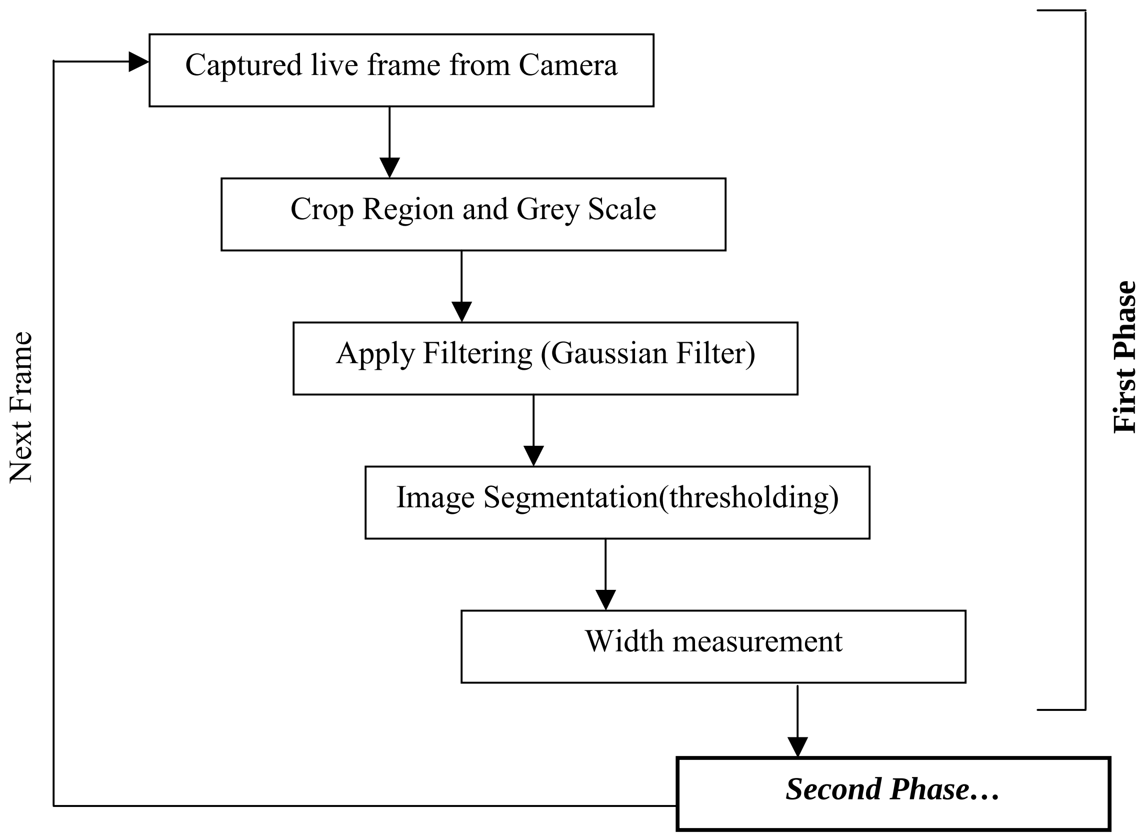


Figure 3.2.1 Phase I (Image Processing) Workflow

Image Capture

There is an Axis 2100 camera mounted on the weaving machine in production area of Xiros. While designing the system, it was decided the system would continuously capture live snapshot from the camera and proceed to next step. The rate at which frames are captured also needed to be considered to prevent any delay in system performance.

Image Crop and Grey Scale

If the whole frame or image, captured from camera, had been processed then it could have led to false results due to the presence of unwanted objects in the scene. If the image had got any other bright object apart from the white tape, it would have been difficult to discard these ones. It was then necessary to crop the image and extract a region of interest i.e. region surrounding the tape. This was one of the major steps in the design of phase one because it would remove the unwanted region in the image.

Next major decision in this concern was to define the dimensions and co-ordinates of region to crop. User while launching the system can locate this region according to the tape location in the current frame. Locating this region dynamically could also be an enhancement to the project and a major step towards system robustness. Image also needs to be converted into grey-scale to enable image-processing algorithms to be applied later.

Image Segmentation

Before applying further image processing algorithms, the image should be made smooth and noise free to certain extent. This would help in successful implementation of further algorithms (Chapter 4). Then the grey level image would be converted segmented (black and white) image. Selection of the most suitable approach for segmentation is crucial because further steps are based on its output image. Chapter 2 discusses the algorithms available for this task and shows that the thresholding was the most appropriate according to the requirements and the test images. More than one approach can also be used here and the result can be judged by having a vote from both approaches.

One major problem with thresholding is its static nature. To make a robust system, it was very important to set the threshold value dynamically according to the contrast and grey-level histogram of current frame. This is crucial because according to system requirements, it should not have any assumption for lighting conditions while running. An adaptive threshold value could serve the purpose. This has been discussed in Chapter 4 in detail.

Width Measurement

This was the last step of system's first phase. Here the segmented image was supposed to be measured. All of the above steps have been designed in this phase in order to provide a segmented image showing tape region and background as opposite grey level values i.e. black and white. A new algorithm needed to be designed and written to read this segmented image and calculate the average width of tape across the image. This has been discussed in Chapter 4 in detail.

Once all of the above functions are processed, the width measurement would be passed to *Phase 2* and the control should again go upwards to capture next frame from the camera. This iteration will keep on going until the system is shut down.

3.2.2 Phase II – Analysis and Messaging

This phase performs width measurements analysis and messaging service. The design and workflow for this phase is shown in *Fig 3.2.2*.

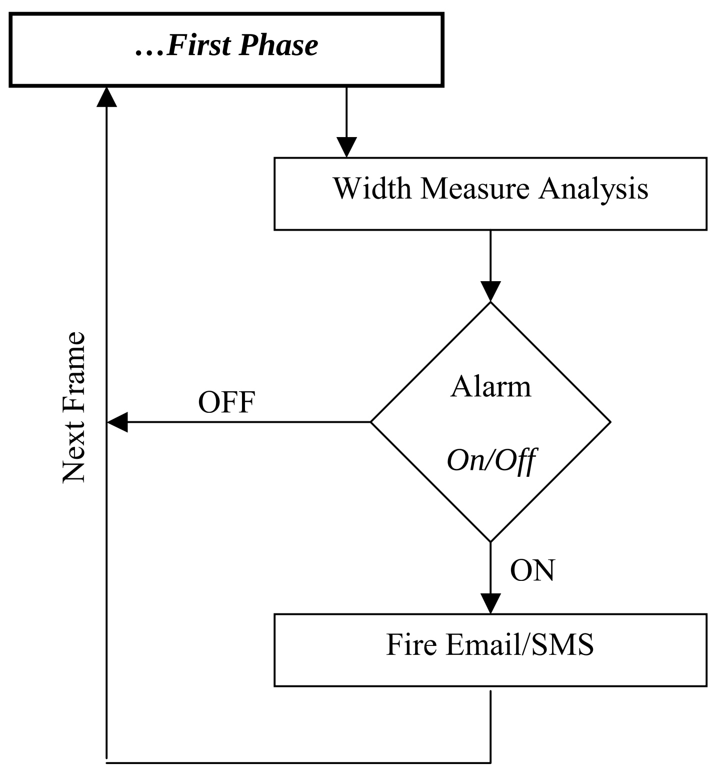


Figure 3.2.2 Phase II (Analysis and Messaging) Workflow

Width Measure Analysis

This function has been designed to monitor the width measured above. Here the width measurements for a number of frames would be analysed and compared with standard measurements over a number of frames or time period. This analysis has been done to prevent the system sending immediate messages to user on the basis of few undesired (not according to standard) width measurements. This feature provides reliability to the system and ensures there is sufficient number of measurement readings, which fall outside standard parameter, before sending alert message.

This was one of the important features of system as discussed with Xiros while designing system requirements and specifications. They wanted an alert message to be sent only if system has made sure the quality is getting suffered. According to the information supplied, this was due to fact that weaving machine starts producing over or under width tape and at times it automatically comes back to normal width. If this happens, system should take it into consideration and sends alert messages only if product width is varying over a period of time or the length of product. There has been two ways to implement this feature - the system should either monitor the measurements over a fix time period or for specific number of frames. The implementation of this has been discussed in Chapter 4.

