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**ISTANBUL GEDİK UNIVERSITY**
**INSTITUTE OF GRADUATE STUDIES**

# ARTIFICIAL INTELLIGENCE UTILIZATION IN PRODUCTION QUALITY MANAGEMENT: PIPING FABRICATION

**MASTER'S THESIS**

**Ibraheem Ismael Ibraheem AL-AZZAWI**

**Engineering Management Master in English Program**

**JULY 2021**

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**Thesis Advisor: Prof. Dr. Arif DEMİR**

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LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ MÜDÜRLÜĞÜ

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**1) Tez Danışmanı:** Prof. Dr. Arif DEMİR

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**3) Jüri Üyesi:** Doç. Dr. Erhan AKMAN

## DECLARATION

I, Ibraheem Ismael Ibraheem AL-AZZAWI, do hereby declare that this thesis titled as “Artificial Intelligence Utilization in Production Quality Management: Piping Fabrication” is original work done by me for the award of the masters degree in the faculty of Engineering Management. I also declare that this thesis or any part of it has not been submitted and presented for any other degree or research paper in any other university or institution. (13/07/2021)

Ibraheem Ismael Ibraheem AL-AZZAWI

# DEDICATION

To my kind father....my role model, and my role model in life; He is the one who taught me how to live with dignity and honor.

To my tender mother... I can't find words that can give her her right, she is the epic of love and the joy of life, and an example of dedication and giving

To my brothers... my support and my support and I share my joys and sorrows.

To all evacuees; I dedicate to you my scientific research.

## PREFACE

I would like to thank my supervisors for their excellent guidance and support during this process. I also wish to thank all of the respondents; without whose cooperation I would not have been able to conduct this study.

July 2021 Ibraheem Ismael Ibraheem AL-AZZAWI

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## ABBREVIATIONS

| | |
|---|---|
| **3D** | : Three Dimensions |
| **BIM** | : Building Information Modeling |
| **CAD** | : Computer-Aided Design |
| **CSR** | : Corporate Social Responsibility |
| **CWQC** | : Company-Wide Quality Control |
| **IJCAI** | : International Joint Conference On Artificial Intelligence |
| **INS** | : International Native System |
| **ISO** | : International Organization For Standardization |
| **NDE** | : Non-Destructive Examination |
| **PCDA** | : Principal Controller Of Defence Accounts |
| **PEM** | : Product Engineering Management |
| **QA** | : Quality Assurance |
| **QAM** | : Quality Assurance Management |
| **QC** | : Quality Control |
| **QCP** | : Quality Control Program |
| **TQM** | : Total Quality Management |

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**ARTIFICIAL INTELLIGENCE UTILIZATION IN PRODUCTION QUALITY MANAGEMENT: PIPING FABRICATION**

## ABSTRACT

The development of quality control systems in production is one of the matters of concern to producers and quality control institutions alike. The pipe industry is considered one of the important industries because of its wide and sensitive applications in the infrastructure of projects, so limiting quality control to human capabilities only is considered a weakness in these systems. The benefit of the applications of artificial intelligence in quality control has been used by many producers, despite the difficulties that accompany the use of these techniques, as they require training and a special work environment. Deep neural networks were used in this work to monitor the quality of tubes and classify them according to the criteria that were determined. One of the things that have been focused on is to reduce the time and data needed to train the deep game network, by relying on the technology of transfer learning. Transfer learning is one of the ways to train deep neural networks that have been previously trained, which saves time and data for training and allows the user to use high-resolution models in the design and make some modifications to them, making them commensurate with the nature of the application he wants to design. Alexie is used in this work because it has high accuracy in the classification of images. Alexie contains 25 layers, only thee laters were modified to be suitable with our application. About 1000 images were only used in training and validation processes. The simulation results show that the transfer learning is an accepted technique and is also saves time with high accuracy results.

**Keywords:** *Quality, Pipes, Monitoring, Transfer Learning, Deep Neural Networks, Alexnet, Training, Validation.*

**ÜRETİM KALİTE YÖNETİMİNDE YAPAY ZEKA KULLANIMI: BORU İMALATI**

## ÖZET

Üretimde kalite kontrol sistemlerinin geliştirilmesi, hem üreticileri hem de kalite kontrol kurumlarını ilgilendiren konulardan biridir. Boru endüstrisi, projelerin altyapısındaki geniş ve hassas uygulamaları nedeniyle önemli endüstrilerden biri olarak kabul edilir, bu nedenle kalite kontrolünün yalnızca insan yetenekleriyle sınırlandırılması bu sistemlerde bir zayıflık olarak kabul edilir. Yapay zeka uygulamalarının kalite kontroldeki faydası, bu tekniklerin kullanımına eşlik eden zorluklara rağmen, eğitim ve özel bir çalışma ortamı gerektirdiğinden birçok üretici tarafından kullanılmıştır. Tüplerin kalitesini izlemek ve belirlenen kriterlere göre sınıflandırmak için bu çalışmada derin sinir ağları kullanılmıştır. Üzerinde durulan şeylerden biri, transfer öğrenme teknolojisine güvenerek derin oyun ağını eğitmek için gereken zamanı ve verileri azaltmaktır. Transfer öğrenimi, daha önce eğitilmiş derin sinir ağlarını eğitmenin yollarından biridir, bu da eğitim için zaman ve veri tasarrufu sağlar ve kullanıcının tasarımda yüksek çözünürlüklü modelleri kullanmasına ve üzerinde bazı değişiklikler yapmasına izin verir, bu da onları tasarımla orantılı hale getirir. tasarlamak istediği uygulamanın niteliği. Görüntülerin sınıflandırılmasında yüksek doğruluk oranına sahip olduğu için bu çalışmada Alexnet kullanılmıştır. Alexnet 25 katman içerir, sadece sizin uygulamamızla uyumlu olacak şekilde modifiye edilmiştir. Yalnızca eğitim ve doğrulama süreçlerinde kullanılan yaklaşık 1000 görüntü. Simülasyon sonuçları, transfer öğrenmenin kabul edilen bir teknik olduğunu ve yüksek doğruluk sonuçları ile zamandan tasarruf sağladığını göstermektedir.

