MASTER’S THESIS

Topic:
Использование лазерных сканеров
dля контроля профиля рельса
(Usage of Laser Scanners for Rail Profile Control)

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TASK FOR THE MASTER'S THESIS

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Topic: Usage of Laser Scanners for Rail Profile Control

Institution: Saint Petersburg Electrotechnical University

Initial data (technical requirements):
The student is provided with the following equipment:
1) triangulation laser scanner RifTek RF-625;
2) manual railway bogie.

The student should perform experimental measurements, and develop a mathematical algorithm for recognizing the rail profile against the background of highly correlated noise.

Contents of the thesis:
the thesis contains review of the laser triangulation technology and existing ways of combating image noise, as well as the peculiarities of using optical sensors in railway conditions.

List of report materials: explanatory note, illustrations.

Additional sections: safety analysis.

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SUMMARY

Explanatory note 81 p., 27 fig., 61 sources.

LASER SCANNER, DIGITAL IMAGE, LASER TRIANGULATION, MOON GLADE EFFECT, DIGITAL IMAGE PROCESSING, PATTERN RECOGNITION.

The subject of the research: Usage of Laser Scanners for Rail Profile Control.

The target of the thesis is optical image recognition of the railway head profile against the background of highly correlated noise.

Main contents of the thesis:

Optical measurement methods are rapidly replacing conventional contact methods in the field of railway measurement. One of the most widely used methods is laser triangulation scanning. This method, however, requires performing image recognition of the railway head profile in the video signal acquired from the scanner’s camera. This task can prove to be difficult in harsh railway environment. This thesis is focused on the problem of optical image recognition of the railway head profile against the background of highly correlated noise.
АННОТАЦИЯ

Сегодня задача путеизмерения железнодорожных путей всё активнее выполняется при помощи бесконтактных методов, которые вытесняют привычные контактные благодаря большей точности и скорости измерения. Наиболее распространённым методом бесконтактного измерения является лазерная триангуляция.

С другой стороны, оптические методы подразумевают задачу распознавания оптического сигнала, зашумлённого фоновыми засветками, переотражениями и прочими паразитными сигналами. Это делает данную задачу нетривиальной.

Данная работа посвящена разработке математического алгоритма распознавания видеосигнала, получаемого от лазерного сканера, который бы обеспечивал обнаружение профиля головки рельса на фоне сильно коррелированного шума.
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DEFINITIONS, DESIGNATIONS AND ABBREVIATIONS

The present explanatory note uses the following abbreviations and designations:

ALS – Airborne Laser Scanning
ALTM – Airborne Laser Terrain Mapper
CAD – Computer Aided Design
CCD – charge-coupled device
CMM – Coordinate Measuring Machine
CMOS – Complementary Metal oxide Semiconductor
ECG – Electrocardiogram
EEG – Electroencephalogram
FPGA – Field Programmable Gate Array
GIS – Geographic information system
GPS – Global positioning System
IRS – Inertial Reference System
NAS-RIF – Non-negative and Support Constraints Recursive Inverse Filtering
NDT – Non-destructive testing
PSD – Position Sensing Detector
TLS – Terrestrial Laser Scanning
TOF – Time-of-flight
VGA – Video Graphics Array
INTRODUCTION

The development of urban in different countries in the world, goes with the high spread of high-speed train and the increasing in cost of road transport, railway research for technical improvement and cost reduction has increased during the last decades. One of the main focus has been in rail track. Rail track irregularities have a large effect on railway safety and operation, mainly systems safety, train speed optimization, movement behavior and passenger comfort abilities. To ensure a good maintenance of the rails, frequent measurements are needed, which are costly and require specific tools for different aspects of the rails geometry. Railways require preventative diagnostic assessments to ensure that erosion or other environmental changes haven't made the tracks unsafe.

The structure gauges, distance between tracks, track bed stability, and ballast bed profile must be measured for the entire length of a track. Such a task requires rapid data gathering, rapid analysis, and a quick response. Since the required measurement speed increased beyond of what contact measurement systems can provide, the current trend is to move towards non-contact measurement systems, which use various optical sensors.

Laser scanning offers the advantage of acquiring accurate 3D as well as 2D measurements of all the objects present in the railway environment in a short operational time. However, a serious obstacle on this path is high noise level of the optical signal, which complicates the process of image recognition. Because of that, non-contact systems still haven't completely pushed contact ones out of the market, despite their numerous advantages.

The problem of recognition of the image signal received from railway optical sensors is relevant and absolutely necessary. Therefore the main objective of this research project is to develop an image recognition algorithm that will be effective for filtering highly correlated noise with low entropy.
1. THE FUNDAMENTALS OF RAIL TRACK CONTROL

1.1. Background on Rail track Control

Earlier before 1900 there was no proper rail track control techniques. Thereafter, the rail profile inspection was done but it was visual procedure, without any technical instrument to be used. In 1911 at Manchester, New York train accident happened where the train leave its track and go off. The particular accident resulted in the death of 29 people and others 60 injuries. The investigation of the accident showed that cause was a long narrow line of breakage made by crack which lies perpendicular to the length of the rail (transverse fissure). In the late 1920s further investigation showed that this type of defect was quite common. The development of urban in different countries in the world goes with increased rail traffic at higher speeds and with heavier axle loads today, critical crack sizes are shrinking and rail profile changes and rail profile inspection is becoming more important and necessary.

In 1927, Dr. Elmer Sperry under contract with the American Railway Association built a massive rail inspection car which uses magnetic induction techniques, and becoming the first rail profile inspection cars. The technique behind this method, it was done by passing large amounts of magnetic field through the rail and detecting flux leakage with search coils. Thereafter, many other inspection cars and other different rail profile control and inspection techniques were developed [1].

1.1.1. Problems on railways

Every railroad has problems. Trains go off the rails. Railway lines collapse. Every these problems result in money losses and delays. Rail inspection is the practice of examining rail tracks for flaws that could lead to catastrophic failures. According to the United States Federal Railroad Administration Office of Safety Analysis, track defects are the second leading cause of accidents on railways in the United States. The leading cause of railway accidents is attributed to human error.
North American railroads spend millions of dollars to inspect the rails for internal and external flaws. Non-destructive testing (NDT) methods are used as preventative measures against track failures and possible derailment [1].

![Figure 1.1 – The problems caused by incorrect rail profile](image)

The general reason for all these problems is that the railway track was not in the safe, correct condition because of incorrect rail profile [1].

### 1.2. Non-contact measurement in rail profile control

Lasers scanners have been used for surveys since the beginning of 1960s, within the past decade laser profiling and scanning systems have undergone phenomenal rapid development and have become the most important data acquisition technology of the millennium. The technology includes different types of laser scanners including airborne laser scanners, Terrestrial laser scanners and Micro Laser scanners or hand held laser scanners that possess the ability to collect very large quantities of explicit 2D as well as 3D data at the speed and accuracy which have never happened before. The recent improvement and advances in the field of information technology and introduction of more reliable computers and software programmes has made the processing of measured and acquired data relatively simple and fast. The introduction of geo-referencing technology in the mid-1990s
has been a key factor of laser profiling and scanning systems use for topographic mapping commercially viable [2].

Several researchers have reviewed the rail track inspection techniques. The developments in rail track inspection have been reviewed by [3], although there are different techniques rail profile control. They are divided into two main techniques, contact and non-contact measurements. The major problem with the contact techniques are that they produce rail wear and due to speed requirements. Also the non-contact methods include accelerometer and gyroscope devices which are affected by the train vibrations and cannot assess the wear of the rail surface [4]. With no doubt, nowadays the optical methods is useful for accurate rail profile control measurement and seems to have many advantages [5].

The importance of acquiring accurate geometry of the rails is not limited to railway inspection, but involve providing better information for father research on deterioration modelling [6] show the opportunities for maintenance and economical planning in rail deteriorating modelling, and systematical acquisition of rail geometry can improve the development of those models.

As transportation projects become more complex to design and build, it is important to take advantage of appropriate innovative technologies for reducing project cycle time. Laser scanning is one such technology that has potential benefits over standard surveying techniques such as total station or aerial photogrammetry for providing accurate as-built drawings. Laser scanning is a terrestrial laser-imaging system that quickly creates a highly accurate three-dimensional (3D) image of an object for use in standard computer-aided design (CAD) software packages. It is anticipated that such a system can produce more accurate as-built data and/or drawings in less time compared to the standard approaches.

1.3. The moon glade effect

Moon glade effect is due to laser radiation which are diffusely reflected along the length of the rail resulting the blue sky in the polished surface of the rail head.
In the recent days the research goes further, where the problem of processing the video signals caused by sun glints which cause high entropy noise with low correlation was solved, but the problem is the receiving the video signals which suffers from moon glade effect.

![Figure 1.2 – The moon glade effect](image)

1.4. Introduction to railway

There are several definition of railway, but in simple way, it may be defined as a prepared track which so guides the wheels of the vehicles running on it that they cannot leave the track, This is According to Dr. Michael J T Lewis, the eminent scholar of early railways. In the definition wheels need not to be a feature because it has the merit of technical simplicity and thus embraces many kinds of transport systems apart from those conventionally known as railways.

Railways may have different purposes, but for the real advantage of the definition is that in referring to a prepared track it draws attention to the fact that railways are built with a specific purpose in mind. That purpose may vary from system to system, but the principle remains the same – a railway is a linear transport feature that is a permanent track composed of a line of parallel metal rails fixed to sleepers, for transport of passengers, goods, etc (usually railway track consist of rail installed on ties/sleepers and ballast). Sleepers are the rectangular kind of sup-
port for rail in railroad tracks, they hold the rail up right and maintaining the spacing at the correct gauge [10].

![Figure 1.3 – Design parameters of an UIC 54 rail profile](image)

In this introductory party of railway, it has been divided in 3 parts with the name of head, web and foot, describing the top part, the linking central part and the base of the rail respectively. There are several types of railway designs, but the basic traits of steel rail are 70 mm width in the top, 159 mm of total height, 140 mm width in the base and 16 mm width in the body.

### 1.5. Introduction to Laser

The word laser is an acronym that stands for “light amplification by stimulated emission of radiation”. There are three major factors that distinguish laser light from ordinary light. These unique characteristics are as follow.