Alarm

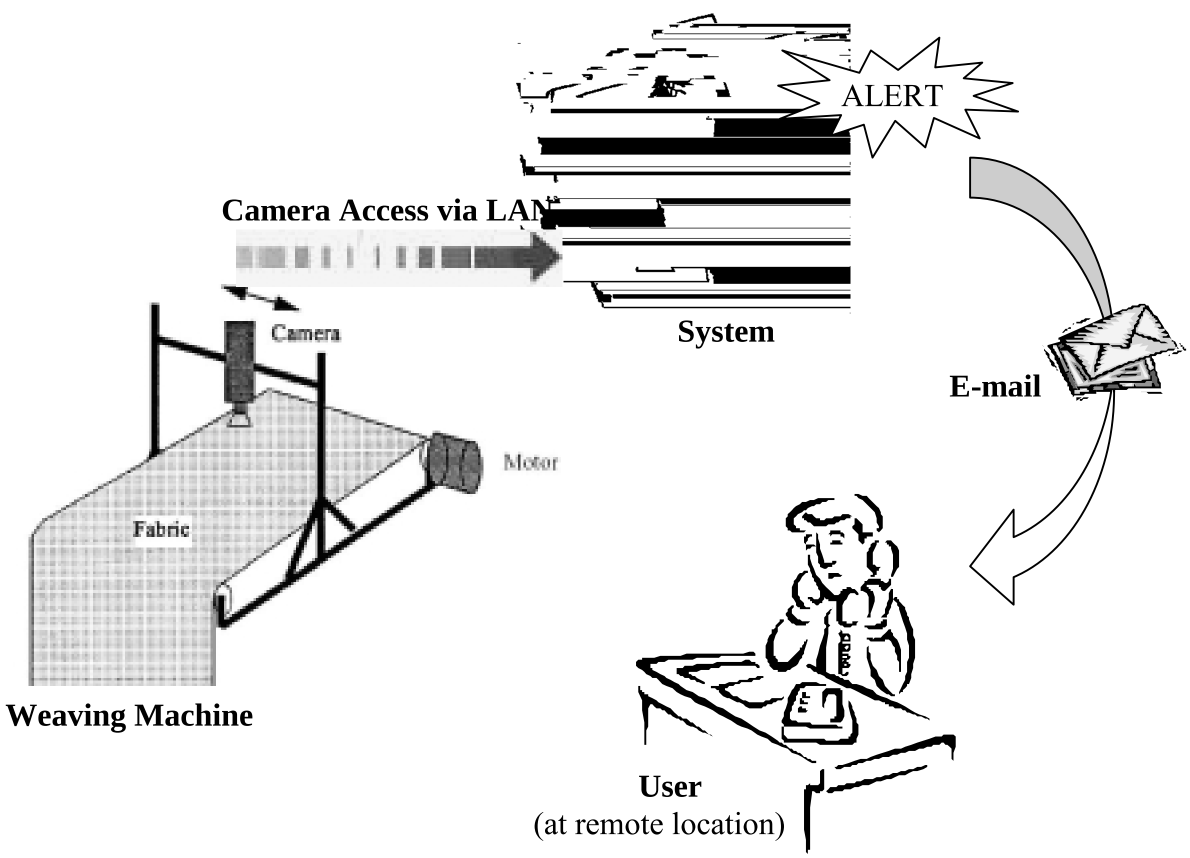
Now a decision has to be made, whether to send an alert message or not. A virtual *Alarm* has been made for this, which would be turned ON, if its quality falls beyond tolerance levels and would remain OFF, if the product qualifies the standards in the above step. The aim is to implement a switch mechanism here to simplify the process and hide all the already done analysis and measurements from further steps. If *Alarm* is turned OFF, then the control will flow back to the first phase and start next iteration. On the other hand if it is turned ON, control goes to next step for message firing.

Messaging Service

The next and final step for the system is sending alert messages to the user, if the *Alarm* has been turned ON in above step. According to the discussion with Xiros, there were two main ways to inform the user remotely i.e. Email or SMS (short message service).

Email was decided as the default method and if this works fine with initial system setups, then sending SMS could be a possible enhancement. As discussed in Chapter 2, Java libraries and activation framework has been used to send email via SMTP server. Messages can be sent from anywhere using these libraries provided SMTP server is accessible and the network is available. The email would contain the time and date details and a message informing the user. It was also possible to send the measurement details of analysed faulty frames in the email. This would help user in detecting the scope of error. The java libraries can also be used for sending attachments. The image (captured frame) of faulty product could be attached with email as an enhancement to the system for the user assistance. Once the email has been sent, control should flow back to first phase and move towards next iteration to analyse coming frames. This process keeps on going until system is shut down.

After careful consideration of user requirements and analysis, a conceptual scenario in which system would work is works is shown in *Figure* below.



Chapter 4 System Implementation

This chapter discusses the actual implementation and working of system in real time. I t covers all user interfaces, system logics and image processing algorithms used/developed at various stages of development process.

4.1 User Interface - Launcher

Being a dedicated system, there was no specific requirement for user interface. Still, an interface has been designed and implemented to launch the system *(see Fig 4.1)*, which would be used to supply input parameters to the system at start up. This is a separate interface, not exactly a part of system, which is only used as launcher to fire the system with customised input parameters. The main use for this interface is to make system parameters more customisable. This makes the system flexible enough to work in any all conditions with changed input parameters as well.

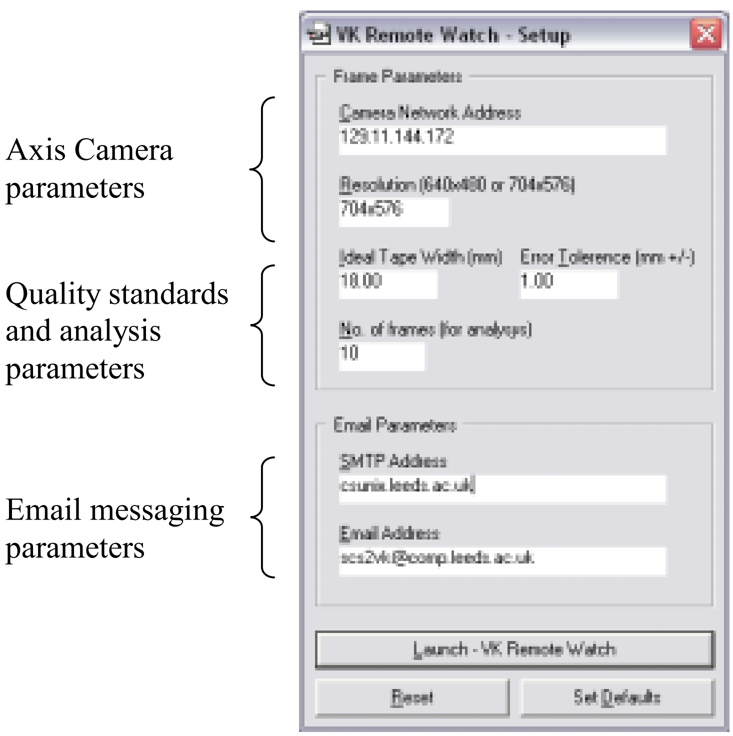


Fig 4.1 System Launcher - Interface

There is an option provided as *'Set Defaults'*, which saves all values in MS Windows registry. At the next start up, these saved values are grabbed from the registry and shown by default. This prevents user feeding these input parameters each time at start up. There are three major categories of parameters i.e. Camera details, product quality standards and analysis details and Email messaging details. Their impact and usage in the system is as follows:

Axis camera parameters

Axis camera has inbuilt web server and an assigned network IP address. Further, different axis cameras support different image resolutions. Supplying these two parameters provides flexibility and mobility to the system.

*strImgURL = "http://" + <**strCamIP**> + "/cgi-bin/jpg/image.cgi?resolution=" + <**strResolution**>;*

Both of these values are used to build a URL string (see above) to make request to CGI script running on camera server, which gives live image snapshot in return.

Quality standards and analysis parameters

These values are required to feed the system with ideal or standard width and the upper/lower tolerance limits. These are very important parameters and quite often changed according to the product type, hence they need to be customised. "*Number of frames*" parameter value is which is used as 'count' of frames to be analysed, while measurement analysis step (Chapter 3). This gives flexibility if measurements readings need to be studied for small period or long period *(details in section 4.4)*.

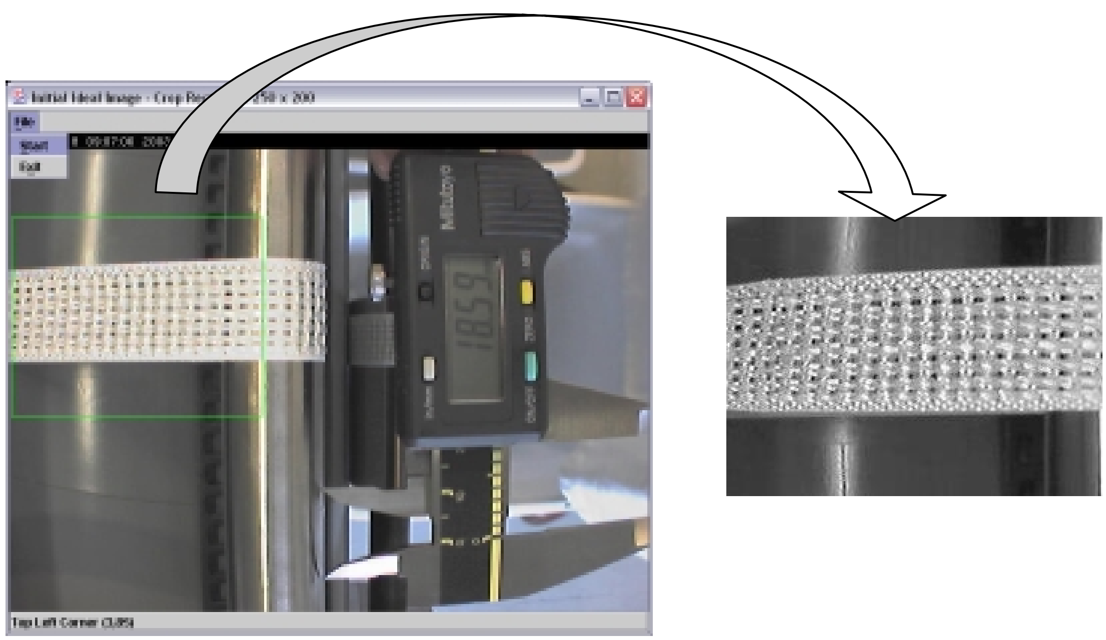
Email messaging parameters

Details supplied here are destination email address and the SMTP server used for sending email. These both parameters can also be customised accordingly.

4.2 Setting Region of Interest (ROI)

As discussed in chapter 3, the image captured from camera has been cropped to a particular region of interest and rest of the image is discarded. Selection of this area is critical because this area should cover the tape region in the image with no other objects in the scene. One solution was, setting static x and y co-ordinates of the image with fixed dimensions as region of interest, but it might fail if camera is shifted slightly. Though according to Xiros, the camera position is not changed quite often. Still, to make system robust enough to deal with this problem, a new feature has been added to the system that enables user to manually set the area of interest in the image at the system start up *(see Fig 4.2)*. In this case, system would ask the operator or user to select the region of interest at the system start up.