**Anahtar Kelimeler:** *Kalite, Borular, Izleme, Transfer Öğrenme, Derin Sinir Ağları, Alexnet, Eğitim, Doğrulama.*

# 1. INTRODUCTION

Traditional building quality assurance (QA) methods are ineffective and there is great hope to increase the quality of the construction process, (Arditi and Gunaydin, 1997)(Rounds and Chi, 1985). There are currently some problems with the implementation of a Quality Assurance (QA) framework for the production of pipes for mega-building projects. Building projects are distinguished by their special existence and therefore the intrinsic lack of standardization (Rowlinson and Walker, 1995). It is also very normal to make extreme adjustments to the product design specifics over the project lifecycle. These issues may lead to delays in the completion of the project and may cause claims by the project owner and other parties, (Kanji and Wong, 1998). In addition, the QA processes depend more on paper forms and manual human activities. The main objective of this study is to enhance the existing QA practice for industrial piping by creating an automated method, thus minimizing errors and enhancing the overall QA model's accuracy and consistency. Under this primary objective, this study assesses the feasibility of using current state-of-the-art technologies to provide an inexpensive, accurate, and reliable measurement method for pipe spools.

In this study, the scope of the research presented was restricted to the quality control of pre-fabricated pipe spools. A profound change in the growth of the construction industry worldwide has been brought about by the implementation of prefabrication techniques. Prefabrication can be defined as "a manufacturing process, generally taking place at a specialized facility, in which various materials are joined to form a component part of a final installation" (Tatum, Vanegas and Williams, 1986). Improved efficiency, improved design, reduced project time, and less dependency on-site labor are advantages. For certain projects, these advantages come with a rise in prices, but could be reduced as the building industry becomes more familiar with technology(Yeung, Chan and Chan, 2002). It can be considered that any product that is manufactured offsite and is not a complete system is prefabricated.

The quality assurance method refers to the use of systematic quantitative and qualitative assessments by owners and contractors to provide sufficient trust that a product, process, or service complies with contract requirements (Lambeck and Eschemuller, 2009) In a highly complex environment, adequate quality standards in construction processes have long been a challenge to achieve on-time and a budget (Battikha, 2003).

The QA process continues until the entire project is completed(Chung, 2002). Most quality assurance processes related to design are governed by a set of criteria for the QA procedure. The responsibility of the contractor and the construction management team is to use these criteria within the quality assurance processes (Barrett, 2000). To enhance existing quality control practice for piping processes, the proposed framework considers all aspects of QA. The project manager monitors the given requirements that are compared with the required code for drawing calculations of the design. The superintendent or appointed supervisor is responsible for ensuring that the incoming, in progress, and final inspections and tests are conducted in compliance with the approved inspection and test plan or Piping System Quality Plan (PSQP) specifications for the examination and inspection program. Typically, these criteria include lengthy checklists that need to be followed. Welding tests are also carried out in compliance with the Quality Control Program (QCP) developed by the company.

The Quality Manager must make sure that each aspect of this QCP is audited at least once a year. During the audit process, non-compliant conditions are found and will be reported in a Corrective & Preventive Action Report and treated in compliance with the audit policy of the organization. In the inventory, inspection, and recalibration of QA test equipment, QA inspection and reporting systems, raw material sampling, monitoring, and handling of consumer complaints, audits discuss the assessment of manufactured pipes and fittings. It will be the responsibility of the Project Manager (PM), Production Engineering Manager (PEM), Quality Manager (QM), or Site QA Manager (QAM)/Supervisor to ensure that specifications for non-destructive examination (NDE) are established on drawings, inspection, and test plans, PSQP's, or other project documents referenced.

### 1.1 Basic Principles from the Theory of Measurements

3D laser scanners are topographic and geodetic measuring systems that have features that distinguish them from other measuring instruments. Regardless of the elements that differentiate scanners from the most traditional measuring instruments, these devices perform measurements in three-dimensional space and for this reason, it is necessary to make a brief reference to some basic principles of measurement theory which will be applied in much of implementation of the experiment of the present doctoral dissertation.

#### 1.1.1 Measurement errors

If we repeat the measurement or observation of the same quantity more than once, the resulting numerical result is not always the same. Instead, it changes from measurement to measurement. The two explanations for this fact are that a) we do not always measure the same size or b) even though the size we measure remains the same, the numerical result of the measurement does not correspond exactly to that. The reality is that both of these phenomena occur, but it is generally accepted that there is a difference between the constant "true" value of the measured quantity and the changing numerical result of the measurement. This difference is called an error. With these in mind, the relationship is valid(Δερμάνης, 1986).

$$\text{error} = \text{measurement} - \text{true value} \qquad \textbf{(1.1)}$$

In science, the word error does not have the usual meaning of the term error. When it comes to scientific measurement, the error means the inevitable uncertainty that governs all measurements. By that logic, since mistakes are not mistakes, one cannot eliminate them by being very careful. The best he can hope for is to make sure the bugs are as small as possible and estimate their size(Taylor, 1997).