Laser light is monochromatic, which means all the light it produces is almost exactly the same color. Laser light has far greater degree of directionality (small divergence) than ordinary light which is a key factor in the ability of laser light being focused in to a beam and on a very small spot, increasing its intensity. Phase consistency which means all light (photons) from a laser beam are aligned with each other [11].
Generally, lasers are classified depending on different criteria, based on the pumping schemes lasers can be classified as optically pumped laser and electrically pumped lasers, on the basis of the operation mode, laser fall into classes of Continuous Wave Lasers and Pulsed Lasers. According to the materials used to produce laser light, lasers can be divided into four categories which are solid-state lasers, gas lasers, semiconductor lasers, and die lasers [12].

1.6. Basics of laser scanners

You need not to be confused by what it means by laser scanning. In modern engineering and technology, the term ‘laser scanning’ is used to describe two separate meaning but very march related, of which is better to make the meaning clear. The first meaning which is more general, is that, laser scanning meaning is the invisible or visible controlled deflection of laser beams [13]. The Scanned laser beams are widely used in different manufacturing application such as lithography machines, in rapid prototyping, in machines for material processing, in laser engraving machines, not only that but also in ophthalmological laser systems for the treatment of presbyopia, in confocal microscopy. More ever laser scanning of the first meaning includes laser barcode scanners, printers, in laser shows and Laser TV.

The second meaning which is more specific and is mostly used in this work is that, laser scanning is the controlled steering of laser beams followed by a distance measurement at every pointing direction that is in x, y, z which is often called 3D object scanning or 3D laser scanning, is used to rapidly capture shapes of objects, buildings, and landscapes. The laser scanner are also used in subsidence monitoring, infrastructure mapping, environmental lease statistics etc.

Laser scanner, may be shortly defined as the device that creates highly accurate three dimensional image of objects by producing light that interact with the object to resulting image of objects for use of standard computer aided design software package, or in other way, a device that analyses a real-world object or environment to collect data on its shape and possibly its appearance (e.g. color). The
collected data can then be used to construct digital three-dimensional models. Laser scanners are composed of three parts:

- laser canon that generates the laser beam;
- a scanner that circulates the laser beam;
- detector that measures the reflected signal and thus measures the distance to the target [14].

1.7. Introduction to 2D and 3D laser scanners

The 2D laser scanners and 3D they all work on the same principles and techniques. They both use non-contact measurement techniques. The only different between 2D and 3D laser scanners is the output of the acquired image. 3D laser scanning is a way to capture a physical object's exact size and shape into the computer world as a digital 3-dimensional representation. It has the capability of picking up thousands to millions of points per second, measuring everything within your area of interest.

The technology creates what is called a “point cloud,” which in-turn can be used to create a 3D-model. In contrast 2D laser scanner consist of a high resolution, high speed and accurate non-contact measuring sensors for position and displacement measurement, The sensors contain a solid-state laser light source and a PSD or CMOS/CCD array detector (two dimension sensors). PSD stands for Position Sensing Detector, whereas the active pixel sensors in complementary Metal oxide Semiconductor (CMOS) and semiconductor Charged Coupled Device (CCD) is a pixelized Array Detector.

In figure 1.4 below is an example of 2D laser scanner, where most of 2D laser scanners are hand-held and short-range scanners or MicroLS are designed with triangulation-based techniques, but all Terrestrial laser scanners are designed with either pulse-based or phase-based techniques.
Laser Scanners are intended for non-contact measuring and checking of surface profile, position, displacement, dimensions, sorting and sensing of technological objects, 3D scanning [14].

1.8. Operating principle of laser scanners

A laser beam is projected on the object that needs to be measured and a portion of the beam is reflected through focusing optics onto the detector array. The result of a scan acquisition is a huge number of points in space, each having an x, y, z coordinate and usually a laser reflectance value. Some scanners even provide color information in the form of RGB values. The point cloud can be represented by drawing all these points on the screen, but this gives a very chaotic impression and a user will have difficulties recognizing structures from the cloud. When every point is given its reflectance value or a color value, the overall structure becomes understandable. Since most laser scanners scan a scene in columns and rows, one way to represent a point cloud is in a very simple way as a depth map.

A depth map is a matrix-like structure (2D) in which each pixel represents the distance of the 3D point to the scanner in the form of a grey value. Because this type of representation incorporates neighboring information, it is of great use in point cloud processing algorithms and is known as an organized point cloud. A 2D laser scanner provides distances and angles to the surrounding objects by scanning.
the environment in a plane, usually parallel to the ground. 3D laser scanning picks up thousands to millions of points per second, measuring everything within your area of interest. The technology creates what is called a “point cloud,” which in turn can be used to create a 3D-model.

This data can be exported to various standard CAD, GIS and 3D modelling programs.

At the same time that the device is picking up 3D points, it can also take high-resolution digital images which are then mosaicked together to create a single image.

This image is merged with the point cloud to create a “3D-Photo.” Every pixel shown in the merged photograph has 3D coordinates, providing accurate measurements between features [15].

1.9. Types of laser scanners

There are two main types of 3D scanners, namely Contact and non-contact 3D laser scanners. 3D contact scanners as the name suggested, the main principle is that the measured object must be in physical touch, while the object is in contact with or resting on a precision flat surface plate, ground and polished to a specific maximum of surface roughness. There is a special feature to support and held filmy in the place by fixture if the object to be scanned is either round or cannot rest in the flat surface.

The typical example of 3D contact scanner, is the Coordinate Measuring Machine (CMM). The machine is mainly composed of three axes, in the direction of X, Y, and Z, which are orthogonal to each other in a typical three-dimensional coordinate system. There is a scale system for indication of location in each axis. The touch probe may directed by the programmer or manually by the operator, so that the machine will read the input from the touch probe. To determine size and position with micrometer, the machine uses the X, Y, Z coordinates of each of these points.
There are several necessary components in Coordinate measuring machines but the following are three main components include:

- the main structure which include three axes of motion;
- probing system;
- data collection and reduction system – typically includes a machine controller, desktop computer, and application software.

Generally the coordinates measuring machines are manufactured with a variety of different probe technologies in a wide range of sizes and design, which allow them to offer different configurations such as bench top, freestanding, handheld, and portable.

1.9.1. Non-contact scanners (laser scanners)

As the name implies non-contact laser scanners there is no need to make physical contact with an object surface. Instead, noncontact 3D scanners rely on some active or passive techniques to scan an object. Non-contact laser scanning is the modern scanning techniques known as 3D non-contact scanner where high speed laser single point laser line scanning is used and is advancing very quickly. The electromagnetic waves are projected against the surface of the part, which uses either laser beams or white light. The non-contact scanning process result are highly accurate cloud of points that can be used for feature and surface inspection reverse engineering, virtual assembly, engineering analysis, or rapid prototyping. Many thousands of points can then be taken and used to not only check size and position, but to create a 3D image of the part as well. With the aid of CAD software the 3D model of the working can be created by transferring the point cloud data to those software. To facilitate reverse engineering and soft or delicate parts, the optical scanners are used [15].

1.9.2. Non-contact passive scanners

Passive 3D imaging techniques is does not depends on its own radiation but it depends on detecting reflected ambient radiation. There are several type of radia-
tions which can be detected by this system, but mostly depends on detecting visible light because it is a readily available ambient radiation. Other types of radiation, such as infra-red could also be used. They do not depend on particular hardware but simple digital cameras, for that matter techniques becomes very cheap. Just to mention some of the techniques used in non-contact passive scanners.

- The first system is called Stereoscopic where two video cameras which are placed slightly apart while looking at the same scene. The images seen by each camera are analyzed and the slight differences between them, then it becomes possible to determine the distance at each point in the images. Generally the same principles of driving human stereoscopic vision become the key to this method.

- Photometric systems depend on multiple images under varying lighting conditions, taken by use a single camera. In order to recover the surface orientation at each pixel, the techniques need to invert the image formation model.

- Silhouette is another techniques where the solution allows reconstructing the model with moderate inaccuracies using a combination of data gathered from multiple embedded sensors and processing of the data. It also depends on using outlines created from a sequence of photographs around a three-dimensional object against a well contrasted background. To form the visual hull approximation of the object, the silhouettes are extruded and intersected. The approaches ends complication where some concavities of an object (like the interior of a bowl) cannot be detected.

1.9.3. Non-contact active scanners

A non-contact scanner is the type of scanner that does not touch the measured object during measuring, but emit some kind of radiation or light and detect its reflection or radiation passing through object in order to probe an object or environment. The light pattern on the surface of the object distortion measured by sensors inside the camera. Non-contact Laser Scanners can generally be categorized into three main categories; time of flight, phase shift, and laser triangulation.
The above mentioned scanning techniques are typically used independently. The more versatile scanning system can be created by the combination of the above mentioned technologies [16].

1.10. Classification of laser scanners

There are very different ways in which laser scanners can be classified, but before much improvement, laser were used by surveyors for range measurements. Laser rangers were incorporated with theodolites to make total station that were capable of precise angular measurements using opto-electronic encoders. To build these 3D-scanning devices, many different technologies can be used of which each technology comes with its own limitations, advantages and costs. 3D Laser scanner can be classified arcading to the following criteria:

1. depending upon the scanning distance and scanning area used for capturing different sized objects that is from a small tool to a large building, or from few mm up to tens of hundreds of meters. Therefore we have, Airborne Laser Scanning (ALS) Terrestrial Laser Scanning (TLS), & Hand held laser scanner or Micro-Laser scanning (MicroLS);

2. depending upon the scanning principles we have Pulse-based; Phase based; Triangulation-based.

1.10.1. Airborne Laser Scanners (ALS)

Airborne laser scanners have being used since, the early 1980's where spatial data acquisition tasks including exploration mapping, regular mine planning and stockpile measurements was done by the aid of the analytical stereo compiler as the workhorse. It has also played a lesser role in subsidence monitoring, environmental lease statistics and infrastructure mapping. Thereafter in 1994, a new airborne terrain modelling technology has been available to the surveying industry. The term "Airborne Laser Scanner" (ALS) is a laser Profilers used primarily by the forestry industry for many years, it was then evolved as the hardware utilized in the aircraft as logical advancement measurements.
Therefore ALS has expanded its application used to capture 3D data of large areas, such as agricultural or forestry sites, urban areas, industrial plants, it was possible to scan large area in short time because the scanning system is used on an aircraft. There are different names which attributed to the same piece of hardware such as “LiDAR” (the term used in United States), and "Airborne Laser Terrain Mapper (ALTM)” is the name used to brand the major hardware manufacturer in this technology. Different names are given to the component, but laser technology is offering an alternative to traditional photogrammetric acquisition.