To implement this feature, a separate class *Firstpr.java* has been designed which opens a window (java frame) showing the very first image captured from the camera and creates a dummy green rectangular box in it. This box could be dragged by user and set to the best suitable region, which covers the tape properly without any unwanted objects in the box *(a)*. While the user is selecting the region, system is in sleep mode and not progressing further. Once user selects the region and clicks the *Start* in *File* menu, the cropped region *(b)* is grabbed and sent back to main program. Here left (x) and top (y) co-ordinates of this region have also been set globally to crop succeeding images from the same values. So this selection process is done only once while system start up and then it sets the base for next frames.



(a) Image captured from camera **(b) Cropped Region (ROI)**

Figure 4.2 Selecting ROI

4.3 Image Processing Algorithms

Now onwards, all of the processing would be done on the already cropped region of image only. Using this approach, further algorithms would not be applied on the undesired sections of image, which leads dual benefit of preventing false results and increase in processing speed. The algorithms extensively used are Gaussian Filter, Adaptive Thresholding and Width Measurement. Their implementation in solving the current problem has been discussed in this section of report.

4.3.1 Gaussian Filter

First, image is blurred using Gaussian filter. Gaussian filtering is also called Gaussian blurring. The main reason for using for blurring the image before further processing was to make it smooth enough for further image processing algorithms to work on more efficiently and effectively. Burring would help the system in discarding the cross pattern of white cloth tape to a certain extent *(see Fig 4.3.1)*. Gaussian filtering [6] is a kind of low pass filtering with a non-uniform kernel that is generated by formula (shown below):

$$h(x,y) = \exp[-\frac{(x^2+y^2)}{2\sigma^2}]$$

where: σ is the standard deviation.

Gaussian Blur algorithm has its main parameter to be supplied as *Sigma*. One has to be very careful while supplying this value because greater *Sigma* results in greater blurring. In this project, the value of sigma is set as *1.0f* (low) for the simple reason that more blurring could distort the edges of the white tape, which might not be ideal input image for next steps processing.

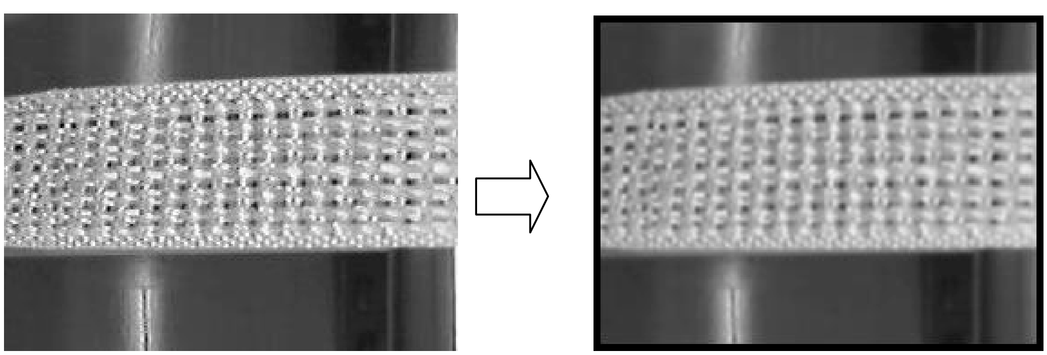


Figure 4.3.1 Gaussian Blur (Sigma =1.0f)

The implementation of Gaussian blurring has three steps: i) setting the value of sigma, here 1.0f; ii) generate gaussian kernel according to formula above; and iii) convolute image with gaussian kernel (using Java Gaussian Kernel available with JDK). See the code snippet below:

```
float sigma = 1.0f;
Kernel kernel = new GaussianKernel(sigma);
ConvolveOp blurOp = new ConvolveOp(kernel);
outimage = blurOp.filter(image, null);
```

This has been implemented in separate method called *Blur* which takes buffered image as input parameter and returns blurred image as output.

4.3.2 Adaptive Thresholding

An algorithm, *Known Distribution* (Chapter 2), is used for adaptive thresholding, which is based on a convention, that the concerned object is brighter than the background and occupies a certain fraction 1/p of the image. In this case, the white tape is brighter than the background and occupies approximately half of the image area. The dimensions of cropped region has already been customised on the basis of ideal tape width, which allows the tape to be the only object in the scene covering its half of its region. So, the convention can be duly followed in this case. The threshold can be set the by simply finding the intensity level such that the desired percentage of the image pixels are below this value, which is extracted from the cumulative grey level histogram.

Known Distribution Algorithm (implementation):

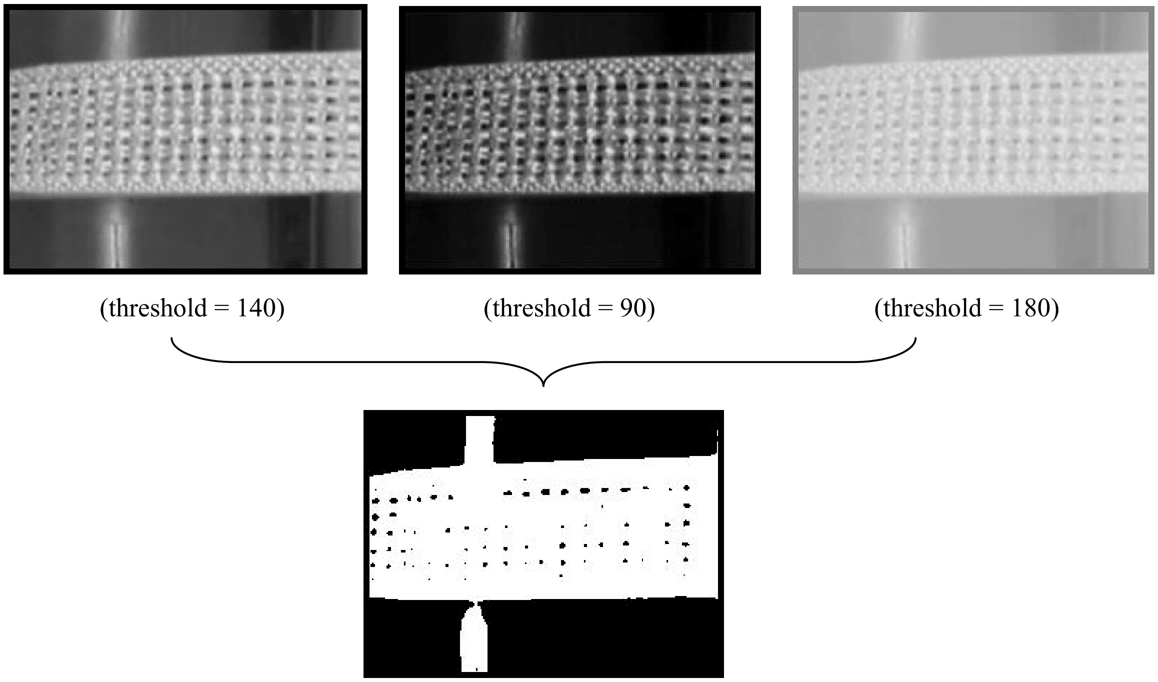
```
#Prepare grey level frequency histogram
FOR EACH pixel along Y axis
      FOR EACH pixel along X axis
            index = GET grey level
            INCREMENT HistogramArray [index]
      NEXT
NEXT
```

```
#Calculating fraction of pixel value
totalpixels = Image Width * Image Height
FOR ALL grey levels
      HistogramArray [greylevel] = HistogramArray [greylevel]/ totalpixels;
NEXT

#Calculate cumulative frequency
For ALL grey levels
      HistogramArray [greylevel] = HistogramArray[greylevel] +
                                   HistogramArray[greylevel - 1]
      #Approx 50% of the image is bright area
      IF HistogramArray [greylevel] >= 40% AND HistogramArray[greylevel] <= 60%
      THEN
            Threshold = threshold + greylevel
            INCREMENT counter
      END
NEXT
threshold = threshold / counter
```

This has been implemented in separate method called *Adaptivethresh*, which takes already cropped buffered image as input parameter and returns a threshold integer value as output. The main function of this method is to implement the *Known Distribution* algorithm on the supplied input image and provide a dynamic value of threshold to segment the image. This eliminates system dependency on any static threshold value. This value is provided to the parent method for segmenting the image in black and white region. There might be possibility of captured image varying in brightness and/or contrast due to daylight and other factors *(see Fig 4.3.2)*. This feature makes system robust enough to perform consistently under different lighting conditions.

The adaptive thresholding algorithm handles the light variations, generates separate threshold values for each frame and finally contributes towards desired segmentation (white tape region). Desired segmentation here refers to extraction of 'only' tape region from the background as white colour pixels. On the other hand, if a static threshold value was used, it could have resulted in false results i.e. white pixels showing other region apart from tape.



4.3.2 Adaptive Segmentation (dynamic threshold value)

Still there was one minor problem i.e. presence light reflection behind the tape. It is visible as bright vertical strip line behind the tape *(see Fig 4.3.2)*. Since that area has also got similar (bright) grey levels as the tape, it has also been segmented as white region. This could create problems while measuring the width and this has been dealt in next step of width measurement.

4.3.3 Width Measurement Algorithm

An algorithm needed to be developed at this stage, which could measure the width of tape from the segmented image. As whole the image has been converted into black and white grey levels, it was relatively simpler to read the image programmatically and perform checks on pixels values. The underlying logic was to scan all the white pixels in the image, which should give the region covered by tape only. The algorithm designed and followed as follows:

i) ***First scan the (horizontal) top edge of the tape and store in an array.*** This is done by started scanning the whole image horizontally from top row of the image. Then the pixel value of each row is checked per column *(see Fig 4.3.3).* If the pixel value is white then the algorithm stops scanning that particular column and stores the (x,y) co-ordinates of that pixel in a (top) array and starts scanning next column. This way it stores the top edge of the tape in an array.