**Gross errors:** These are errors that are due to human error. Typical examples of such errors are the incorrect recording of the result of a measurement, perhaps due to numbering (digit switching).

**Random errors:** Any error that cannot be described as gross or as systematic is characterized as random. The characteristic of these errors is that their prices are unpredictable. This means that random errors, under seemingly unchanged conditions at least, change from measurement to measurement. Although the behavior of each individual random error is unpredictable, the collective behavior of a fairly large number of them can be predicted, identified, and described.

The effect of errors is inevitable on measurements, no matter how many attempts are made to modify the mathematical model that describes physical reality to take them into account, some of these effects cannot be removed. In practice, they always expect some errors due to their complexity and number. For this reason, it is better to use statistics and probability tools to try to describe the behavior of their overall result, which we call random error. When analyzing data from observations, we consider that they are free from gross or systematic errors, either in advance or following specific procedures. On the other hand, random errors can not be removed but only their effect can be limited(Δερμάνης, 1986).

## 1.2 Traditional Quality Assurance Management

Present procedures for quality assurance are sluggish and susceptible to human error. Technological advancements help very few procedures. The following components are usually included in typical quality assurance procedures for the manufacture of pipes used in construction companies: drawing design and specification accounts, review and inspection program, auditing, non-destructive inspection, sealing of nameplates, repair, and alteration of shops, record keeping of the approved inspection agency and material management (Safa *et al.*, 2013).

The project manager controls the specifications presented which are compared with the appropriate code for drawing design accounts. For the inspection and inspection program, the assigned supervisor or supervisor is responsible for ensuring that incoming tests and tests operations and final tests are performed according to the approved examination and test plan or pipeline quality system (PSQP) requirements. These requirements usually contain long checklists that you must follow. Welding tests are also performed according to the company's QC program. For repairs and modifications in stores and the field, the Quality Management is responsible for ensuring compliance with the Quality Control Manual for repairs and modifications and reclassification of symbol elements. The quality manager is responsible for preparing procedures for the work done, and in the case of fieldwork, the certified inspector must be provided with those procedures(Ji and AbouRizk, 2018).

### 1.3 Laser Scanning-Based Quality Inspection of Prefabricated Elements

Until shipment to assembling or installing on-site, prefabricated building components are assembled in plants. To ensure the effectiveness of the following construction procedures, therefore geometrical quality inspections of the prefabricated elements are necessary. Present laser scanning methods can be classified into two groups of the geometric consistency inspection:

1. A model as designed.
2. Without a model as planned.

To define the quality issues of the construction elements as planned, the model is always the simple reality. By recording and comparing the point cloud data with the model as expected, variations in measurements and positions can be observed. The model can be further divided into the CAD models and BIM models, into two major groups. The geometric knowledge of building elements is only available for a CAD model(Bosché, 2010). Using an ICP-based registration algorithm, a site scan was compared with a 3D CAD model and the as-built poses of the CAD model artifacts were measured for dimension compliance control. The CAD model, however, is a mesh model, which derives geometric knowledge from its model. A BIM model richly displays objects as contrasted with regular CAD models, which only contain geometric details(Kim *et al.*, 2015). The importance of BIM models in terms of quality inspection and control is usually at two stages. The first level is the incorporation of the BIM model of product requirements, which allows for accurate and effective data processing over the life cycle of the project. The second stage is a more rigorous quality inspection of construction assisted by promptly updated and completed details(Bosché and Guenet, 2014).

### 1.4 Quality Management

In the '80s and '90s, although quality control was popular, companies from the 21st century still had difficulties with the notion at the time of industry 4.0. General Motors and Toyota's recent product reminders are remarkable examples of major problems with quality management which lead to considerable financial losses due to the increase in the cost of poor quality. To offer affordable care and innovation through service design and delivery methods, service companies face many obstacles of quality, (Gunasekaran, Subramanian and Ngai, 2019).

A recent study has confirmed that the quality of a real culture allows all employees to be passionate about imbuing rather than merely following dull rules, such as quality management systems or following best procedures and practices. Leadership, message credibility, peer involvement, employee ownership, and autonomy can significantly lower costs of poor quality and the whole cost of quality efforts The cost of poor quality for manufacturing and service organizations is estimated to range from 5% to 30% of total revenue. The good news is that organizations with a highly established quality culture spend an average of 350 million dollars less than organizations with low-quality cultures, (Chahrazed, 2019).

The quality control of the fabrication process entails checking the product's quality since the material is placed in the production line and the final product is created. The quality control shall, in particular, be based upon design, process, and manufacturing quality control plan documentation and criteria. Several factors influencing quality will be implemented to ensure that the manufacturing can meet product design and customer requirements Specific control activities, (Zhang, Jiang and Jiang, 2017). The following things should be considered for the quality control of the manufacturing process:

- A clear line of responsibility for all types of human resources.

The primary responsibility should be obvious from line length to library managers to process management personnel, operators and inspection staff, and other roles of product quality protection on the production site. The second step should be clear responsibility and authority. Specific processes and the appropriate manager of material transceivers, semi-completed/finished product turnover, process recording and self-inspection, completion inspection at the process level, and unqualified product testing and rework/repair and the other quality companies must also be determined, (Zhang, Jiang and Jiang, 2017).