ALS is made up of different hardware’s but the three fundamental components of system can be summarized as follows (see figure 1.5):

- **GPS (Global positioning System )** Aircraft position is determined by kinematic dual frequency, typically at 1 second epochs;
- **Inertial Reference System (IRS)** at the rate of 50 times per second is used for monitoring Aircraft orientation or attitude;
- the terrain measurement device emits a number of discrete laser beams (typically 5000 to 25000 per second), measuring the time taken for the beam to reflect from the ground back to the aircraft [17].

![Figure 1.5 – Three components of the ALS system](image-url)
1.10.2. Terrestrial laser scanners (TLS)

Terrestrial Laser Scanning (TLS) is the base ground laser scanner and uses the same principles as ALS, but the only different is for scanning at the ground surrounding’s. TLS is a ground based active imaging method that rapidly acquires accurate, dense 3D point clouds of the object surfaces by laser range finding. For capturing discrete objects from multiple angles the laser scanner needs to be located on the ground. It is very simple to measure several thousand points per second allowing data sets to be collected far in excess of that, which could be obtained by traditional surveying or photogrammetric techniques [18].

The irregular objects such as buildings, earthworks and landforms such as cliff faces can be profiled and monitored by TLS. The system is very usefully for capturing small objects relative to those captured from an aircraft, in airborne laser scanner. As the result the technology becomes the best for digitizing large objects and entire scenes in efficient way. The development of laser technology leads to several manufacturers to offer different systems, which are designed and developed more or less for specific tasks [15].

Terrestrial laser scanning has already found its place between the standard technologies for objects acquisition. It now clear that automatically measurement all the points in its horizontal and vertical field becomes easily and possible through this system. To get the exactly information laser scanner needs to measure each point, and its distance to the laser scanner together with the horizontal and the vertical angles are recorded [15]. So, the space coordinates relative to the scanner position can be easily computed, see figure 1.6.

The dense point cloud is immediately delivered at each position of the laser scanner. Depending on the type of scanner, where Some types, can capture the whole hemisphere from just one position, as shown on figure 1.6.
The scanning process will lead to points space coordinates, where the laser scanner also measures the intensity value for each point. The electronic signal strength is obtained by converting and amplifying the backscattered optical power which define the measure of the intensity. To support the visual analysis of the point cloud depends on commonly used measurement. In the registration and the classification by the surface material property, it depends on the intensity of the points that has a potential in more sophisticated applications. The possible influence on distance measurement can be reviewed as well as the investigation of the quality of the intensity values [12].

1.10.3. Hand-held laser scanners

Are sometimes known as Micro-Laser scanning (MicroLS), are those 3D scanning devices used to scan an object over a short distance by using triangulation mechanism, (from mm to a few meters). The hand laser scanner are used in documentation of cultural artifacts, reverse engineering and prototyping, quality control/inspection. Most of hand laser scanners depends on triangulation mechanism which is discussed in the classification of laser scanners based on principle opera-
tion. Usually the laser scanner project the electromagnetics lines (waves) to the object and a sensor (typically a charge-coupled device or position sensitive device) measures the distance to the surface. The purpose of scanning is to acquire the image where, we need to have the information from features on the surface being scanned and the objects features are used to determine the position from the scanner. Also the object features can be determined by using an external tracking method.

In the external tracking method, the output is the same but with the different techniques, where to determine the orientation of the scanner) or a photogrammetric solution is by using 3 or more cameras providing the complete Six degrees of freedom of the scanner often takes the form of a laser tracker. This is possible because of integrated camera provided with position sensors. The scanner is attached with infrared Light emitting diodes which are seen by the camera(s) through filters providing resilience to ambient lighting.

The data points within three-dimensional space, are recorded and collected by computer for processing w converted into a triangulated mesh and then a Computer-aided design (CAD) model, often as Non-uniform rational B-spline surfaces. Hand-held laser scanners can combine this data with passive, visible-light sensors—which capture surface textures and colors—to build (or "reverse engineer") a full 3D model.

1.11. Classification of laser scanner basing on the scanning principles

As explained above, the classification laser scanner depending upon the scanning distance and scanning area used for capturing different sized objects that is from a small tool to a large building, or from few mm up to tens of hundreds of meters. The laser scanners have classified as, Airborne Laser Scanning (ALS) Terrestrial Laser Scanning (TLS), & Hand held laser scanner or Micro-Laser scanning (MicroLS. The next is the classification of laser scanner depending upon the scanning principles, we have the following types of laser scanners, Pulse-based; Phase based; Triangulation-based.
1.11.1. Pulse-based scanner (TOF)

This is another type an active scanner that uses laser light to probe the sub-
ject which depends on the Pulsed based laser principle. It is also called the time-of-
flight (TOF) scanner. It works by measuring, very precisely, the time taken for a
laser pulse to go out, reflect off an object, and return. Combining the range with
angle encoder measurements provides the 3D locations. Time of flight scanners are
characterized by longer range measurement, low noise characteristics, tilt compen-
sators, but slower data acquisition (4,000 to 12,000 points per second).

The TOF stand for time of flight which is calculated by finding the distance
of a surface by timing the round-trip time of a pulse of light. The amount of time
before the reflected light is seen by a detector is timed, when a laser emits a pulse
of light. Since the speed of light c is a known quantity, the round-trip time deter-
mines the travel distance of the light, which is twice the distance between the scan-
er and the surface. When t, the round-trip time, is recorded, then the distance can
be calculated with the following equation [12]:

\[
\text{Distance} = \frac{\text{Speed of Light} \times \text{time of flight}}{2}
\]

The typical time-of-flight 3D laser scanners can measure is the distance of
1,000–150,000 points every second.

![Figure 1.7 – Basic operation of timed pulse or TOF method](image-url)
1.11.2. **Phase based measurement**

In phase based measurement method scanner modulates the emitted laser beam into multiple phases and compares the phase shifts of the rebound signal energy. The scanner uses phase-shift algorithms to determine the distance based on the unique properties of each individual phase. The maximum effective range of phase based laser scanners is shorter than that of TOF based scanners usually ranging between 25–75 m but their data collection rate is much higher. The phase shift technology works by emitting a continuous laser beam with a sinusoidal wave at the center of a rotating mirror which deflects the beam out of the scanner and towards the target.

After reflection from an object, the phase shift in the sine wave of the returned signal is measured by the instrument, deriving distance. Using encoders to measure mirror rotation and horizontal rotation of the laser scanner. The 3D coordinate of each point can be calculated. Phase shift extreme speed (up to 500,000 points per second) and point density, but a shorter range, and somewhat lower positional accuracy.

Compared to the TOF scanner, this type of scanner has a high speed scanning rate and better accuracy, but a short distance in the range of tens of meters. In this technique the distance is calculated using the phase difference between the transmitted and received wave, while the transmitted beam is modulated by a harmonic wave. This technique has a higher precision. A c/w (continuous wave) laser is used as the carrier for a signal modulated onto it, typically using amplitude modulation. Finally the two phase’s signal are compared that is the emitted and the received signal.
Figure 1.8 – Phase shift comparison between transmitted and reflected signals

Figure 1.9 – Comparison of Phase and TOF

1.12. Project Objectives

Nowadays, since the required measurement speed increased beyond what contact measurement systems can provide, the current trend is to move towards
non-contact measurement systems, which use various optical sensors. However, a serious obstacle on this path is high noise level of the optical signal, which complicates the process of image recognition. Because of that, non-contact systems still haven’t completely pushed contact ones out of the market, despite their numerous advantages. Therefore, the problem of recognition of the video signal received from railway optical sensors is relevant and vital”.

Therefore the main objective of this research project is to develop an image recognition algorithm that will be effective for filtering highly correlated noise with low entropy, with the following specific objectives:

- study the laser scanners and their types;
- study the scanner protocol and software;
- conduct preliminary field tests to get experimental data;
- develop the image recognition algorithm in MatLab.

In addition, to come to the solution of the problem the system have organized, in such a way that the boggy is manually constructed and actual in-service rail track from local railways and other proper components and equipment to aid in the development of the this system consists of a computer systems, image acquisition hardware, that is 2D laser scanner and power source have organized so image acquisition, image processing and image recognition for obtaining image of actual components of in-service track from local railroads obtaining the become possible.
2. TRIANGULATION LASER SCANNING

The radiation of a semiconductor laser are projected to an object which are formed by a lens in a line. The lens collect all the scattered radiations from the object, to a two dimensional CMOS image sensor. The field Programmable Gate Array (FPGA) is used for analyzing the image of object outline and the signal processor, which calculates the distance to the object (Z-coordinate) for each point of the set along the laser line on the object (X-coordinate) see figure below.

Figure 2.1 – Triangulation laser scanning

Most of hand held laser scanners uses the principle of triangulation, where scanners that use laser light to probe the environment. With respect to time-of-flight 3D laser scanner the triangulation laser shines a laser on the subject and exploits a camera to look for the location of the laser dot. At different places in the camera's field of view the laser dot appears, but it depending on how far away the laser strikes a surface [14].

In laser triangulation, the laser is projected over an object and reflected back to the camera, and the image is captured by a camera. The term triangulation
comes because of the line joining the laser, object and the camera makes a triangle as shown in the figure below.

Figure 2.2 – Triangulation technique for laser scanning

In another language, the triangle is made up of three components within the laser scanner, the camera the laser dot, and the laser emitter which form a triangle, hence the name triangulation appear. Normally in this system, the length of one side of the triangle, the distance between the camera and the laser emitter are known. To extract the information from the scanned object, the following must be known, the angle of the laser emitter corner and by looking at the location of the laser dot in the camera's field of view, the angle of the camera corner can be determined. From the above information we can determine the shape and size of the triangle and give the location of the laser dot corner of the triangle. Usually the numbers of the laser stripes, swept across the object to speed up the acquisition process, instead of a single laser dot [21].

Most of the hand-held and short-range scanners or MicroLS are designed with triangulation-based techniques. The mapping of world to window coordinates can be done when we know the angle between the laser axis and the reflected ray from each position of the object:

- laser and camera are kept at a known distance say a;
distance between the laser and the object is say $D$;
• focal length of camera is also known say $f$.

A simple, less time and less space consuming way of finding the angle between the laser axis and the reflected ray ”$b$” is shown from the figure 2.2:

• thus for each point is calculated and is stored in a 2D array and for each $D$ corresponding value of $b$ is calculated. In the above figure 2.2, the value of $D$ and $b$ for a particular point is calculated and depending upon their values the point is plotted on the screen as shown by the dot;
• when all the points on the object are scanned, the image formed on the screen is 3D;
• once the point is drawn on the screen, we can rotate the axis in any direction, so that we can have a 3D visual. The axis and the point are shown in figure below.