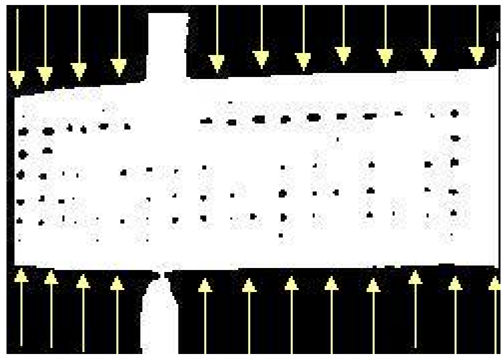


Figure 4.3.3 Width measurement algorithm

ii) ***Similarly scan the (horizontal) bottom edge of the tape and store in an array.*** This time, scanning is started from the bottom row of the image. Then the pixel value of each row is checked per column *(see Fig 4.3.3).* If the pixel value is white then the algorithm stops for that particular column and stores the (x,y) co-ordinates of that pixel in an (bottom) array and starts scanning next column. This way it stores the bottom edge of the tape in an array.

iii) ***Find the difference in relative (y) co-ordinate of top array and bottom array.*** Now, both arrays' *y* co-ordinate is compared and difference would be the width of tape per column. These difference values are stored in an array.

iv) ***Calculate Median of the width across all the columns.*** Next step is to find an average value of width across the whole tape. There were three options considered to find an average i.e. mean, median and mode. Mean is not suitable for this case because few peak values can disturb the mean and may not reflect the true average width. Mode is also not suitable because of lack of high frequency of one particular value. Median has been found as a true reflector of the average width in this case. This was because all the values are sorted in ascending order and then the middle value is chosen as average, while finding median. Its main is discarding any peak values present in the width array. As shown in *Fig 4.3.3*, there is a white region that does not belong to tape and still present in segmented image. The width value has been noticed much higher than others at these columns. This problem can be solved by taking median as mean of calculating average.

Above mentioned algorithms have been implemented in order to process images captured from camera and to find out the average width of tape.

4.4 Width Measurement Analysis

As discussed in Chapter 3, this width has been then analysed over a period of production. There has been two ways to implement this feature - the system should either monitor the measurements over a fix time period or for specific number of frames. According to information provided by Xiros, the production speed varies at times. Hence, the width measurement was analysed on the basis of number of frames rather than time.

```
----- VK Remote Watch -------------------------------

Pixel to Milimeter Ratio ..: 1 px = 0.15 mm
Ideal Width supplied ......: 15.1 mm or : 100 px
Lower Tolerence Limit .....: 14.6 mm or : 97 px
Upper Tolerence Limit .....: 15.6 mm or : 104 px

----------------------------------------------------
Press <return> key to continue...


Threshold (px): 140
Tape Width: 99 px  or : 14.85 mm
Threshold (px): 177
Tape Width: 96 px  or : 14.4 mm
Threshold (px): 135
Tape Width: 97 px  or : 14.55 mm
Threshold (px): 98
Tape Width: 99 px  or : 14.85 mm
Threshold (px): 135
Tape Width: 97 px  or : 14.55 mm
.............................. OK

Threshold (px): 110
Tape Width: 96 px  or : 14.4 mm
Threshold (px): 42
Tape Width: 99 px  or : 14.85 mm
Threshold (px): 177
Tape Width: 96 px  or : 14.4 mm
Threshold (px): 110
Tape Width: 96 px  or : 14.4 mm
Threshold (px): 184
Tape Width: 99 px  or : 14.85 mm
>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>  ALERT! FIRING SMS/EMAIL..

Threshold (px): 81
Tape Width: 99 px  or : 14.85 mm
Threshold (px): 42
Tape Width: 99 px  or : 14.85 mm
Threshold (px): 203
Tape Width: 100 px  or : 15.0 mm
```

Fig 4.4 System Output (Measurement readings)

The user at the system launch supplies this parameter *(Number of Frames)* to the system. The measured width is then compared with the standards and checked its scope under tolerance limits. This check continues till '*Number of Frames'* have been analysed. If the width falls outside standards, it is stored in an array. If the count of this array is more than or equal to *50%* of '*Number of Frames'* then the quality is treated as suffered. System makes sure the existence of error before sending alert. Hence, this analysis prevents system sending alerts immediately on each unqualified measurement.

Fig 4.4 shows the system output with threshold and width measurements (pixels and mm). This is clearly visible that system is analysing fixed number of frames before coming to a result. In this particular test, the value of '*Number of Frames'* is set as *5,* which result in '*Ok'* or '*Alert'* only after analysing five frames.

4.5 System Modules Implementation

The system has been implemented using Java. The Java 2 Platform, Standard Edition (J2SE) is at the core of Java technology providing the essential compiler, tools, runtimes, and APIs for writing, deploying, and running applets and applications in the Java programming language. It is divided in three major classes i.e *AutoPr, FirstPr* and *Jmail*. Class *Autopr* contains the main function and instantiate *FirstPr* and *Email* classes. All of the above-explained steps are performed in class *AutoPr* at various stages using basic functions of Java Image processing libraries. Class *FirstPr* designs the frame and menu interface, for selecting region of interest, using Java *Swing*. Class *Jmail* wraps all the email messaging functions using *javax.mail* and *javax.activation.* The user interface, for system input parameters, is designed in VB. Java system is called from VB with all the values supplied as command line parameters.

Chapter 5 Testing and Evaluation

This chapter is aimed at testing, reviewing and evaluating the system against some evaluation criteria already decided in advance. Major criteria include objectives proposed at the start of project, testing system with test data and evaluating against design criteria. All of these criteria and the system performance against these have been discussed in detail in the coming sections.

5.1 Evaluation against minimum objectives

The system has successfully achieved the set minimum requirements (Chapter 1). It has been a success in measuring and analysing the width of product (cloth tape) and sending emails, if the product quality is getting suffered. Hence it automates the whole process of monitoring a weaving machine remotely and eliminates the manual effort for watching product quality remotely.

5.2 Evaluation against design criteria

Apart from overall requirements in the design criteria, there was one possible enhancement i.e. to send SMS, which has not been implemented in the current system. There are two major ways for sending SMS. First, sending via dedicated mobile phone connected to the system. Second, by using third party controls to send via Internet. Research shows both of the methods are expensive. It depends on the frequency at which messages are sent. If there is requirement of huge number of messages to be sent, then using third party libraries proves to be a better option for the simple reason that the charges would on rent basis instead of per SMS sent. On the other hand, if only few messages are required to be sent, then dedicated mobile could be a better solution. If the third party libraries are used, then a small module needs to be added in the system, which wraps all the methods provided by the library, and then all these methods can be called from the main program. Implementing dedicated mobile needs Software Development Toolkit (SDK) to be installed on the system (PC) using which, all the mobile functionality can be customised and hence messages can be sent programmatically.

'*Nokia SDK* for Java' is one of the examples in this technology though which functions of Nokia phone can be accessed programmatically.

5.3 Testing (with test data)

System has been tested with test data to evaluate its performance under different conditions and scenario. To generate the test data, images have been processed manually in image processing software to simulate different lighting conditions, *Fig 5.3* and variation in tape width in the image. Source images were received from Xiros and were replicated by applying different brightness, contrast, colour balance and distortion. This provided all possible variations in the image, which could occur during daytime at the production area. System was tested on these dummy images to check the performance. The output readings were stored in log files to analyse the results later.

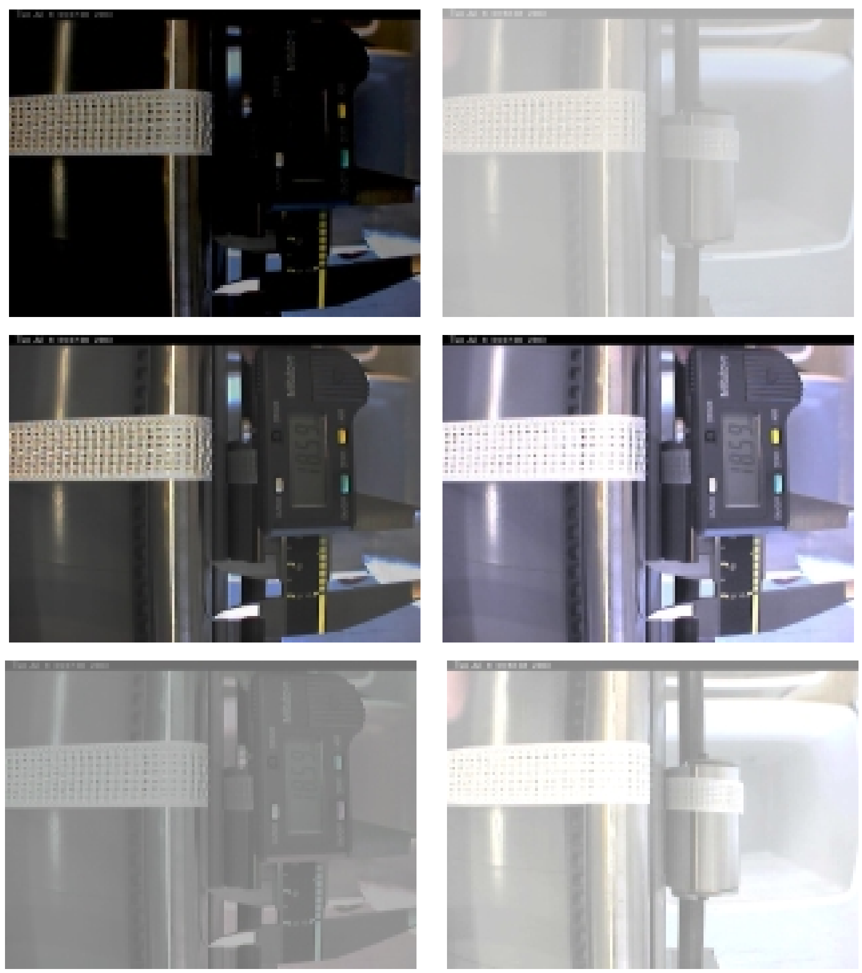
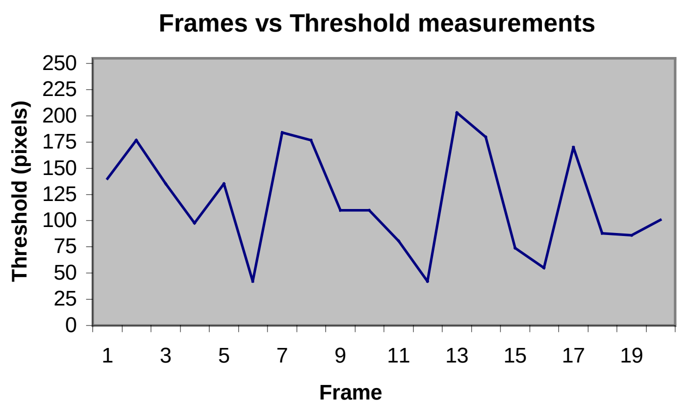


Fig 5.3 Test Images (different lighting conditions)

5.3.1 Performance under different lighting conditions

This section shows the graphical representation of evaluating system under different lighting conditions. The system was tested with 20 dummy images (discussed above), which were saved on a network location. Then the system was launched with that particular network address provided as parameter. Hence, each image simulated a frame captured from the camera. In the real time, system would be getting images in the similar manner from the camera.