- Confirmation of Incoming Quality Status:

The quality of the income state of the electrical properties of the finished product, airtightness, and manufacturability of multiple chip modules included in a broad variety of materials have a major impact. Thus, the second control of entering quality on the production plant is required by the purchase inspection, however, there must be a clear and convenient feedback channel on the presence of various difficulties with entering material, (Zhang, Jiang and Jiang, 2017).

- Verification of Security Conditions:

Safety requirements include protection of equipment, tool shielding, metering protection, sales protection, etc. The product is equipped with appropriate turnover/storage equipment to prevent bumps, whether the unit is in maintenance time and is currently in normal operational condition, whether it is in place and meets the requirements of process documentation, measurement instruments, and instruments in the period of validation, and complete with calibration. And the problems that exist should always be feedback, (Zhang, Jiang and Jiang, 2017).

- Strengthen WIP Management:

Firstly, guidelines on the creation of the bar code and the material management system. This allows a linkage between the product batch and the material batch to be built to establish traceability, with the real-time records of the installed components and the important raw material batch information. The status of the manufacture of products should be followed in real-time, if necessary streamlined into a single single product. In particular, it is important to enhance the control of unqualified product status. The problems following delivery and returned products should also be considered to eventually construct the data files for the product life cycle, (Zhang, Jiang and Jiang, 2017).

- Records of good quality data:

Quality data records in the manufacturing process must be documented before starting production. Including the operator and operating time for each step, batch information for the materials being used, the key process parameters and software programs set, production and instrumentation equipment used, electro-performance test data, self-test and inspection parameters should be collected on six elements: men, materials, method, environment, and testing, (Saleh, Sweis and Saleh, 2018).

- Improving Special Control Process:

Specific process control should be focused on the fact that, when batch-by-lot inspections in the manufacturing process, it is not easily established that the quality attributes of a product created by a particular process are qualified. Records pertinent to production should be completed on time, in-depth, and in faithful compliance with operating procedures and process documentation standards. The SPC chart can be utilized for process defects and corrective action taken in good time to preserve process stability and process output, (Saleh, Sweis and Saleh, 2018).

- Quality assessment of staff Implementation:

The awareness of quality and the degree of staff has a direct influence on the progress of production processes. Normal staff-quality surveillance and evaluation based on real process discipline should be implemented. Quality difficulties caused by lack of ability or skills and other factors, as an important basis to encourage continual self-improvement, should be included in personal-quality statistics, (Saleh and Sweis, 2017).

- Improving the statistical and analysis of quality data:

Make full use of different types of mathematical tools for statistical analysis to produce different dimensions and quality charts that are useful for obtaining information from complex data of quality in support of production decisions. A good diagram valued at 1,000 words. All statistics and the final yield of the production process, from macro-statistical through rate and output microscopic analyzes of the characteristic index by several changes to process parameters, from the horizontal comparison of quality problems of various types of products in parallel production, to the vertical tracking of the yield changes over time, (Saleh and Sweis, 2017).

## 1.5 Contributions

Study contributions may be listed in the following:

1. Minimize the human interactions in pipes production process quality management process.
2. Proposed an updatable system that can be used with other applications.
3. Utilize 3D laser scanning techniques in a computerized way to ensure the highest quality products.
4. Combine artificial intelligence AI and quality management to have modern production lines.

## 1.6 Thesis Outline

This thesis consists of five chapters. Chapter one is an introduction about laser three dimensions scanning and its utilization in quality monitoring. A literature review is discussed in chapter two. The proposed system design is discussed in chapter three, the results and discussion are listed in chapter four. Finally, the conclusions and recommondations are included in chapter five.

# 2. LITERATURE REVIEW

## 2.1 Pipes Production

The use of a semi-finished product is important for the optimal production process, both from the point of view of production and from an economic point of view. By using semi-finished products, shorter machine times and more efficient production are achieved. One of the most commonly used semi-finished products in mechanical engineering is a pipe. The term tube means a hollow blank of circular cross-section, which is defined by the outer diameter and the wall thickness. Said semi-finished product may be of different material composition, whereby the desired properties can be achieved. Depending on the wall thickness, the pipes are divided into thin-walled and thick-walled and according to the production technology into seamless and seam. Figure 2.1 shows the pipes classification.