But during the reconstruction process sometimes thresholding is required since noise is generated while reconstructing the depth which leads to error. Gaussian filter with a width of a few pixels can be used for filtering purpose [22].

2.1. Higher precision Triangulation laser scanning

The higher precision triangulation laser scanning the range is not determined directly, it through angle measurements. The laser energy is widened in order to form a plane, rather than a beam, where plane is swept through object space but with the help of a rotating mirror. It means that one angle of the mirror, the results in one curve or multiple curves is by intersection of this plane with the surfaces in object space [22].

The main interested are only the curves, where by to extract the curves of interest is by finding the difference image of two images. The first image being the scene without the laser plane and that which contains laser light curves being the second. The curves in the image plane form a bundle of rays, connecting the map of the curves with the projection center. The bundle with the plane of laser energy make intersection to yields the position of the points in object space.
poor quality in this methods, because the quality of the intersection decreases with range, for that reasons, this type of scanning is restricted in depth, in practical reasons, there is no big distance from the emitter to the camera. Scanning of this type of scanners is restricted to ranges of one or a few meters [22].

The precision is typically better than ±1mm. usually sequence of points along the laser light curves on the objects of interest are required not one point at a time. In a few seconds the entire field of view can be scanned. To get the best scanned image depends on many factors, among of them is the resolution of the camera. The good number of points depends can be obtained, with standard VGA [video Graphics Array] of resolution 250000 points per scan approximately [22].

2.2. Field scanning procedures using laser scanners

This part focuses on Field experience with laser scanners, the field scanning procedures where a typical scanning procedure and the associated data are be described. For a typical scanning job in the field, both reference surveying and scanning are needed. In scanning process, the proper field procedures and methodology can help to eliminate error, resulting good collected data.

2.3. Control surveying

We need to determine the relative position of natural and manmade features on or under the earth’s surface on the areas where the scanning process is to be done. It usually involves the simple scanning plans, and the determination of specific locations. By using a total station to set up a local coordinate system around the scanning area, this help to make reference surveying. The surveying data are applied for positioning of each scanning set into the global reference co-ordinate system by linking the local co-ordinate system to a global co-ordinate system [23].

3D laser scanning is a recent technology that uses laser measurements to collect thousands of points per second in an automated fashion. This technology has the potential, when properly applied, to enable 100 to 150% increases in productivity in the field. Surveying professionals are always looking for dramatic gains in
productivity in order to increase profits; however, the unfamiliar workflow, together with the unique system hardware may present pitfalls for the uninitiated.

The first commercially available 3D laser scanners were generally used for specialized applications rather than typical survey tasks. Scanner manufacturers now offer scanning systems that are truly designed for the surveying industry with software and hardware that mimic traditional surveying methodologies. In contrast, the scanner is capable of measuring thousands of points per second.

Measurement science tells us that the more observations you have the more likely that the correct answer will be obtained. Laser scanning methodologies is that the laser scanner is an indiscriminate, purely line-of-sight instrument. It will collect points on whatever it hits. As a result, obstructions cause shadows in the data, and the closer to the scanner the obstruction is the corresponding shadow is larger due to the radial nature of the measurements.

The scanning crew must take a time to study the scanner to be used in scanning process, while observing the scanners limitations and make adjustments to the field workflow to accommodate them. Factors like a scanner’s effective range help to determine the number of set-ups required the accurate acquisition of data. It is also not advisable to scan in adverse weather conditions, such as under foggy, and rainy weather that cause noise and false signal detection for the measurements.

It is good for the crew scanner to have the theoretical knowledge about the laser scanners and the scanning process. That during scanning, the so-called point cloud, which is a set of vertices in a 3D co-ordinate system, are generated as the result of raw scanning. The external surface of the object are digitally represented which are vertices usually defined by x-y-z coordinates [24].

2.4. Scanning process

For any type of laser scanners, the corresponding intensity image in both 2D and 3D can be obtained in the raw scanning data is combined as both point and intensity, which is useful for documentation and identification of objects in detail. The color photos are captured by a digital camera, when scanning at the location,
meanwhile these photos are registered to the scanning data in the software, resulting the true color 3D model of an object.

The requirements of scanning software and reference surveying, decides which operation is to be used because the operation of each scanning systems is different. The crew scanner must be correctly select the basic parameters for different applications. During the scanning process normally, the points reflected from all objects in FOV (field of view) are captured by scanners.

This is the basic knowledge in scanning process of the crew scanner which is necessary to have. Selecting the area of interest has to be done prior to modeling and any kinds of measurements.

There are several further pre-processing steps are needed, but depending on the processing software’s requirements, converting the point cloud in the required format is necessary. Other process like filtering outliers, interpolating points into a pre-defined grid are needed so as to achieve a clean dataset that meets the requirements of the further processing steps. In some applications segmentation and/or classification of certain areas in the point cloud is needed, but in most cases the entire data set has to be modeled. Modeling can cover wide ranges of procedures, e.g. triangulating surface, fitting geometric elements on the point cloud, detecting edges and creating vector model etc.

It is not necessary that to have all scanning knowledge for your first field scanning, because you need to derive particular values in some of the engineering survey. Example of these particular values are the displacement between two or more dedicated points or measuring certain distances. There are some situation in which these values are simply executed from the measurements on the point cloud.

It must be taken to account that, any scanning process must be able to extract some usefully information, The scanned results (points clouds) will be useless for the user if the required measurements, evaluations or any kinds of assessments cannot be executed [25].
2.5. Pre-processing data

The field captured scanning data, also termed raw scanning data, are necessary to make pre-processing before any further modelling and calculation. The reasons are:

- each individual scan obtains the scanning data in the local co-ordinate system, and mostly several scans are needed to cover the whole object. That is why it is important to be registered into a common co-ordinate system for each individual scan made;
- not all points in the raw scanning data can be used because there are always some noise points captured, especially there are more noise points from the phase-based scanner. Thereafter the filtration of noise points out from the raw scanning data need to be done.

Therefore there is very great need for pre-processing the raw scanning data. It is completely done by two steps:

- each individual scan must be registered into a common co-ordinate system;
- the noises points must be filtered out from the raw scanning data.

Furthermore it is necessary to convert the raw scanning data into another format because there are different data formats for the raw scanning data from different scanner producers. This is depending upon which modelling software is used for the post processing [26].

2.6. Data processing

After the field work, there are several numbers of steps in the workflow that are to be done in the office that contribute to the overall precision of the survey data.

2.6.1. Registration

Following the field work phase of the process the collected data results in a point cloud for each scan set-up. In most cases these individual point clouds need
to be combined with other scans in order to complete the picture. This process is known as registration. Registration can be accomplished through different methods depending on how the field data was collected. Just to mention few methods of registration.

**Cloud-to-cloud.** In this method the software looks for data in two or more point clouds that overlaps and tries to match common surfaces. In traditional surveying, this would be laughable due to the limited amount of redundant data. With scanning, where you are dealing with millions of points, this process works very well.

**Free station.** Another method known as “free station” uses targets placed within the scene that are visible in adjacent scans. In this method the location of the scanner is unknown and its position is calculated during the registration process. A minimum of three common targets are required, but it is more advisable to use five or more well distributed targets to ensure a good registration. Using this method requires less pre-planning in the field as the scanner location can be moved easily to a more advantageous location.

The limitations of this method are that by resecting the position of the scanner it is subject to positional error due to poorly distributed targets, it does not allow for the reoccupation of the same position at a later date, and it does not provide for a way to calculate a traverse type closure [27].

**Traverse Method.** A third method, and the most closely tied to traditional survey techniques, is the traverse method. Newer scanners now allow for set-ups to be made over ground control points in the same way as a total station. Some scanners also incorporate tilt compensators which maintain the vertical axis of the scanner. This addition greatly limits the error in registration. In essence by fixing the vertical axis, and by setting over control points orientation error is reduced to fewer variables including only the azimuth (back sight direction) and the instrument height [27].
2.6.2. Data Extraction / Modeling

All the previous steps in the workflow result in a registered point cloud. Aside from some visualization applications a point cloud alone is not that useful as a deliverable. It’s usually in a proprietary format requiring specific software and the file size is generally huge (anywhere from 1 to 120GB). Using scan oriented software, office technicians can use tools to extract specific locations that are analogous to the shots taken in a total station survey. Points, line work, and surface models can be extracted to serve as the basis for CADD drawings. Most scanning software platforms allow the user to literally pick points in the point cloud to draw lines and planes, etc. as a way of extracting data.

The picking method can be compared to the process followed by a rodman in the field. This method is quick and easy, but is subject to the level of noise in the scan data, and to inaccurate picks by the user. With proper care this method can be effectively used. Another more accurate method leverages the vast number of points in the point cloud to determine planar patches and rigid known shapes.

In many of the applications where scanning is currently used, flat planar surfaces (Buildings, structural members etc.) make up a large part of what is being located. Sub-selections in the point cloud can be analyzed by the software to establish an average surface. By using this method two adjacent walls of a building can be projected and the corner of the building can be very accurately determined.

Most software packages also can model other objects like cylinders, piping, steel members, etc. It is quite easy to compare the modeled object against the point cloud for both positional accuracy and completeness. In a total station survey the only way for the completeness of the survey is to revisit the field and visually inspect the drawing vs. the existing conditions (granted things may have changed since the original field work), and positional accuracy must either be assumed to be correct or re-measured.

In addition, with a complicated object, there can be a question as to what exactly was shot in the field. With a point cloud, the line work can be viewed along with the scan data to see exactly what is being depicted [28].
2.6.3. Post-processing data

After pre-processing of the raw scanning data, the point clouds are positioned and oriented in a certain co-ordinate system, and all scanning points are correctly located in a known co-ordinate system, so the post-processing can be performed. The post processing is done by two different situations or software, as follows.

**By special developed software.** As the scanning data are quite substantial, compared to other data, and also have a special data format, special software has been developed. These software methods can process large amounts of scanning data, and create different results, including support for a CAD model, mesh-model, cross-section, etc. And then, the results can be exported into other existing systems, such as CAD, GIS or other user-familiar systems for different applications [29].

**Input into existing software.** This was difficult in the earlier period of the development, but now many types of so called ‘plug-in’ software have been developed, and this plug-in software makes it possible to import a large scanning data file into user-familiar software, such as CAD, GIS and so on.

In addition, many hardware producers will now attract more users, so they allow their special data formats to be converted into a neutral format, available for post-processing in many different software programs [29].