Frame	Width (mm)	Threshold (pixel)
1	14.40	140
2	14.40	177
3	14.40	135
4	14.50	98
5	14.50	135
6	14.45	42
7	14.50	184
8	14.50	177
9	14.50	110
10	14.60	110
11	14.45	81
12	14.50	42
13	14.60	203
14	14.60	180
15	14.45	74
16	14.50	55
17	14.50	170
18	14.55	88
19	14.60	86
20	14.55	101



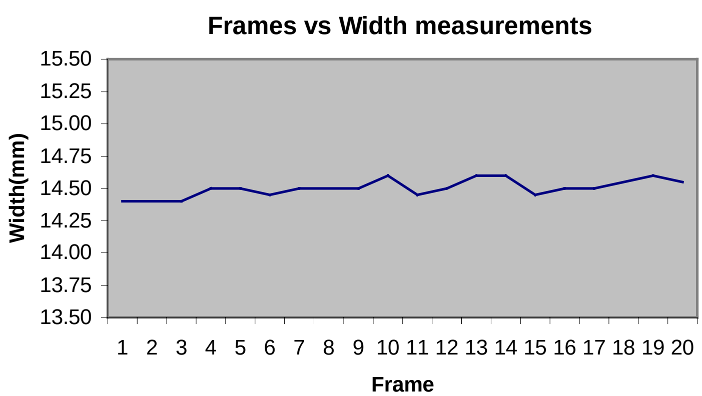


Fig 5.3.1 System measurement readings (width & threshold)

The width of tape has been kept under tolerance limits in all of these images. Aim was to vary the lighting in the images but not the width. The major evaluation here was to check whether it was reflected by the system or not. The system output readings were recorded and shown in the Table *(Fig 5.3.1)*, which are one threshold value and one width measurement per frame. *Frame vs Threshold* graph shows that the value of threshold is getting changed dynamically as the number of frames progress. This is according to the grey-level intensities of the image. Brighter images are producing higher value of threshold and vice versa. This dynamic adjustment of threshold gives consistency to the segmentation and hence the correct width is measured. *Frame vs Width Measurements* graph reflects the consistent width across all frames. There are still some variations in the width, but these are under tolerance level. There is no major deviation in the width measurements. Hence, this test proved that the system is able to measure width correctly even under varied lighting conditions.

5.3.2 Width measurements analysis

This test evaluates the system's width measurement analysis feature, which is performed once the width has been measured for specific number of frames. As discussed earlier, this feature is important in the system to make sure the existence of error over a period of time before sending alert message to the user. Again dummy images were created (from the original source image obtained from Xiros), using image-processing software by varying the width of the tape region in the scene *(see Fig 5.3.2 a)*.

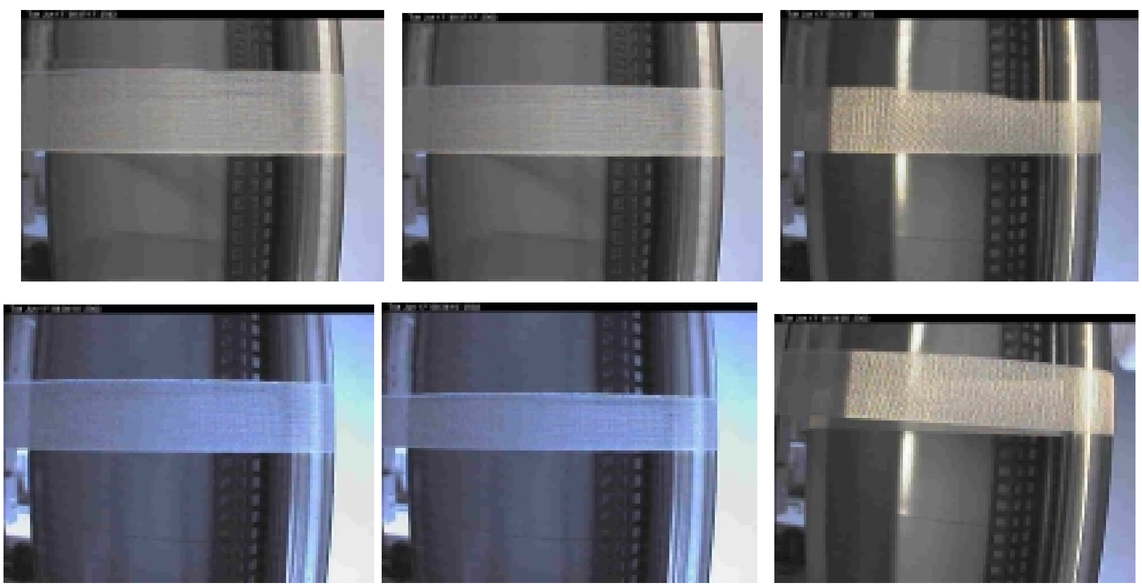


Fig 5.3.2 (a) Test Images (different width)

This test was performed to verify the system's decision on faulty frames. To perform this evaluation, 20 images were used with varying tape width. These images were then accessed by the system via network location (as in previous test). All the system output readings were recorded in log file *(see Fig 5.3.2 b)* to be analysed later. These reading include frame number, actual width, ideal width, tolerance limits and alert message frequency. The ideal width was supplied as *14.50 mm* and the number of frames to be analysis was given as *5*.

Frame	Actual Width	Ideal Width	Tolerance(+/-)	Width Status	RESULT
1	14.40	14.50	0.50	OK	
2	14.40	14.50	0.50	OK	
3	14.40	14.50	0.50	OK	
4	13.95	14.50	0.50	WRONG	
5	13.90	14.50	0.50	WRONG	**OK**
6	14.60	14.50	0.50	OK	
7	14.90	14.50	0.50	OK	
8	15.20	14.50	0.50	WRONG	
9	15.25	14.50	0.50	WRONG	
10	15.25	14.50	0.50	WRONG	**ALERT**
11	15.20	14.50	0.50	WRONG	
12	15.30	14.50	0.50	WRONG	
13	15.10	14.50	0.50	WRONG	
14	14.75	14.50	0.50	OK	
15	14.65	14.50	0.50	OK	**ALERT**
16	15.10	14.50	0.50	WRONG	
17	14.60	14.50	0.50	OK	
18	14.55	14.50	0.50	OK	
19	13.95	14.50	0.50	WRONG	
20	14.55	14.50	0.50	OK	**OK**

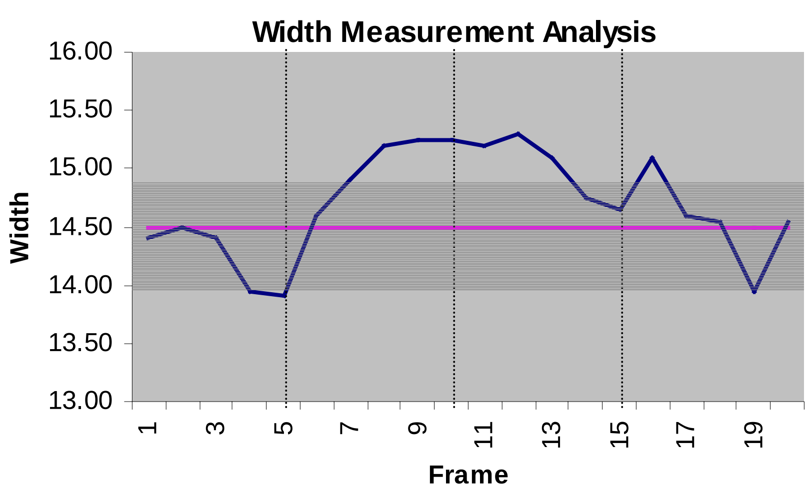


Figure 5.3.2 (b) System measurement readings (width & alert message)

The graphical representation shows the tolerance region, which is *14.00 mm to 15.00 mm* and the ideal width, is represented by straight line at *14.50 mm*. Ideal width was compared with the actual width per frame and a width status *(Ok or Wrong)* was made per frame. Then decision for alert message was based per *5* frames.

Results show that the majority of first five *(1-5)* frames' tape width was found under tolerance region and hence final result was *'OK'*. As the number of frames progressed, width kept on varying and majority of next five frames *(5-10)* was outside tolerance region. It was the case with successive five frames *(10-15)* as well. As its clearly visible from the graph that the width is varying to significant extent. Hence, the final result decided by system was *'Alert'*. This proved that the system is analysing the sufficient number of measurements before taking decision of sending alert messages.