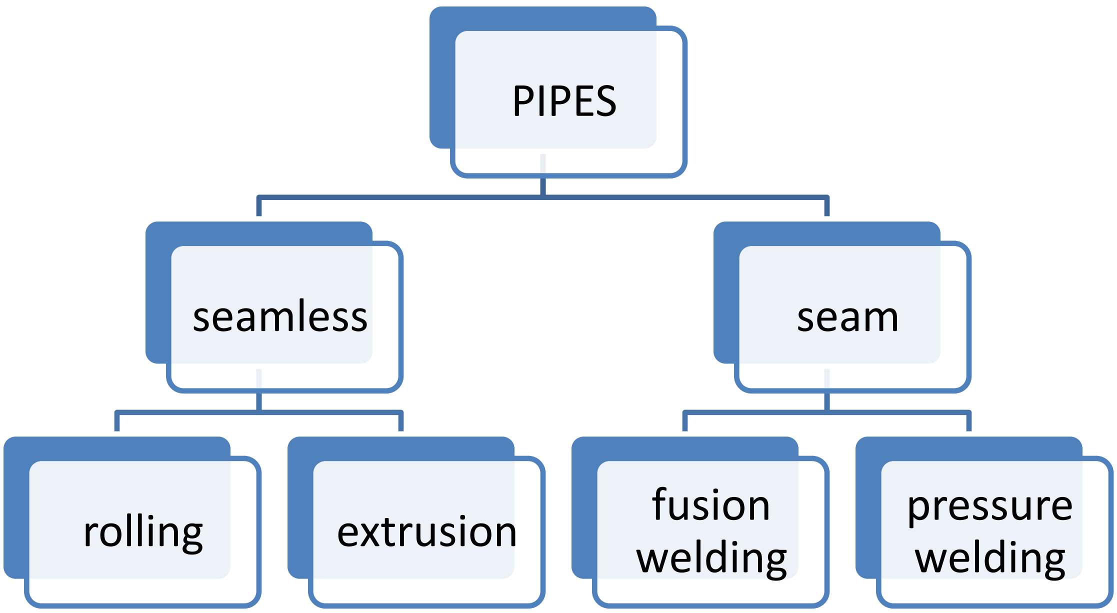



**Figure 2.1:** Pipes classification

It is also possible to classify the semi-finished product according to the design of the ends and surface on smooth, threaded, with narrowed or widened ends, etc. Steel pipes are a basic element of engineering, construction, and other technical fields.

They are used, for example, in the manufacture of structures, pipes, and the like, see Figure 2.2 (Zohuri, 2016).

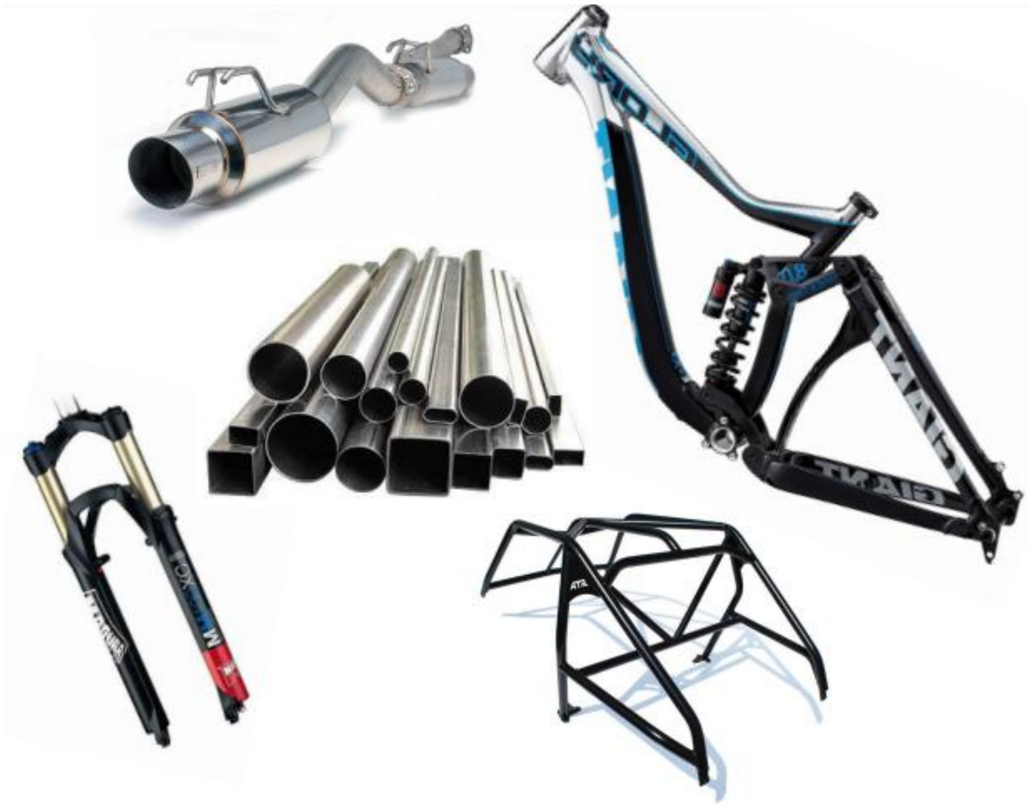


**Figure 2.2:** Examples of the use of pipes

### 2.1.1 Seamless pipes

Seamless pipes are made of solid material using technology that allows you to produce the surface without any welds. Ingots or billets, most often of circular cross-section, are semi-finished products for the production of seamless pipes. In some cases, the pipes are made of a square billet or also of a hexagonal and hexagonal ingot. Ductile properties are an important aspect of the starting material. Plastic properties depend on the forming temperature, structure, and overall homogeneity of the material. A significant advantage is a resistance to high pressure, low and high temperatures, and rust. They are produced mainly by rolling with the help of rotating work rolls, but also with the help of other technologies, such as forward extrusion.

Figure 2.3(Cernuschi, 2008) shows a seamless pipe shortly after the rolling process. One of the manufacturers is Benteler, which produces seamless hot-rolled tubes measuring 21.3 to 153.7 mm, but also precision cold-drawn steel pipe with a diameter of 4 to 160 mm. Their products are used in the automotive industry as a line for high-pressure injection systems for diesel engines with pressures up to 200 MPa. Furthermore, also in the construction, oil industry, they are used for hydraulic piping, heat transfer, as stabilizers, and others.

**Figure 2.3:** Seamless tube

Rolling is the most common production technology, it is a continuous process in which the formed material is deformed between the work rolls, which perform a rotational movement, see Figure 2.4. The gap between the work rolls is smaller than the initial dimension of the formed blank. According to the production process, a distinction is made between rolled, cold-reduced, and hot-reduced tubes.