2.7. The factors in the scanning accuracy

The accuracy of laser scanner is very important issue in the scanning process, because it is the one which leads to either better or worse output of the scanned object. Most the electronics instruments and components usually given the specifications by the manufactures. The same is done to laser scanner producers in their publications and pamphlets to state the laser scanner accuracy. But the experience shows that are not comparable. Sometimes the accuracy stipulated by the scanner producer in their publications and pamphlets should not be trusted. The accuracy of these instruments depends on the individual calibration and the care that...
has been taken in handling the instrument. Since these instruments (laser scanners) are built in small series varies from instrument to instrument therefore the accuracy depends very much on Individual calibration.

The point’s clouds are the results produced by a laser scanner during the scanning process, they will contains a considerable number of points that show gross errors if the scanner has the accuracy below the required. Therefore the quality guarantee, as possible for other surveying instruments, methods, and results, cannot be given. That is why some institutions had already published the methods and results concerning accuracy tests with laser scanners. The comprehensive test program was developed, based on this knowledge and as many different scanners as possible were compared since, using the same installations [30] [31].

2.7.1. Angular accuracy

The readings of angle measurements made by the laser scanners are used for the computation of the 3D point coordinates. From the basic understanding of laser scanning that, laser pulse is deflected by a small rotating device (the mirror or prism) and sent from there to the object, since the first and second angle which are perpendicular to each other, may be changed using a mechanical axis or another rotating optical device. The angular reading devices will result in errors perpendicular to the propagation path, due to errors caused by the axes or bearings. Very few investigations of this problem are known because the positions of single points are hard to be verified. By measuring short horizontal and vertical distances between objects (e.g. spheres) which are located at the same distance from the scanner, the errors can be detected.
2.7.2. Range accuracy

The range of laser scanner is determined in different manners that is depending to its operating principles of a particular laser scanner. The main range determination principles are time of flight, phase based and triangulation. By using the time of flight or a phase comparison between the outgoing and the returning signal the range for the range scanner can be computed. For any range to distances up to 100 m the ranging scanners is able to show about the same range of accuracy.

In case of Triangulation laser scanners three components within the instrument which are the reflection point on the object’s surface and the projection center of a camera, mounted at a certain distance from the deflector and the laser dot form a triangle which is used in the range determination. The camera is used to determine the direction of the returning signal. In the triangulation laser scanner the accuracy depends on the distance the scanner and the scanned object, that is the accuracy diminishes with the square of the distance between scanner and object [32].

It is not difficult to determine the ranging errors, when the scanner is used to measure the known distances in range direction the error can be determined. When the scanner is not equipped with defined reference point (such as forced centering), to measure range differences between targets it is possible. The best way of finding their accuracy if their precise positions are surveyed with instruments and methods.
are more accurate than the laser scanner, this is possible by using Plane, cylindrical or spherical targets.

When a plane target perpendicular to the observation direction is scanned, the range measurements can be achieved. This is very fast and easy way to check for the noise or accidental error, or precision of range measurements. It is very important that the standard deviation of the range differences of the points from an intermediate plane through the point cloud is computed [33].

### 2.7.3. Influence of Surface Reflectivity

For the laser scanner to scan the object, it depends on the receiving the reflected signal from the object. For the case of the ranging scanners, it is the receiving unit which receive the signal reflected back from the object. In triangulation it is the camera which receive the reflected signal from the object. The concept of the surface reflectivity comes here because each scanned object have different ability to reflect the light, apart the strength of the reflected signal which is influenced by several factors, such as distance, atmospheric conditions, incidence angle, and even the color of the object hinders the surface reflectivity.

The reflection is strong to the white surfaces whereas reflection is weak from black surfaces. The spectral characteristics of the laser such as green, red and near infrared determine the reflectivity. That is why the shiny surfaces are usually are not easy to record. It has been observed that surfaces of different reflectivity result in systematic errors in range.

The scanner technology have go further in such a way that, some scanners are made with ability of showing errors in the first points after the laser spot has reached an area of a reflectivity from previous area. After the few points then the correct range is achieved. For objects farther more, it is expected to have serious errors when scanning the object consisting of different materials or differently painted or coated surfaces.
The following are material with different colors which shows the different reflectivity:

- white dull spray paint, reflectivity 90%;
- white dull spray paint, reflectivity 80%;
- gray dull spray paint, reflectivity 40%;
- black dull spray paint, reflectivity 8%;
- spray paint with metallic appearance;
- polished aluminum foil [34].

2.7.4. Environmental Conditions

**Temperature.** Every measuring instrument operate at the specified ranges of temperature and other factors, for that matter the laser scanner, to function properly it must be used in a certain temperature range as specified. However there are some deviations may be observed even if the temperature is within the range especially in the distance measurement. The laser scanner, during the scanning process may generate the temperature above the temperature of the surrounding atmosphere due to internal heating or heating resulting from external radiation like the sun. That is why temperature effects may show systematic changes over time [34].

**Atmosphere.** Large interaction of different wavelengths of incoming solar radiation from the sun is the weather we experience at the land surface, within the atmosphere. Cloud formation, precipitation, and local weather conditions the change of the propagation speed of light due to temperature and pressure variations may affects any optical distance measurement results. The effect is not a problem for short range measurements.

**Interfering radiation.** The issue with the interfering radiation is the limited frequency band in which the laser operate. During the scanning process, enough of the ambient radiation will pass the filter and influence the accuracy or prevent any measurements if the radiation of the illumination source is strong as compared to the signal. That why filters must be applied in the receiving unit allowing only this frequency to reach the receiver respective camera [34].
3. DIGITAL IMAGE PROCESSING

This part focuses on basic of digital image processing, and steps in digital
image as well as digital image processing components.

3.1. The basic concept on Digital image processing

It is well understandable to everyone that, human beings are mostly visual
creatures. Human being rely heavily on our vision to determine and make them
know all of the world around us. For the human being it is also not possible to look
at things and easy identifying, but we can obtain an overall rough “feeling” for a
scene with a quick glance after several and different scan so that we get know what
has been looking.

However humans have evolved very precise visual skills that is why we can
identify faces and differentiate color at instant. With no doughty we able to process
a large amount of visual information very quickly. Most of the surrounding things
such like a building or a mountain, will change its appearance depending on the
time of day that is day or night. The amount of sun light whether it is clear or
cloudy, make different appearance of the same thing. It apply the same thing in
digital image processing. Therefore you may say Image is either a picture of a per-
son, of people or animals, or of an outdoor scene, or a microphotograph of an elec-
tronic component.

3.2. Image processing

Here the key is issue to deal with, is the digital image processing, which in-
volves using a computer and its processing software to change the nature of a digi-
tal image. It is important to realize the context of image. Image of an object can be
said to be the reflection of an object on mirrors, camera obscurer, or scene dis-
played on cathode ray tube, or is the visual representation of something, i.e. a pic-
ture that has been created or copied and stored in electronic form.
Therefore, Image processing is the processing of images using the mathematical operational by using any form of signal processing of which the input is an image or series of images or videos or such as photographic or video frames [35]. No need to be confused by digital signal. A signal is the function of one or more independent variables like time, distance, position, or temperature that has the information about the phenomena (event) that produces it, to make it simple, motion signal, sound signal, image signal, video signals are few example of signals. Image processing is among of rapidly growing technology of which it form a core research areas within Engineering and computer vision science.

The output of image processing may be either an image or set of image of characteristics. To be familiar with the image processing, the following, are the purposes of image processing:

- visualization (observing the object that are not seen);
- sharpening of image and restoration (to create better image);
- image retrieval (seek of the image of interest);
- measurement of pattern (measures of various objects in an image);
- image recognition (Distinguish the objects in an image).

It is very important to realize that, these five above aspects represent four separate but equally important aspects of image processing. But it also resulting an image look better. It is very necessary images looks sharp, clear and detailed, machines prefer their images to be simple and not having or impeded by too many objects, details, or elements.

In the figure below, is an example which demonstrate the processed image for enhancing the edges of an image to make it appear sharper, look how the second image appears cleaner than it was before processed [36].
Noise is unwanted signal which contain unwanted information on the image signal. Removing noise from an image is also some of process in image processing. Noise is a very common problem in data transmission, all sorts of electronic components may affect data passing through them, and the results may be undesirable.
3.2.1. Edge detection

When we take photos of different objects with any optical instruments like camera or scanner, it will tend to produce a changes in the image intensity, this is because different surfaces of an object receive different amounts of light, which again produces intensity changes in an image. This is the reason that most of geometric information that would be conveyed in a line drawing is captured by the intensity changes in an image. There are other reason of intensity changes that are not due to geometry, including the surface markings, texture, and specular reflection. Therefore the intensity boundary information that we extract from an image will tend to indicate object boundaries, but not always. That is to say the main objective of edge detection is to produce something like a line drawing of an image.

There are a lot of and variety of mathematical methods in edge detection with the mission of identifying points in a digital image at which the image brightness changes sharply or, more formally, has discontinuities. The same problem of finding discontinuities in one-dimensional signals is known as step detection and the problem of finding signal discontinuities over time is known as change detection. In machine vision and computer vision, particularly in the areas of feature detection and feature extraction, edge detection becomes the fundamental tool in image processing [37].

Figure 3.3 – Image of the simple scene and the edges extracted
3.3. Fundamental steps in image processing

The most requirements for image processing of images is that the images must be available in digitized form i.e., array of finite length binary words. A typical approach of storing an image digitally on a computer is by sampling the image at a rectangular grid. The color or intensity at each of these points is converted into a numeric value and stored in the computer. Apart from the color/intensity at those specific points, everything else is discarded when the image is stored in the computer.

Regardless of how we reconstruct the image, if we do not use enough digital samples, that is, not enough samples per image area, we are not able to reconstruct the original, continuous image. If the image is in analogy, it must be converted into digital form, before going to processing stage. Digitization includes sampling of image and quantization of sampled values. After converting the image into bit information, processing is performed [39].

In this part, we will discuss the basic necessary Image Processing steps and techniques which are:

• image acquisition;
• image enhancement;
• image restoration;
• morphology processing;
• image segmentation;
• image representation & description and finally;
• object recognition.
3.3.1. Image acquisition

To extract the information from the object, we need first to acquire video or image by any special optical component such as laser scanner. The image may be captured by a camera and converted into a manageable entity. This is the process known as image acquisition. The image acquisition process consists of three steps:

- energy reflected from the object of interest;
- optical system which focuses the energy (e.g. laser scanner);
- sensor which measures the amount of energy (e.g. CCD & CMOS in a camera).