5.4 Real-time testing

System has also been installed at the company Xiros production area and tested in real time for one whole day. While ongoing production, the production staff deliberately varied the width of tape to test the system's reliability and robustness. According to the feedback received from the company, they are satisfied with the functionality of the system and its added features of sending image (current frame) as an attachment with the alert email. Considering the feedback, it was marked a high score in terms of its usability and efficiency. Being a Java based system, is has also scored good rank in portability. It is also possible to transfer the system to some other environment like Linux and Mac. System is independent of any physical location where the weaving machine is installed. According to Xiros, they might have to shift the site where weaving machine is installed and hence system should have no assumptions regarding machine's physical location.

In summary the project has been a success in as the project objectives and minimum requirements have been achieved in a high standard. However, there is more to building a successful system that has its practical implementation in a real-life situation than just achieving the project goals. Hence fulfilling user requirements and providing customer satisfaction was considered as first and foremost goal of the project.

Chapter 6 Limitations and Future Work

This chapter discusses all the existing limitations in the system and enhancement features that Xiros intend to implement in future, which would enable them to remotely monitor some other quality measures of the product as well. Implementations of these new features now seem more achievable once the first step is successfully passed towards monitoring the product quality remotely.

6.1 Limitations and Improvements

Although minimum requirements and the objectives of the project have been met successfully, there are some limitations, which need to be addressed, and some improvements that can be done as system's enhancement features. These functionalities could not be implemented in the existing system because of limited time constraint. These features are:

- ***Automatic selection of ROI:*** In the existing system, user has to manually define the region surrounding tape at the start-up. This functionality can be automated and system could be made robust enough to find this region in the scene. This needed some more time and research in the field of computer vision and image processing.
- ***Check on Email:*** In the existing system, once it finds faulty frames (width not according to the standard), it sends an alert message. The problem here was once the system has sent alert message and error still exists for next many number of frames then in that case it will keep on sending e-mails after analysing fixed number of frames. This problem could have been sorted by putting a check on the number of emails sent, but according to Xiros, sometimes it was required to analyse the fault for a longer time periods. Then it would be necessary to check all emails sent by system continuously, that provide the fault and date & time details.
- ***Efficient System:*** Being a dedicated system, it makes full use of available hardware resources. It could be possible to make the system using hardware

resources, such as processor and memory, efficiently. The aim is to make system work on as economical hardware configuration as possible.

- ***Camera distance:*** In the existing system, user is allowed to customise the ROI in the image if the camera location in changed and the tape region is not exactly the same as before. The problem here was the distance between axis camera and the tape. If this difference varies then the tape region would not be shown by same number of pixels in both cases *(see Fig 6.3)*. Hence the tape of similar width would be measured different by the system.

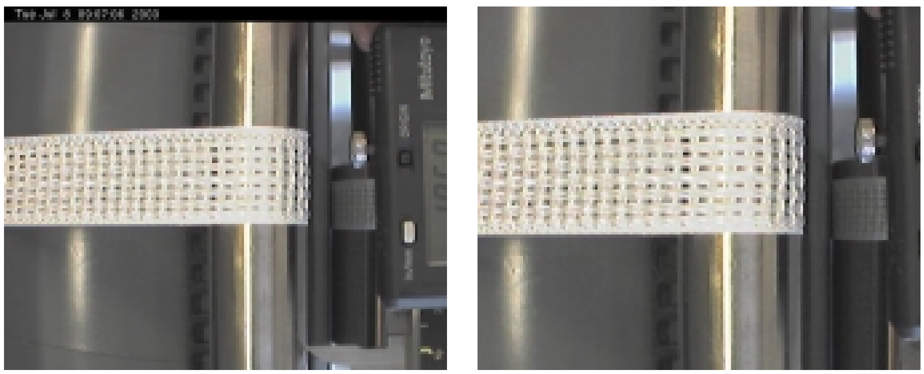


Figure 6.1 Similar widths from different camera distance

The possible solution could be to allow the user supply camera distance from tape as a parameter to the system and then it would automatically perform pixel to millimeter mapping to measure the exact width consistently.

- ***Remote Controlling:*** Being a dedicated system, it is installed on a PC that is connected to weaving machine via LAN. Once it has been started, it is supposed to run continuously locally at that machine. There could be a possible enhancement to control this system remotely by the user. *Remote control* here refers to the functionalities such as - user could change the system parameters, shut down and restart the system. To implement this functionality, a separate architecture needs to be designed using Remote Method Invocation (RMI).

6.2 Future Work

While discussing the project objectives and system requirements, Xiros also had plans for monitoring other quality parameters apart from the tape width. But these were not included as the objectives of this MSc project. The major quality parameters, they are looking forward are to monitor the crossed pattern of the tape and detecting the defects in weaving *(see Fig 6.2)*. They want to make sure that the weaving is going as per standards i.e. in check pattern and are looking for minute defects in the tape weaving. They also want to monitor the quality of stitching at borders of the tape.

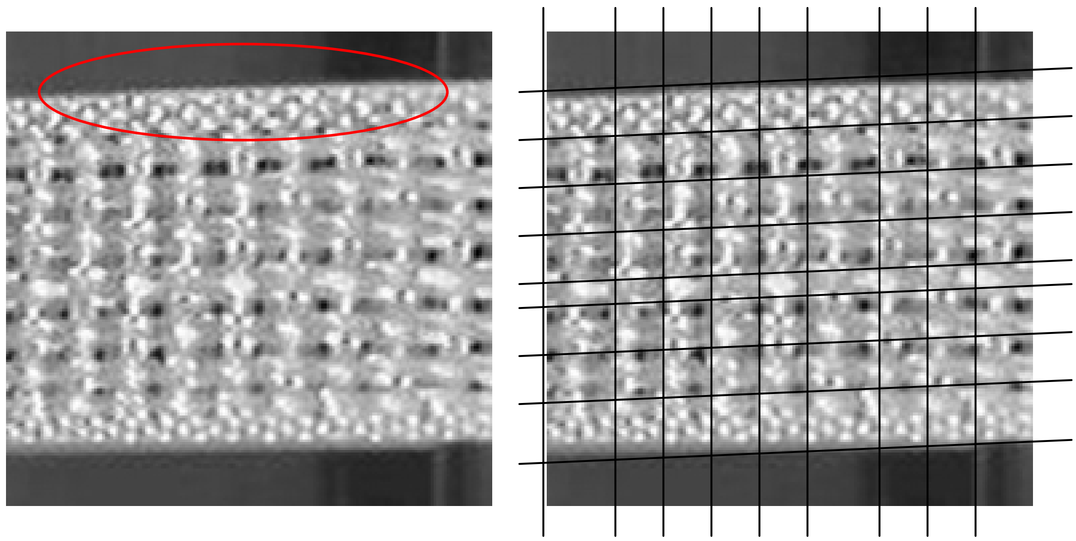


Figure 6.2 Detecting crossed pattern of tape and weaving faults

Images need to be captured at very high resolution to detect these minor faults within thread weaving. Use of pattern recognition algorithms could be handy in solving the problem. Some more research needs to be done to detect these defects and build a robust system.

Chapter 7 Conclusion

As discussed in Chapter 1, the project faced both technical and non-technical challenges during the system development. There were many unexpected issues that have been resolved and cannot be allowed to delay the final system. There has been several efforts and methods devoted to achieve the project objectives. A research and background study, related to the problem, was performed, once the company people defined the system requirements and objectives. Then a system design was prepared on the basis of requirement analysis and research study. This design was then implemented to actually start building a system. Finally, an evaluation was performed against design criteria, once all the functionalities were implemented and tested.

Overall, the project has been a success in both achieving project objectives and minimum requirements and the practical implementation in a real-life situation. Being an external project, customer satisfaction has been given more importance than anything else.

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Appendix A – Personal Reflection

This MSc project has been a wonderful opportunity for me to show my efficiency and capabilities. I had a very good personal experience at various stages while doing this MSc Project, which are as follows:

Project scheduling: This project was proposed in March'03 and full time work has been started since June'03. To perform the task more smoothly, project scheduling was followed successfully. This project would not have been completed without the scheduling. The experiences of proposing a reasonable project scheduling with several measurable milestones are useful.

.

Knowledge preparation: Being a student of MSc Distributed Multimedia Systems (DMS), this project proved to be an ideal match according to the modules studied during the semesters. The involved knowledge in the project include the major contents of perceptual systems, object oriented programming and numeric analysis. Knowledge gained from the module Perceptual system has been directly applied in this project in terms of *Digital Image Processing* and *Computer Vision* technologies. Being a Java based system, OOP concepts are used while designing the system.

Professional experience: It was a great opportunity for me to work with an external company Xiros. Numbers of meetings were arranged with related IT people at the company during the project life cycle. I found people at the company very helpful and responsive. They spent a great deal of their time at various stages, right from discussing the requirements to installation of system. Overall, this provided me an invaluable experience of dealing with the companies professionally, which would certainly prove to be handy in the future.

Appendix B – Interim Report Feedback

School of Computing, University of Leeds

MSc PROJECT INTERIM REPORT

All MSc students must submit an interim report on their project to the MSc project co-ordinator (Mrs A. Roberts) via CSO ***by Thursday 8th May 2003.*** Note that it may require two or three iterations to agree a suitable report with your supervisor, so you should let him/her have an initial draft well in advance of the deadline. The report should be a maximum of 10 pages long and be attached to this header sheet. It should include:

- the objectives, deliverables and agreed marking scheme
- resources required
- progress report and project schedule
- proposed research methods
- a draft chapter on the literature review and/or an evaluation of tools/techniques
- the WWW document link for the project log to date

The report will be commented upon both by the supervisor and the assessor in order to provide you with feedback on your approach and progress so far.

The submission of this Interim Report is a pre-requisite for proceeding to the main phase of the project.