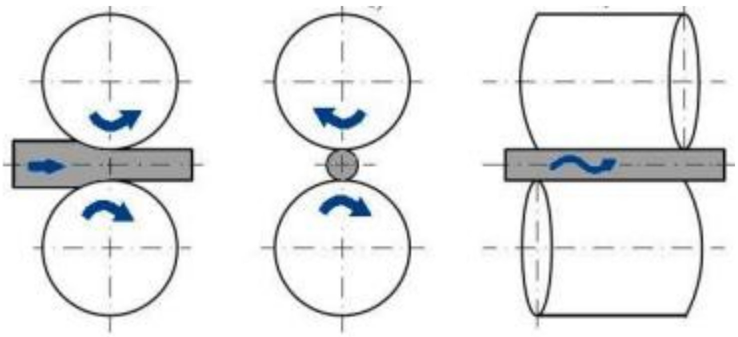


**Figure 2.4:** The principle of rolling

### 2.1.2 Seam pipes

Seam pipes are made of strip steel, the edges of which are butt welded, overlapped, or in a helix, see Figure 2.5('API 5L Welded Line Pipe Supplied by AGICO', no date). The welding process is preceded by a bending operation, which consists of gradually forming a steel strip in bending machines until the final slot pipe shape.

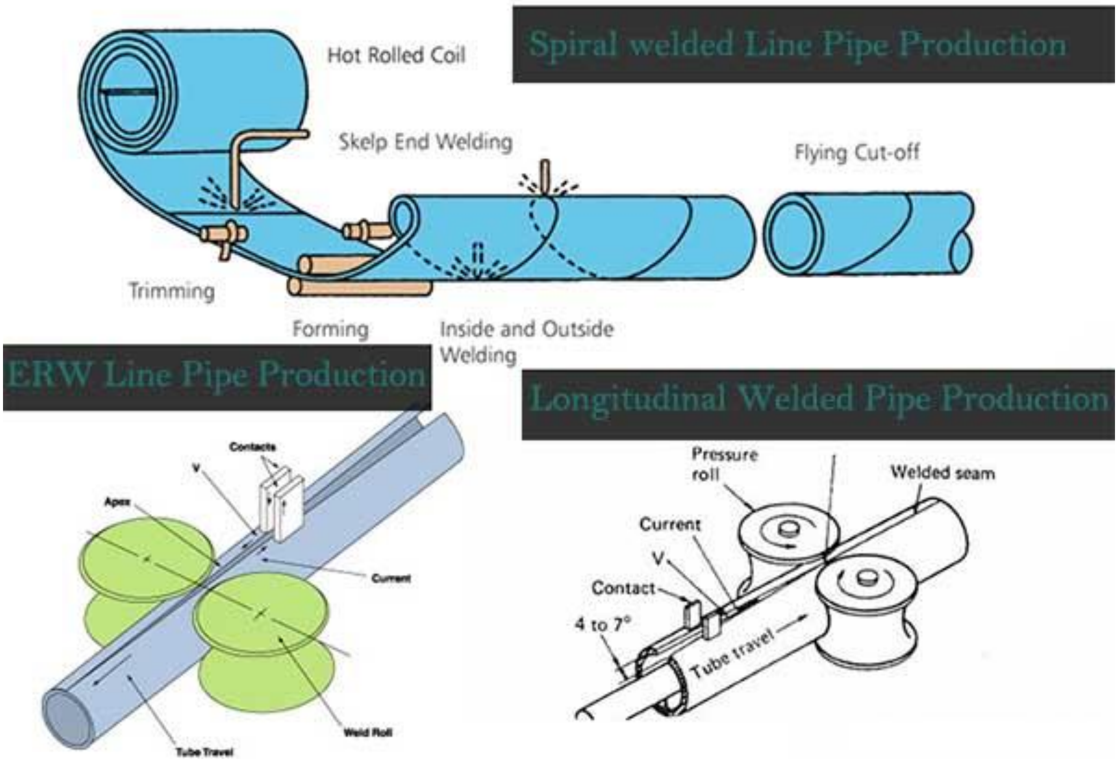



**Figure 2.5:** Possible methods of production of welded pipes

The starting semi-finished product is strip steel, which is produced by hot or cold rolling. The surface quality and dimensional tolerance of the hot-rolled steel strip coincide with the starting semi-finished product. If the pipe is made of strip steel that has been hot rolled on wide strip rolling mills, a very smooth surface with fine forging and uniform wall thickness is obtained. Pipes made of cold-rolled steel strip have a very uniform wall thickness along their entire length. Such uniformity cannot be achieved by hot rolling. The shaping of the strip, the so-called bending using profiled rollers, is a transverse continuous bending, when the thickness of the strip does not change. During this process, therefore, only a shape change occurs. Pipes with a diameter of up to 89 mm are manufactured by bending the strip through four to six passages in calibers. The number of passes depends on the mechanical properties of the individual strips, the sheet metal made of a material of higher hardness is bent by a larger number of passes, eg up to 12 pairs of rollers(STANĚK, no date).

This method of forming, which is used in the production of seam pipes, can be divided according to several technological procedures:

- The bending takes place in a series of dies, which are placed one behind the other. The rollers of the dies stretch the strip through the individual dies and gradually form it into the shape of a slit tube, as shown in Figure 2.5. These gauges are composed of two pairs of rotating rollers. The belt is gradually subjected to an increasing transverse bend, which increases continuously and gradually.