3.3.2. Energy

Some sort of measurable energy is needed in order to capture an image. The electromagnetic waves are the energy of interest in this context. An electromagnetic (EM) wave can be described as massless entity, a photon, whose electric and magnetic fields vary sinusoidally, hence the name wave. Photons can be described in three different ways:
• a photon can be described by its energy $E$, which is measured in electronvolts [eV];
• a photon can be described by its frequency $f$, which is measured in Hertz [Hz]. A frequency is the number of cycles or wave-tops in one second;
• a photon can be described by its wavelength $\lambda$, which is measured in meters [m].

A wavelength is the distance between two wave-tops. The three different notations are connected through the speed of light $c$ and Planck’s constant $h$: $\lambda = c f$, $E = h \cdot f \Rightarrow E = h \cdot c \lambda$. An EM wave can have different wavelengths or different energy levels or different frequencies.

![Diagram](image.png)

Figure 3.5 – Overview of the typical image acquisition process

### 3.3.3. Illumination

As shown on the figure above, to capture the image some kind of energy source to illuminate the scene are needed. The Optical System such as laser scanner, after having illuminated the object of interest, the light reflected from the object now has to be captured by the camera. It is not necessary to put but you may
put the material sensitive to the reflected light placed close to the object, an image of the object will be captured.

When capturing the reflected from the object, light from the surroundings will also be captured resulting in even worse results. The solution is to place some kind of barrier between the object of interest and the sensing material. Although this will result an upside-down image, which is its consequence. Normally there is rearranges of image so that you never notice the consequence upside down of image done by the hardware and software used to capture the image.

### 3.3.4. The optical component

For the optical instrument like a laser scanner to acquire the interested image, we need the combination of two things at a time, the illumination source and the reflection or absorption of energy from that source by the elements of the scene being imaged. As stated area, the good example illumination source is a laser scanner. But, laser energy may originate from other less traditional sources, such as ultrasound or even a computer-generated illumination pattern. Here the scene elements means the scanned object, but they can just as easily be molecules, buried rock formations, or a human brain. To acquire image is not necessary only the reflection from the scene to take place, illumination energy is either reflected from, or transmitted through the objects depending on the nature of the illumination source. X ray that pass through patient’s body for the purpose of generating a diagnostic is an example of image acquiring without reflection but through the absorption or transmission. The photo converter which converts the energy into visible light are focused into the reflected or transmitted energy. Electron microscopy and some applications of gamma imaging use this approach.

In modern image processing system, there are four essential components from image acquisition to processing system:

- the image acquisition system, this can be CCD camera. Laser scanners, or video camera;
• the flame grabber, used to convert the electrical signal of the acquainted image in to digital image;
• the person computer with the processing power;
• the tool for manipulating and analyzing the images (Image processing software) [40].

3.3.5. Basics of digital image and pixel

For the basic understanding about the digital image, imagine the way you see pictures within the computers, it is just like a data structure containing a number or code for each pixel or picture element in the image. The color of each pixel is determined by this codes or numbers. That is to say every pixel, take a look like a discrete sample of a continuous real image. We can say the term digital image is a two-dimensional picture by a digital computer. Or is an array of real numbers represented by a finite number of bits [41].

Therefor the digital image is defined as “a two-dimensional function, $f(x, y)$, where $x$ and $y$ are spatial coordinates, and the amplitude of $f$ at any pair of coordinates $(x, y)$ is called the intensity of gray level of the image at that point, If $x$, $y$ and the amplitude values of $f$ are finite and discrete quantities, we call the image a digital image”. The finite number of elements which is the pixel together make a digital image, each of each have a particular location and value.

Image processing refers to digital image processing i.e., processing of a 2D picture by a computer:

• an image in “real world” is considered to be a function of two real variables, for example $a(x, y)$ with $a$ as the amplitude of the image at a real co-ordinate position $(x,y)$;
• a digital image is an image $a(x, y)$ that has been discretized both in spatial co-ordinates and brightness;
• digitization of spatial co-ordinates $(x, y)$ is called image sampling;
• amplitude digitization is called gray level quantization;
• modern digital technology manipulates multidimensional signals with systems that range from simple digital circuits to advanced parallel computers.

The image acquisition process is the results of an illumination source and the reflection or absorption of energy from that source, which generate the image by the elements of the scene being imaged. The image sensors are used to convert or transform the illumination energy into digital image. There are three types of sensors used, these are single sensors, line sensor, and Array sensor. But to be specific there are two types of array sensors used in most of camera, which are CMOS and CCD.

The full idea is simple as demonstrated in the figure above, the Incoming energy from the laser scanner is transformed into a voltage by the combination of input electrical power and sensor material that is responsive to the particular type of energy being detected. As the result the the output voltage detected by the sensor gives the waveform and a digital quantity is obtained from each sensor by digitizing its response.

![Figure 3.6 – Single imaging sensor, Line sensor, and Array sensor](image)

Therefore the idea of the digital image and pixel is that, pixel is the smallest element of an image, each pixel correspond to any one value. In 8-bit gray scale image, the value of pixel is between 0 and 255. The light photons striking at that any point, gives the value of pixel correspond to the intensity at that point. That is to say each pixel store the value proportional of the intensity of light at particular location. In a picture, there are thousands of pixel that together make up an image.
These finite number of elements, each of which has a particular location and value together make up the digital image. These elements are termed as picture elements, image elements, pels, and pixels. In most cases pixel is the term most widely used to denote the elements of a digital image [42].

3.4. Image Enhancement

During the image acquisition there are some factors which results the distorted image, thus bringing out detail that is obscured, or simply to highlight certain features of interest from an image is what we call the image enhancement. Actually decreasing or increasing the contract of an image and filter it to remove the noise so that it looks better than it was before, is an enhancement process. It not possible to discuss the image processing steps without talking about image enhancement, because it is a very subjective area of image processing. Therefore enhancement is aiming at more suitable image than the original for further image processing:

- usually to make a graphic display more helpful for display and analysis, by accentuating or sharpens image features such as edges, boundaries, or contrast;
- the enhancement increases the dynamic range of the chosen features so that they can be detected easily, but it does nothing about the inherent information content of the data. That means it does not increase more information from the original image [43].

Figure 3.7 – Image Enhancement
There are large numbers of image enhancement techniques but all of them are intending to reduce the greatest difficulty in image enhancement. Basically the enhancement methods can broadly be divided into the following two categories:

- spatial domain methods;
- frequency domain methods [44].

### 3.4.1. Spatial domain enhancement methods

As we discussed above, that pixel is the smallest element of an image, each pixel correspond to any one value, therefore the spatial domain is the technique image enhancement dealing with the image pixels. To achieve desired enhancement, the pixel values are manipulated. They are spatial domain enhancement techniques used, such logarithmic transforms, power law transforms, histogram equalization, in which all of them are based direct manipulation of the pixels in the image. The gray level values of individual pixels are directly changed and hence the overall contrast of the entire image. The key operating formula is given as

\[ g(x, y) = T[f(x, y)]. \]

Where \( g \) is the output, \( f \) is the input image and \( T \) is an operation defined over some neighborhood of \((x, y)\).

In the process of image enhancement, by spatial filtering the operations on the image pixels, can further be divided into 2 categories. These are point operations and spatial operations (including linear and non-linear operations), but we won’t discuss on point operation and spatial operations [44].

### 3.4.2. Frequency domain methods

In the frequency domain methods the Fourier Transform of the image is computed but the image is first transferred in to frequency domain. The further process of enhancement by frequency domain methods where the Inverse Fourier transform is performed to get the resultant image after the operations of the Fourier transform of the image are perfumed. As discussed above results of enhancement operation is decreasing or increasing the contract of an image and filter it to re-
move the noise so that it looks better than it was before, by modifying the image brightness, contrast or the distribution of the grey levels. As the results the values of pixel that is its intensities of the output image will be modified according to the transformation function applied on the input values [45].

3.5. Image Restoration

Acquiring good image, is very much depending on the real situation during image acquisition process. During the Image acquisition process there are several reason leading to the degraded and blur image. It is very difficult to completely avoid blur from the image, because it the results of camera shake during image acquisition. There are other environmental condition such as rain and snow resulting image noise which is unwanted signal which comes in image from sensor such as thermal or electrical signal. Therefore image restoration is process of recovering the original image by removing noise and blur or reduction of degradations from image which are included during the acquisition of images [46].

Figure 3.8 – Source of degradation during image acquisition

Distortion may arise from atmospheric turbulence, relative motion between an object and the camera and an out-of-focus camera. Restoration of degraded images is generally required for further processing or interpretation of the images. Because constraints on the degradation and the original image vary with the application, many different algorithms exist to solve the problem.
In some cases, the original image, which is modeled as either a deterministic is blurred by a known function. Many different conventional approaches have been developed to compensate for blur functions when they are known. More commonly the blur function is not known. In this case the model of the blur is often assumed, for example, a linear space- invariant filter. In some applications, several blurred versions of the same original image come from different blurring channels, or several blurred images are available from but highlycorrelated original images and channels, as in shortexposure image sequences, multispectral images and microwave radiometric images [47].

![Degradation model](image)

**Figure 3.9 – Degradation model**

The purpose of image restoration is to compensate for or undo effects. The orientation of the image restoration techniques is towards modelling the degradations such as blur and noise which involves the applications of various filters to obtain the original scene approximation.

### 3.5.1. Median Filter

This is the statistical method as implied by the name. In this method pixel value is replaced by the median of the pixels in the neighbourhood found. The usage is to remove the salt and pepper noise. It is used widely and can reduce the noise in the images excellently. This filtering removes the noise but keeps the edges. This tends to overcome the image to become blur and that is its advantage over the smoothing model [47].

![Median (Center value 18 replaced by 11)](image)

**Figure 3.10 – Median (Center value 18 replaced by 11)**
3.5.2. Adaptive Filter

In adaptive filter behaviour changes based on statistical characteristics of image inside the filter region. It is that type of linear filter which has a transfer function controlled by a variable parameter. For removal of impulse noise in images these filters use the colour and gray space in comparison to other filters. It has best noise suppression results, preserve edges in better way and hence yield better quality [47].

3.5.3. Linear Filters

In this, we replace each pixel by the linear combination of its neighbours. The operations that are implemented include sharpening, smoothing and edge enhancement. This type of filter has its implementation in salt and pepper noise and Gaussian noise [47].