Student:	**VIVEK KUMAR**
Programme of Study:	**MSc DMS**
Title of project:	**Remote Monitoring Weaving Machine**
Supervisor:	**Dr. Andy Bulpitt**
External Company (if appropriate):	**XIROS PLC, Blenheim Terrace, Leeds**

AGREED MARKING SCHEME

Understand the problem	Produce a solution *	Evaluation	Write-up	Appendix A	TOTAL %
20	40	20	15	5	100

*** This includes professionalism**

Signature of student: **Date:** 08-05-03

Supervisor's comments on the Interim Report

Further reading of background material is required to look at a number of possible solutions to the problem. The software library used in PSS may be a useful tool to try a few ideas out. You must ensure you use a wide set of testing images to ensure you do not make any unintended assumptions.

Assessor's comments on the Interim Report

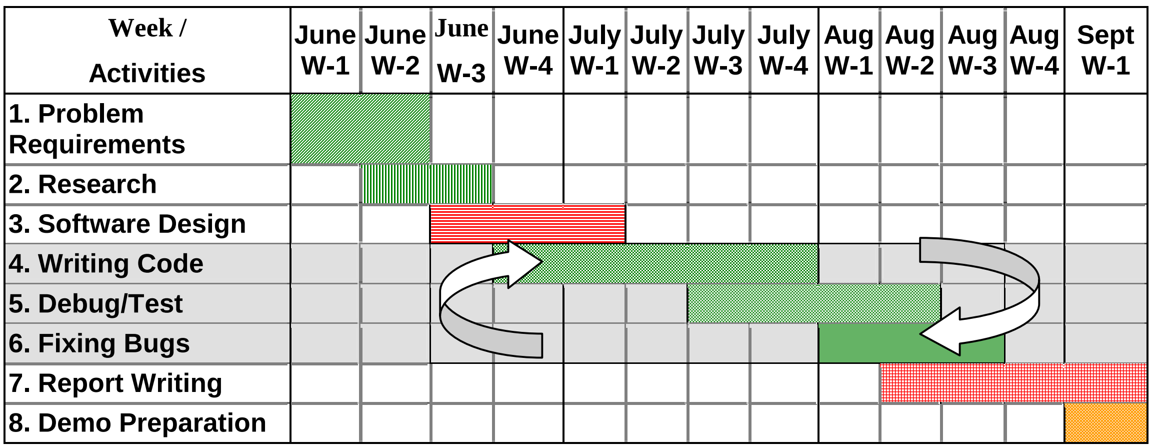
Don't make claims like "... a study of all these projects have been done..." unless you cite and reference all these projects; you only mention 2 projects. Also, too much of your report is direct quotation from sources - you should show that you understand how these sources relate to your project needs, in your own words.

The schedule suggests you will design and implement ONE solution; perhaps it may be better to allow for the possibility that this solution is not perfect first time, so you may need to test/evaluate, find flaws which could be improved, and iterate code/test/evaluate at least one more cycle.

Cited Papers: reference should include Name of Journal/Proceedings, page numbers, publisher - a URL is not enough.

Appendix C - Project Management and Scheduling Revision

The Project has been managed properly right from the very first meeting with Xiros, requirements analysis, system design, and implementation, to write-up the final report. It would be impossible to do a project like this without planning and self-motivation. Initially, a project plan was drafted before Interim report submission. Since then it has been revised once to make it flexible enough to deal with the future unexpected changes. The major change made to the initial plan was providing one more iteration (see fig below) of development process incase the first one does not produce satisfying results. Rest all the task has been performed in accordance with plan.



Tasks and their actual completion Dates

Scheduled task dates were regularly compared with the actual completion dates to assess the effectiveness of time planning and time management.

Date	Task
May 08, 2003	Handed the Interim report
June 16, 2003	Finished the Requirement Analysis
July 05, 2003	Finished the Design Analysis
July 30, 2003	Finished the Implementation (first Iteration)
August 5, 2003	Finished Testing and evaluation.
August 10, 2003	Finished the Implementation (second Iteration)
August 22, 2003	Finished Report Draft
September 03, 2003	Final report completed

Appendix D – Script Extractions

#1 Class used for Messaging service

```
public class jmail
{

public void postMail(String recipients[ ], String strSubject,
                     String strMessage, String strFromAdd , String strSMTP,
                     String strAttachFile) throws MessagingException
{
    boolean debug = false;

     //Set the host smtp address
     Properties props = new Properties();
     props.put("mail.smtp.host", strSMTP);

    // create some properties and get the default Session
    Session session = Session.getDefaultInstance(props, null);
    session.setDebug(debug);

    // create a message
    Message msg = new MimeMessage(session);

    // set the from and to address
    InternetAddress addressFrom = new InternetAddress(strFromAdd);
    msg.setFrom(addressFrom);

    InternetAddress[] addressTo = new InternetAddress[recipients.length];
    for (int i = 0; i < recipients.length; i++)
    {
        addressTo[i] = new InternetAddress(recipients[i]);
    }
    msg.setRecipients(Message.RecipientType.TO, addressTo);


    // Setting the Subject and Content Type
    msg.setSubject(strSubject);

       // Attach file with message
       File file = new File(strAttachFile);
       if (file.exists())
       {
              // create and fill the first message part
              MimeBodyPart mbp1 = new MimeBodyPart();
              mbp1.setContent(strMessage, "text/html");

              // create the second message part
              MimeBodyPart mbp2 = new MimeBodyPart();

              // attach the file to the message
              FileDataSource fds = new FileDataSource(strAttachFile);
              mbp2.setDataHandler(new DataHandler(fds));
              mbp2.setFileName(fds.getName());

              // create the Multipart and its parts to it
              Multipart mp = new MimeMultipart();
              mp.addBodyPart(mbp1);
              mp.addBodyPart(mbp2);

              // add the Multipart to the message
              msg.setContent(mp);
```

```
        }
        else
        {
            msg.setContent(strMessage, "text/html");
        }

        Transport.send(msg);
 }

}//end of class
```

#2 Implementation of adaptive threshold algorithm

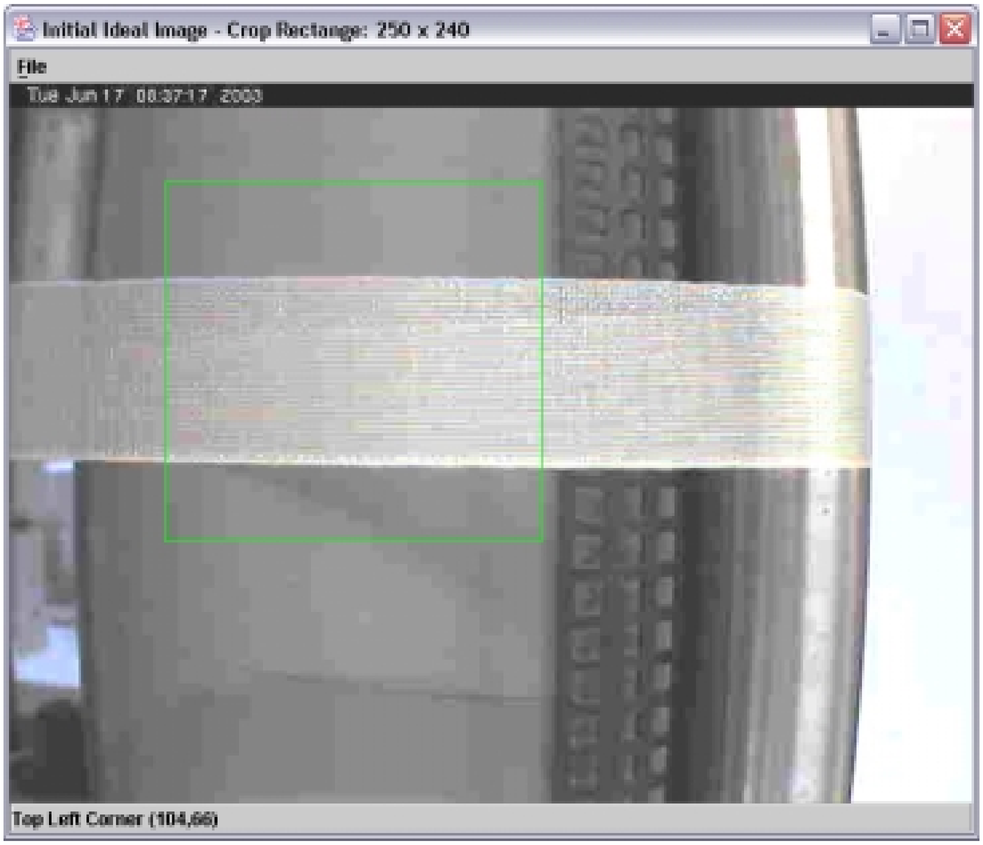
```
public int Adaptivethresh(BufferedImage image)
{
        //approach - known ROI's fraction of image
        double[] hist_ar = new double[256]; //array to store grey levels (0-255)
                                              frequencies
        int tot_px =0;
        int thresh =0;

                WritableRaster raster = image.getRaster();
                int grey_value=0;

                for (int y = 0; y < image.getHeight(); ++y) //preparing histogram
                                                              of frequency
                {
                        for (int x = 0; x < image.getWidth(); ++x)
                        {
                                grey_value = raster.getSample(x, y,0);
                                hist_ar[grey_value]++;
                        }
                }

                tot_px = image.getHeight() * image.getWidth(); //total pixels

                for (int x = 0; x < 256; ++x) //calculating fraction of pixel
                                                value
                        hist_ar[x] = hist_ar[x]/tot_px;

                for (int x = 1; x < 256; ++x) // cumulative frequency
                        hist_ar[x] = hist_ar[x] + hist_ar[x-1];

                int n=0;
                for (int x = 0; x < 256; ++x)
                {
                        //System.out.println(x + " , " + hist_ar[x]);
                        if (hist_ar[x] >= 0.4 && hist_ar[x] <= 0.6)
                        //approx 50% of the image is ROI i.e. bright area
                        {
                                thresh=thresh + x;
                                n++;
                        }
                }
                thresh = thresh/n;
                System.out.println("Threshold (px): " + thresh);
                return thresh;

 } //end of function
```