- The dies are composed of flat plates, which are placed just behind each other. The pulling stools gradually stretch the belt through the individual dies. This technological process requires high-quality lubrication of the dies due to high friction. The strip is shaped into a slit tube by successively drawing a die.
- The long rotating rollers do not exert a longitudinal tensile force on the curving belt, but there is a gradual bending of the belt between these rollers. The gap between the edges of the strip runs along the tube and is parallel to the axis. The diameter of the curved pipe can be regulated by the position of the outer cylinders and by selecting the diameter of the inner cylinder.
- By shaping the steel strip into the shape of a tube, it can also be achieved on presses.

Before the bending process, the edges of the strip are adjusted by cutting with disc shears. The machines performing these operations are located in front of the machine that performs the sheet metal bending itself. The sheets are straightened using a five-cylinder straightening machine, which consists of two upper and three lower rollers. The belt is pulled in by a pair of feed rollers and bends alternately up and down between the rollers, the axes of which must be parallel, both vertically and horizontally. The belt is drawn into the bending machine by rollers which perform a rotary movement. There are two ways to calibrate. In the first method, the cross-section of the strip is formed by two arcs, the inner arc always having the same radius of curvature, which is identical to the outer radius of the tube. This method is suitable for smaller strip thicknesses up to 2 mm. In the second method, the cross-section of the strip is bent in each individual caliber according to one radius, which gradually decreases until it reaches the radius of the pipe. Figure 2.6 shows a diagram of shaping a pipe using five calibers. The second method is also suitable for pipes of larger radii and larger thicknesses. The lower edge is always in a horizontal position, which is parallel to the junction of the axes of the individual cylinders. The rollers exert a vertical pressure on the belt and thus bend it in the transverse direction.

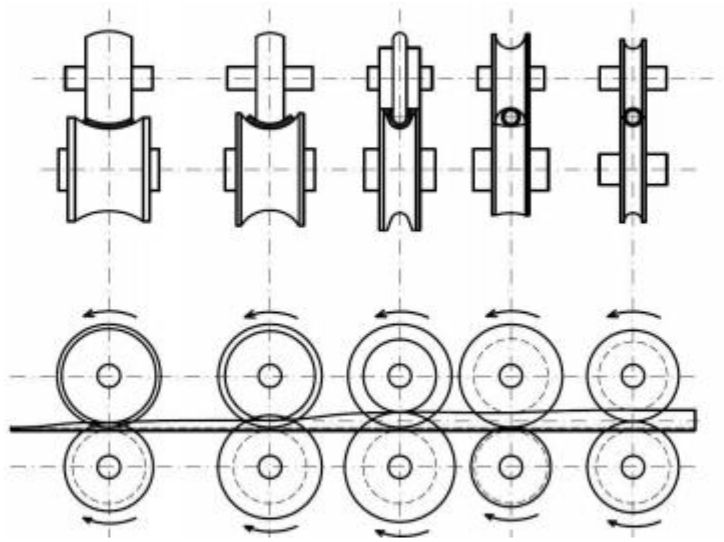


**Figure 2.6:** Schematic of the procedure for bending strip steel into a tube shape

The second step is the welding of the rolled strip steel. Today, welding technology is at such a high level that we can also produce pipes from alloy steels and high-carbon steels, which was not possible in the past. The weld itself is already of such high quality that the pipes can also be used for pipes that are designed for high pressures. The properties of the pipes are affected both by the method of welding and, above all, by the properties of the starting semi-finished product. Welded seam pipes can have a smaller wall thickness than seamless pipes and are widely used in various industries. The use depends on the welding technology used and on the method of production of strip steels. For example, pipes made of strips of greater thickness welded electrically are used for remote distribution of fluids. The main advantage in the production of seam pipes is energy and time savings and theoretically unlimited length of the produced pipe. Welding technology is divided into pressure welding and fusion welding.

## 2.2 Laser Imaging

Over the last two decades, the Close Range Photogrammetries (CRPs) have been used as survey technology instead of traditional methods and have been used instead using laser scanning technology. Significant development is realized with digitalization advances of survey and image processing techniques. Digital processing of images in various industries has begun to proliferate. In civil engineering, different works focus on strategies that combine imaging with computer vision techniques (Photogrammetry, laser scanners, robotic equipment, charging couples). In several industries, such as photogrammetry, the monitoring structures in reinforced concrete or roadway, including heritage documentation, are increasingly significant, cost-efficient, and especially attractive and inventive in excavations and artifact recording. But market demand is centered on low cost, fast, and quick construction documentation hence two different 3D digital building documentation methodologies are available (i.e., the close-range photogrammetry and terrestrial laser scanners), (Galantucci and Fatiguso, 2019). Market demand is nevertheless based on cost-effective, easy, and fast building records, and there are two different digital 3D documentation technologies (i.e., close-scope and land laser scanners) accessible. The acquisition of the important geometric parameter in construction paper might be of great aid to acquire a high precision measuring methodology, (Vosselman and Maas, 2010). In recent years, there have been substantial improvements and implementation of both survey techniques (photogrammetry and terrestrial laser scanner) in architectural sectors in areas such as civil engines, architecture, archeology, and industry. This procedure can measure the internal and external aspects of the object in 3 phases of a scanning procedure designed to build a cloud mesh point using terrestrial laser scanners and combine them with a software. In many fields, this strategy is employed as one of the photogrammetric methods utilized extensively in the sequence of images and measuring 3D model reconstruction (objects or sceneries), (Kwon *et al.*, 2004).