3.5.4. Non Negative and Support Constraints Recursive Inverse Filtering

This filtering technique was put forward by D. Kunde. The aim is to reconstruct a reliable estimated image from a blurred image. In this algorithm estimation of the target image is made. Error function is minimized to make the estimate which contains the domains of image. The advantage is that we only need to find support domain of target area and need to be cautious such that the estimation obtained will be positive [47].

3.5.5. Super-Resolution Restoration Algorithm based on Gradient Adaptive Interpolation

The basic idea is that the local gradient of pixel affects the interpolated pixel value, in the edgy areas of the image. The influence is inversely proportional to the local gradient of a pixel. In this method three subtasks are involved: registration, fusion and deblurring. Low computation complexity is the advantage of this algorithm [39].
3.5.6. Camera filter/optical filter

Camera filters alter the properties of light entering the camera lens for the purpose of improving the image being recorded. The filter may be placed in front of the camera of which it can be either square or oblong shape mounted in a holder accessory. Filters are usually made of a glass or plastic disk with a metal or plastic ring frame. Filters have been included in the list of image processing because it can affect contrast, sharpness, highlight flare, color, and light intensity, either individually, or in various combinations. Care should be taken when using filters of this type, though often negligible, because there is possibility of loss of image definition if using dirty or scratched filters.

![Optical filters](image)

Figure 3.11 – Optical filters

3.6. Morphological processing

The word morphology is a combination of morph, Greek for “form” or “shape”, and the suffix -ology, which means “the study of”. Consequently, the word morphology means the study of shapes. Morphology is a technique of image processing based on shape and form of objects. Morphological methods apply a structuring element to an input image, creating an output image at the same size. The value of each pixel in the input image is based on a comparison of the corresponding pixel in the input image with its neighbors.
3.6.1. Morphological operations

To make up morphological operations there are techniques to use, where by many usefully defined by mathematics called mathematical morphology, where by the language of the set theory is used. The output of the image of the same size is created by applying structuring elements to an input image. The techniques of morphology are such as erosion, dilation, opening, and closing, whereby they can used separately or even the combinations of these operations are used to perform morphological image analysis. We will discuss only the basic idea of these techniques, but we won’t discuss the concept behind sets in mathematical morphology where by the object in an image is represented the set of mathematical morphology [39].

3.6.2. Dilation

Dilation is the morphological operations technique where by an image that is the same shape as the original is produced but is a different size by the transformation process. In the dilation process it stretches or shrinks the original figure, thus increases the valleys and enlarges the width of maximum regions. The dilation process removes negative impulsive noises but do little on positives ones.

3.6.3. Erosion

Erosion is the opposite of dilation in sense that, it can remove positive noises but affect negative impulsive noises little. The erosion reduces the objects in the image and known that erosion reduces the peaks and enlarges the widths of minimum regions.

3.6.4. Opening and closing Operation

Opening and closing in morphological operation may clear understood by using mathematical set theory, but closing of an image is simply the reverse of opening operation. Coming to recognizing, measuring or locating an object seen in an image requires finding what pixels in the image correspond to that object [48].
3.7. Image segmentation

Image segmentation is the image processing technique where a digital image is partitioned into several number of parts, into meaningful parts have that have similar features and properties. In order to locate and identifying objects or boundary of an image, partitioning on the basis of set of pixels in a region that are similar on the basis of some homogeneity criteria such as color, intensity or texture simplifies the process. It is first stage for many higher level image processing and computer vision operations, including shape recognition, medical imaging [48].

3.7.1. Image segmentation requirements

Although there are several proposed many techniques for segmentation but no general technique exists, which may be used for all images. However, it was suggested that good image segmentation should meet the following requirements:

1. every pixel in the image must belong to a region and each region should be homogeneous with respect to a chosen characteristic, which could be syntactic e.g. color, intensity or texture or the characteristic based on semantic interpretation;

2. every region should be connected and non-overlapping i.e. any two pixels in a particular region should be connected by a line that does not leave the region;

3. it should not be possible to merge two adjacent regions to form a single homogeneous region [49].

The tasks such as object recognition & detection, feature extraction and classification are dependent on the quality of segmentation process. The quality of image segmentation can be improved by selecting the parameters in an optimized way.

3.7.2. Image segmentation techniques

Despite the availability of many methods for image segmentation, there is no general algorithm that works well for all images, basically, there are two categories
of segmentation techniques: Edge-Based, and Region Based Segmentation, which are basing on the discontinuities or similarities.

3.7.3. Edge-Based Segmentation

The optical instruments like camera or scanner, produces a changes in the image intensity, this is because different surfaces of an object receive different amounts of light, which again produces intensity changes in an image. In digital image processing and computer vision, edge detection is very important step. Edge detection refers to algorithms which try to identify points in a digital image where there is an abrupt change in image brightness or there is a difference in intensities. The closed object boundaries is formed by linking together [49]. The corner, lines and curves are the features can be extracted from the edges of an image. In image analysis, edge detection is very necessary feature used by higher-level computer vision algorithms (e. g., recognition). The binary image is the result of segmentation using edge detection [50].

3.7.4. Region-Based Segmentation

This is another technique of image segmentation which rely on common patterns in intensity values within a cluster of neighboring pixels. The main goal of cluster, is grouping the region according to their anatomical or functional roles. The region based segmentation algorithms are simple and more immune to noise compared to edge detection method. Therefore region based methods, partition an
image into regions that are similar according to a set of pre-defined criteria. This is very different technique where in edge based methods partition an image based on rapid changes in intensity near edges [51].

### 3.8. Image representation and description

Image representation and description is critical for successful detection and recognition of objects in a scene. After an image has been segmented into object and background regions, one intends to represent and describe them in characteristic features for computer processing during pattern recognition or in quantitative codes for efficient storage during image compression.

Shape is an important visual feature and it is one of the basic features used to describe image content. However, shape representation and description is a difficult task. This is because to have 2-D image plane, one dimension of object information is lost from 3-D real world object. That is why the extracted shape from an image is partially represents the projected object.

Furthermore the shape becomes more complex because it is often corrupted with noise, defects, arbitrary distortion and occlusion. Visual information is produced by the interaction between light and the objects and attained by the ability of sight. Therefore, anything that appeals to the sight can be related to the visual information. Among different aspects underlying visual information, the shape of an object plays a crucial role. Shape represents to extents of object and can be conveyed by color or texture information. Since many properties of objects in our world are strongly determined by geometric properties, shape is one of the most important visual attributes of an object. Shape features provide a powerful clue to object identity and functionality, opening an important door for object recognition. Humans can recognize objects solely from their shapes, because; shape often carries semantic information [52].

Once the shape of interest has been acquired in the image, a set of techniques can be applied in order to extract information from the shape, so that it can be analyzed further. This process is called shape description and generally results
in a feature vector (descriptor vector). Feature extraction is performed in two steps: In the first step, shape is represented in such a way that the “important” properties of the shape are preserved for a specific application. The shape representation approaches are classified in two groups:

1) boundary based techniques (external characteristic);
2) region based techniques, i.e. the pixels comprising the region (internal characteristics).

Boundary based techniques represent the shape by its outline (external characteristics), an external representation is chosen when the primary focus is on shape characteristics. For example, a region may be represented by

- its boundary with the boundary described by features such as its length;
- the orientation of the straight line joining the extreme points;
- the number of concavities in the boundary.

An internal representation is selected when the primary focus is on reflectivity properties, such as color and texture. In all cases it is advised that the features chosen as descriptors should be as insensitive as possible to variations such as change in size, translation and rotation [53]. The classification of shape representation and description techniques, are shown which are the basic features for image and pattern recognition.
3.8.1. Representation schemes

In the representation scheme, the pixels contained in the region or raw data in the form of pixels along a boundary are the results of the segmentation techniques. The data are used directly to obtain the descriptors, example of simple descriptors such as length (e.g., for chain code), diameter (the length of major axis). In the computation of descriptors the schemes that compact the data into representations are more usefully.

3.9. Object and pattern Recognition in digital image processing

3.9.1. Basic concept of pattern recognition

When we talk about image recognition or pattern recognition, we may have a lot of difference thoughts and thinking about the real concept of that. Human beings can easily recognize (come to know) things or objects based on sensing organs in the body and past learning experiences. That why human being have an ability of sensing their environment and taking actions according to what they ob-
serve, e.g. recognizing a face, understanding spoken words, reading handwriting, distinguishing fresh food from its smell. The same situation and capabilities is given to machines. For example, if we need the computer to recognize if there is a train in a picture, the thing to be recognized is a train. But how could a computer detect a train from a matrix with thousands of elements and the value of each could have hundreds of possibilities (a digital picture is actually a 2-D array raw data). This is the key concept to understand about pattern recognition. Below is the block diagram to conceptualize the pattern recognition process [55].

![Block diagram of a pattern recognition system](image)

**Figure 3.14 – Block diagram of a pattern recognition system**

### 3.9.2. Pattern Recognition

Pattern recognition is among of the last step of digital image processing, where the raw data based on the category helps to come up with meaningfully information from the set of irrelevant details. In pattern recognition the meaning of analyzed image is discovered and provides the global understanding of the image seen.
Pattern recognition is the science and ability to extract meaning information from the set of irrelevant details, with the aid of artificial intelligence and computer vision, by making inference from perceptual data using tools in signal processing and design algorithm. Different tools are used such as statistics, probability, computational geometry, machine learning etc. This systems allow computer to interact more effectively with natural words and human such as speech recognition software. The artificial intelligence and computer vision, has wide applications in engineering, science, medicine, and business. Therefore the pattern recognition may be defined as the study of how machines can in the first step data are acquired from the environment, followed by feature extraction so as to learn to distinguish various patterns of interest from its background, and make reasonable decisions about the categories of the patterns [56].

During recognition, the given objects are assigned to a prescribed category. It is also considered as the process of classifying the given input data into certain patterns based on key features. It is also defined as a field concerned with machine recognition of meaningful regularities in noisy or complex environments. Pattern recognition is the technique where the physical object or one of several specified categories are assigned.