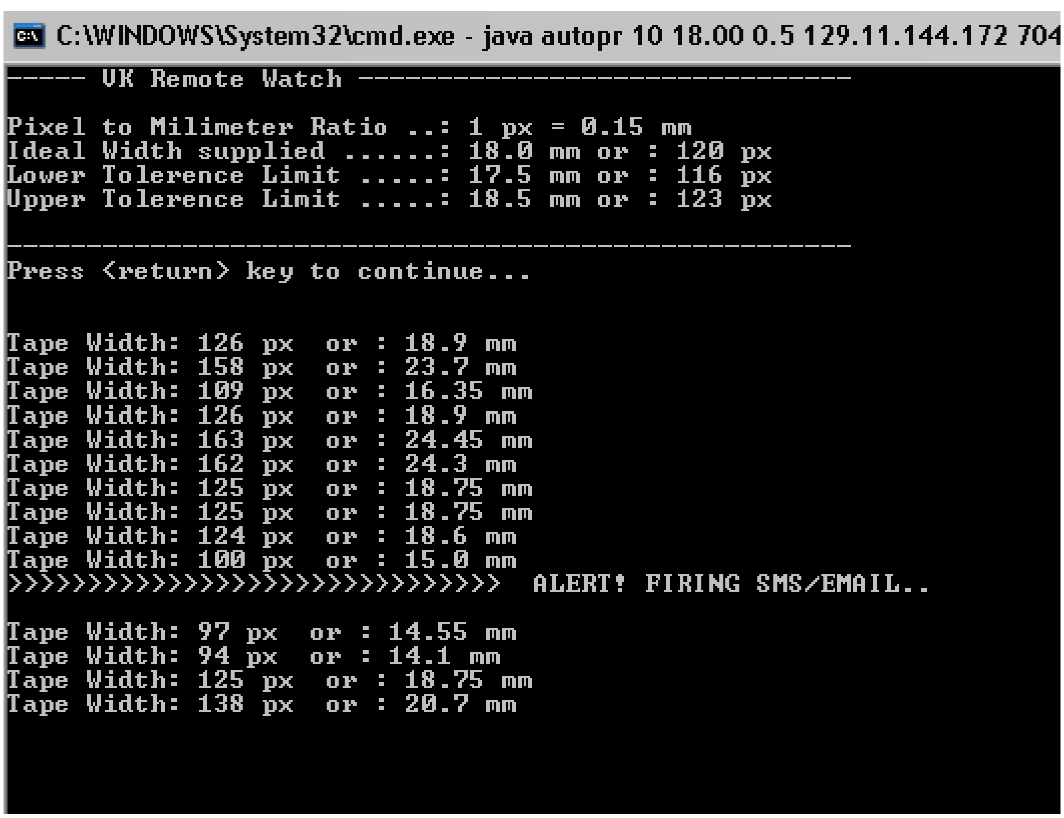
#3 Implementation of width measurement algorithm

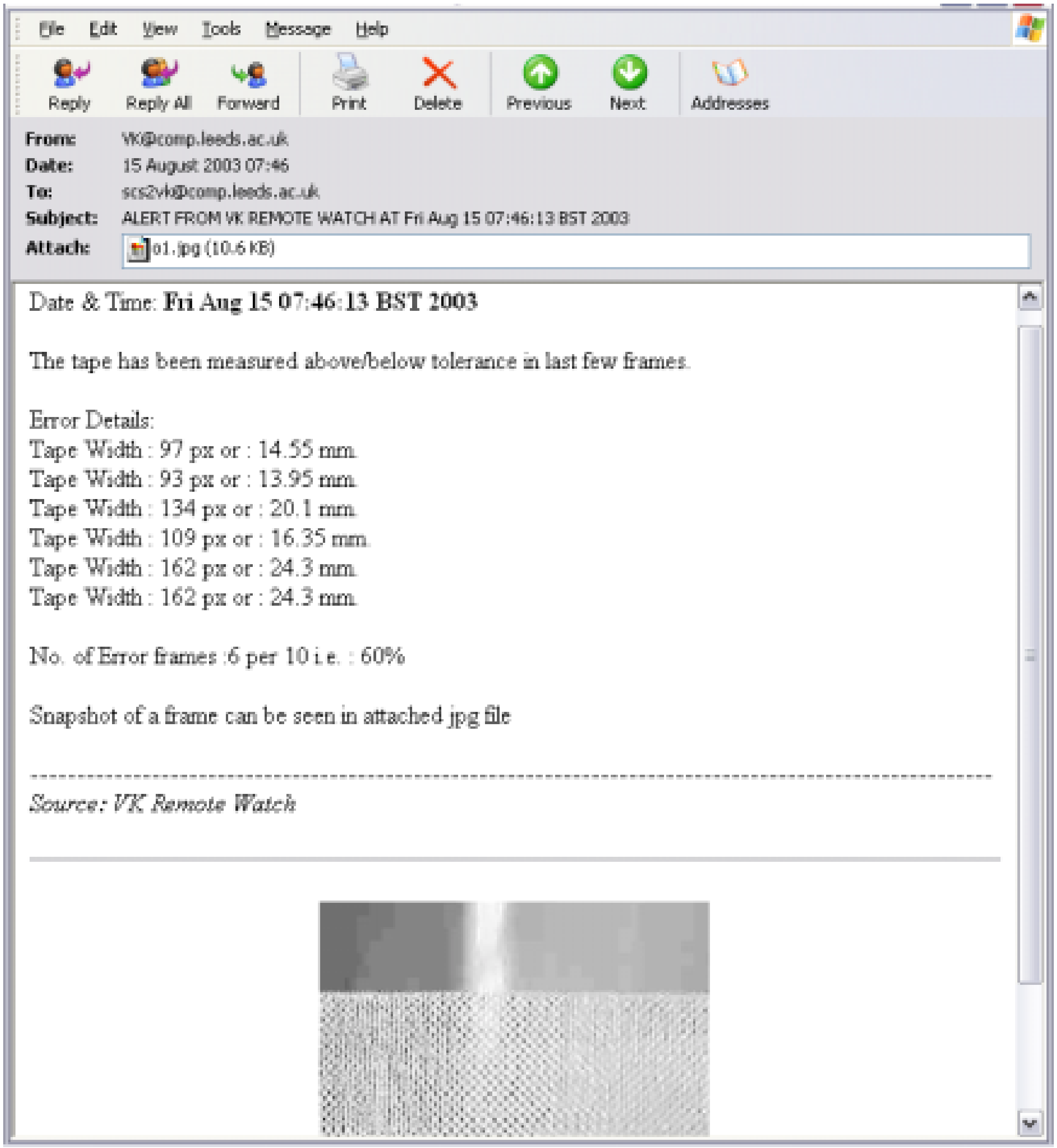
```
public int Measure(BufferedImage image)
 {
	int read_width = crop_width - 5;

	//ignoring first and last few pixels
	long[] med_ar = new long[read_width];
	int[][] top_ar = new int[500][500];
	int[][] bot_ar = new int[500][500];
	int tmp_val = 0;
	double width_m=0.00;
	WritableRaster raster = image.getRaster();

	//to scan the top most edge
	for (int x = 0; x < image.getWidth(); ++x)
	{
		for (int y = 0; y < image.getHeight(); ++y)
		{
			tmp_val = raster.getSample(x,y,0);
			if (tmp_val != 0)
			{
				top_ar[x][y] = tmp_val;
				break;
			}
		}
	}

	//to scan the bottom most edge
	for (int x = image.getWidth()-1; x > 0; --x)
	{
		for (int y = image.getHeight()-1; y > 0; --y)
		{
			tmp_val = raster.getSample(x,y,0);
			if (tmp_val != 0)
			{
				bot_ar[x][y] = tmp_val;
				break;
			}
		}
	}

	int median_w=0;
	int bot_y=0;
	int top_y=0;
	for (int x = 5; x < crop_width; ++x) //to find the difference
	{
		for (int y = 0; y < crop_height; ++y)
		{
			if (top_ar[x][y] != 0)
				top_y = y;

			if (bot_ar[x][y] != 0)
				bot_y = y;
		}

		// saving width(bottom Y  - top Y) for each column(x) in an array
		med_ar[x-5] = (bot_y - top_y);
	}

	// median
	Arrays.sort(med_ar); // sort in ascending order
```

```
        // picking the middle value (read_width - 1)/2 median_w =
        (int)med_ar[(int)(read_width - 1)/2];

        width_m = roundDouble((double)(median_w * dblPxtoMm), 2);

        //average width of tape
        System.out.println("Tape Width: " + median_w + " px  or : " + width_m +
                              "mm");
        return median_w;

  } //end of function
```

Appendix E – Screen Shots







From: VK@comp.leeds.ac.uk
Date: 15 August 2003 07:46
To: scs2vk@comp.leeds.ac.uk
Subject: ALERT FROM VK REMOTE WATCH AT Fri Aug 15 07:46:13 BST 2003
Attach: 01.jpg (10.6 KB)

Date & Time: **Fri Aug 15 07:46:13 BST 2003**

The tape has been measured above/below tolerance in last few frames.

Error Details:
Tape Width : 97 px or : 14.55 mm.
Tape Width : 93 px or : 13.95 mm.
Tape Width : 134 px or : 20.1 mm.
Tape Width : 109 px or : 16.35 mm.
Tape Width : 162 px or : 24.3 mm.
Tape Width : 162 px or : 24.3 mm.

No. of Error frames :6 per 10 i.e. : 60%

Snapshot of a frame can be seen in attached jpg file

Source: VK Remote Watch