A pattern have the elements of similarity, in such a way that, may have a set of objects or phenomena or concepts where the elements of the set are similar to one another in certain ways or aspects. It is characterized by the order of the elements of which it is made, rather than by the intrinsic nature of these elements. Watanabe defines a pattern as “opposite of a chaos; it is an entity [57]“. It can also be defined by the common denominator among the multiple instances of an entity. On figure 3.16 are some of the examples of patterns [58].
3.9.3. Approaches of Pattern Recognition

The pattern recognition algorithm is very important that provides better results for any input data, thus they find variety application in engineering and scientific disciplines such as biology, psychology, medicine, marketing, machine learning, computer vision and remote sensing. Earlier it was studied as a specialized subject due to higher cost of the hardware for acquiring the data and to compute the answers. Pattern recognition becomes very usefully in various practical, due to the fast developments in computer technology, thus leading the demands for further theoretical developments. The pattern recognition becomes very important part, with the aid and developments of machine intelligence system that exhibit decision making capabilities, hence they were able to achieve better results. There are different types of approaches used in pattern recognition with different mathematical techniques, but for the purpose of this work, we won’t go deep to mathematical techniques and we will talk only the following three best-known approaches in the pattern recognition [58].

3.9.4. Template matching

The template matching is the technique used in the detection and recognition of objects from their images, irrespective of their orientation, scale, and view. This method is normally used in in low-level vision tasks to localize and identify patterns in images. To make template matching possible, there are two possible methods used. The first method is Image subtraction. In this the images are considered
as vectors and the measure of their dissimilarity is taken from the norm of their difference. The second method is Correlation where by the measure of their similarity is the dot product of two images. It represents the angle between the images when they are suitably normalized and considered as vectors. After the images have been normalized to have zero average and unit norms, the same results are obtained from both mentioned methods. When the images are normalized to have zero average and unit norm, the two approaches give the same result.

Furthermore in template matching the prototype of the pattern to be recognized is compared against the pattern to be recognized. The similarities between two entities such as points, curves, or shapes of the same type is carried out by matching. In this process there is availability of the template or prototype of the pattern to be recognized. Where the technique is demanding the computation.

The computer developments, has made this approach more feasible because of their higher software and their faster processors. Despite of their effective in some application, the rigid template matching have its advantages. That if the patterns are distorted due to the imaging process, or large intra-class variations among the patterns, it will end up with the fail. Deformable template models or rubber sheet deformations can be used to the match patterns if the deformation cannot be easily explained or modeled directly [60].

### 3.9.5. Statistical Pattern Recognition

In this approach, the normal statistical procedures are applied where the patterns are described as random variables. The statistical basis for classification of data are assumed in the statistical pattern recognition approach, where the random parameters represent the properties of the pattern to be recognized. In statistical pattern classification is mainly used to show in which class a given sample belongs. Just to mention the few statistical feature mean and standard deviation computations, frequency count summarizations, Fourier transformations, wavelet transformations, and Hough transformations, and the second feature describes another characteristic, and so on. All collected features generated are passed in the classifi-
cation task. The Bayes classification, hypothesis testing, correlation and statistical hypothesis testing are the statistical methodologies used for implementing this method. There is another simpler solution such as a parametric classifier based on assumed mathematical forms such as linear, quadratic or piecewise, because Bayesian classifier, its implementation is often difficult due to the complexity of the problems and especially when the dimensionality of the system is high. In these systems it is always important to understand how the number of samples affects the classifier design and performance [61].

3.9.6. Syntactic Pattern Recognition

The basic idea in syntactic pattern recognition is that it is assumed that there hierarchical relationship where a pattern is viewed as being consist of simple sub patterns which are themselves built with yet another sub pattern. That is to say there is interrelationship or interconnection between the features associated with a pattern. Furthermore, in this method the structures such as arrays, strings, trees, or graphs in symbolic data structures are used for pattern representation. These data structures define the relations between fundamental pattern components and allow the representation of hierarchical models. Thus complex patterns can be represented from simpler ones. The numbers of predefined object are compared with its symbolic representation, this is done to accomplish the recognition of an unknown pattern. The similarity measurement is computed by comparison between the unknown input and with known patterns. The patterns are represented by words of symbols or strings from the symbolic data structures.

The components of the atomic pattern are usually represented by the individual symbols in a string. Is very fantastic in this method because many patterns are inherently two or more dimensional, but the strings are one dimension in nature. Usually the graph is most useful tool and powerful symbolic structure for higher dimensional data representation. The set of nodes and a set of edges comprises the graph, not only that but also nodes represent simpler sub patterns and the edges the relations between those sub-patterns. Depending on the problem these
relation may be spatial or temporal. The graph has subclass called tree, of which root, interior and leave are three different classes of nodes. Strings and graphs in which the trees are intermediate between them, becomes very interesting for pattern recognition applications, because they are more powerful than strings. There is another special type of graph called array which has the nodes and edges arranged in a regular form.

Syntactic Pattern Recognition useful for low level pattern representation, because it provides a description of how the given pattern is constructed from the primitives in addition to classification.

In the situation where the patterns have a definite structure which can be captured in terms of a set of rules, the syntactic pattern recognition is used. The implementation of a syntactic approach is limited, because it is very difficult to use this method for segmentation of noisy patterns and another problem is inference of the grammar from training data. By combining the syntactic and statistical pattern recognition technique help to solve the problem hence the Powerful pattern recognition capabilities is achieved [42].
4. OPERATIONAL SAFETY

4.1. General Information

Graduation qualification work is related to the development of mathematical algorithms and processing data with a desktop computer. Therefore, in this section, we analyze the lighting system of the workplace and evaluate the possibility of improving the quality of lighting, taking into account the features of work and equipment used.

4.2. GOST SanPin2.2.1 / 2.1.1.1278-03

4.2.1. Requirements for the room lighting

Premises with a permanent stay of people should have natural light. Natural lighting can be divided into the following types: lateral, upper and combined.

The coefficient of natural illumination, KEO, is the ratio of natural illumination created at the design point of a given plane inside the room by the light of the sky (direct or after reflections), to the simultaneous value of the external horizontal illuminance created by the light of a completely open sky, expressed in percent.

At the top or combined natural illumination of rooms of any purpose the average value of the natural lightness coefficient (KEO) is normalized at the points located at the intersection of the vertical plane of the characteristic cross-section and the working surface. The design point is taken in the geometric center of the room or at a distance of 1 m from the surface of the wall, opposing the lateral light. Calculation of the natural lighting of rooms is done without taking into account furniture, equipment, planting trees, as well as with 100% use of translucent fillings in the floodlights. The reduction of the calculated value of KEO from the standardized KEO (en) is not more than 10%. In the workplace, one-sided side lighting, the standardized value of the KEO must be provided at a design point located at the intersection of the vertical plane of the characteristic section of the room and the floor plane at a distance of 1 m from the wall furthest from the light.
apertures: in one room for 1-, 2- and 3-room apartments and in two rooms for 4-
and more-room apartments.

4.2.2. Requirements for artificial lighting of the workplace

Artificial lighting is the lighting from electric light sources. Artificial lighting can be divided into general, local and combined.

Work lighting should be provided for all premises of buildings, as well as areas of open spaces intended for work, people's passage and traffic. The normalized values of illumination in the present norms are established at the points of its minimum value on the working surface inside the premises for discharge light sources. In the workplace, discharge lamps or accumulation lamps, predominantly halogen

Light sources created using new technologies require a sanitary and epidemiological examination before using them in artificial lighting systems.

4.3. GOST SanPin 2.2.2 / 2.4.1340-03

The work tables should be placed in such a way that the video display terminals are oriented side by side to the light apertures, so that the natural light falls mainly on the left. Artificial lighting in the premises for the operation of a personal computer must be carried out by a system of general uniform illumination. In rooms, in cases of primary work with documents, combined lighting systems should be used (in addition to general lighting, local lighting fixtures are also installed to illuminate the location of documents). Illumination on the table surface in the area where the working document is placed must be 300-500 lux. Lighting should not create glare on the surface of the screen. The illumination of the screen surface does not exceed 300 lux. We limit the direct brightness from the light sources, while the brightness of the luminous surfaces (windows, lamps, etc.) in the field of view should be less than 200 cd / m^2.

Brightness of illumination is the flow sent in this direction by the unit of the visible surface in a single solid angle; the ratio of the intensity of light in a given
direction to the area of the projection of the radiating surface on a plane perpendicu-
lar to the given direction, cd / m^2.

We take into account the reflected glitter on the working surfaces (screen, table, keyboard, etc.) due to the correct choice of the types of fixtures and the location of workplaces in relation to natural and artificial lighting sources, while the brightness of the glare on the screen of the PC should not be more than 40 cd / m^2 and the brightness of the ceiling should not exceed 200 cd / m^2. The brightness of general lighting in the area of the radiation angles from 50 to 90 ° with vertical in the longitudinal and transverse planes should not exceed 200 cd / m, the protective angle of the luminaires should be at least 40 °. Fixtures of local illumination should have an unglit reflector with a protective angle of at least 40 °. It is necessary to limit the uneven distribution of brightness in the field of view of the user of the PC, while the ratio of brightness between the working surfaces should not exceed 3: 1-5: 1, and between the working surfaces and the surfaces of walls and equipment 10: 1.

The safety factor (Kz) for general lighting lighting installations should be taken equal to 1.4 and the ripple factor should not be more than 5%.

It is possible to clean glass windows and luminaires at least 2 times a year and to make timely replacement of burnt lamps to provide normalized values of illumination in the premises for the use of personal computers.

Conclusion: In the life safety section, various possibilities for improving the quality of lighting in workplaces were analyzed, taking into account the particular work performed and the equipment used. Working conditions are optimal. Possible measures to improve performance: improve lighting in the workplace, make combined (both natural and artificial lighting, optimally halogen lamps), alternate work and gymnastics.
CONCLUSION

Non-contact measurement methods are rapidly replacing conventional contact methods in the field of railway monitoring because of their superior accuracy, higher measurement frequency, lower mechanical vulnerability and so on.

One of the most commonly used optical methods used for measuring railway parameters is laser triangulation scanning, which uses a laser (a ray or a laser line) and a camera (CMOS or CCD).

However, this method requires performing image processing of the video signal acquired from the scanner’s camera, in order to recognize the profile of the rail’s head. This task is made complicated by numerous sources of optical noise contaminating the signal.

Methods of combatting this noise include optical filtering (using polarization or interference filters) and various mathematical algorithms. Experience shows that in real-life conditions it is impossible to completely filter out optical noise, so it is necessary to use algorithmic filtering.

One of the most widely used mathematical algorithms is ICP (Iterative closest point). Unfortunately, this algorithm is very sensitive to the correlation properties of the noise; highly correlated noise can lead to false recognitions.

A more complex and computationally expensive, but more robust algorithm is CPD (Coherent Point Drift), which is based on Gaussian cores.


56. S. Watanabe, “‘Pattern Recognition: Human and Mechanical’,”