These techniques (photogrammetry of closing range and laser scanning) enable millions of 3-D data points to be collected in a fast and reliable manner so that efficient and dense surface geometries of cultural artifacts can be produced. Point cloud data provide baseline information for façade, plan, and part designs, which, in addition to the 3D model of the structure, require measured drawing plans. The measured drawing consists of an inspection approach that offers plans and sections for the reconstruction of an object damaged or ruined. In terms of practices of architectural conservation, art and architecture history, architecture, and architectural study these procedures are developed and monitored. Advanced methods like as photogrammetry and laser scanning have been frequently employed for documentation in recent years. This technology, a vital aspect of architectural conservation initiatives, can be utilized to create measured diagrams. These methods can also be used to document your analysis (construction features, degradations, changes, etc.). In addition to geometry, the minimum under clarity for the beam built of concrete was validating for Riviera et al. [3] to offer comparison research based on total station data. The inspection procedure on a bridge, based on both techniques of photogrammetry and TLS, was examined.

### 2.2.1 3D Laser scanning

3D laser scanners have been shown in surveys in recent decades. This is analogous to the operation of geodetic stations, which can measure distances without the use of a prism or reflector (reflectorless - prismless total stations). But 3D scanners may measure several thousand points per second, or perhaps a few hundred thousand points per second, in contrast to those which measure individual points. It is also necessary to deploy them in locations with established coordinates for geodetic stations. Instead, random data, the generated data (point clouds) refer to the instrument center and a complete overview of the study region to be carried out by transferring the clouds to the same coordinate system are common practice with a laser scanner. Of course, the coordinates of the location of the instrument, leading to the direct georeferencing of cloud spots, are allowed in many versions of laser scanning devices, (O’Keefe *et al.*, 2007).

### 2.2.2 Applications of 3D laser scanners

The introduction of laser scanning technology in the science of geometric documentation offered new possibilities in existing techniques. Since the use of laser scanners became widespread, the widest acceptance of these devices was expected by an increasing number of the scientific and professional community of geometric documentation engineers of the earth's surface and the human structures found on it. Whether we are referring to surveyors, photogrammeters, surveyors, or even Geographic Information Systems engineers, the integration of laser scanners has expanded the capabilities of the science itself and the applications that each of them serves.

Laser scanners are devices that measure the distance between two points. The first point is the one located in the mechanical center of the scanner and the second is any point located on the surface of the area or object being scanned. To achieve this measurement, most scanners emit a beam of radiation to the object and record the time it takes for the beam to reach the object and return to the device. The time recorded leads to the calculation of the distance between the two points and the latter leads to the calculation of the three-dimensional Cartesian coordinates (x, y, z), concerning the mechanical center of the scanner, the point at which the reflection of the beam took place. Up to this point in the operation, a laser scanner is very reminiscent of the way a geodetic station operates. The main difference between the two devices is the rate at which the above measurement is performed, (Ebrahim, 2015).

Laser scanners and their data (point clouds), in addition to the wide range of applications to which they are addressed, also offer many fields of research. Due to the large volume of data that emerges, great emphasis has been placed on automation techniques for their management and processing. The main categories that pique the interest of researchers and users of laser scanners are:

- Construction monitoring.
- Urban documentation.
- Forest environment.
- Documentation of monuments and archeological sites.
- Aerial scan.
- Sorting and grouping.
- Scanner quality control (this study is based on this application).
- Other studies.

It is logical and inevitable that some, if not most, of the above categories, are interconnected and include each other. It is obvious, for example, that aerial scanning is directly related to urban documentation and the forest environment, always depending on which part of the earth's surface (urban-forest) is selected as the object of research. Respectively, the monitoring of the constructions and the documentation of monuments and archeological sites are related to the urban documentation, in the case in which the construction of the monument is integrated into the urban fabric. Finally, classification and grouping are the subjects of study and research in most of the others, (Ebrahim, 2015).

Several of their features have evolved with the debut of laser scanners as an imaging technique. Devices are compacter, they do not also have to require an external power source, they do not have to operate with a computer. The software that supports current scanners is further enhanced by giving the user with the appropriate actions in point clouds and 3D models (joining clouds, creating 3D models, controlling and further processing cloud points and models). But the main change concerning scanners is the engineering community's attitude toward this kind of equipment. Laser scanner imaging techniques have been widely accepted by imaging engineers and engineers in general. Nowadays, laser scanning is considered as one of the main imaging methods and is applied in many jobs. Sometimes the use of a laser scanner is combined with the parallel use of other imaging and positioning methods. The combination of methods provides more efficient data collection and processing.

The use of laser scanners in fingerprints provides a wealth of information that is collected. Most scanners collect up to a million points per second. This leads to the possession of a large amount of data that the engineer has to process and export two-dimensional (2D) drawings or 3D models, always depending on the application. Thanks to this large amount of data, laser scanners have become a very efficient method in many applications and scientific fields. The primary data (here we are referring to the data available to the user) of the use of a laser scanner is a 3D cloud of points of interest. Laser scanner measurement belongs to the category of internationally referred to as line-of-sight measurements. This leads to the need for many different shots to obtain cloud spots for the entire object being scanned. Creating "shadows" during the measurements requires the attention of the engineer in the selection of data receiving points.

### 2.2.3 Categorization of 3D laser scanners

Laser scanners are active devices that create groups of points in 3D space. Active devices are devices that, when measured, generate their own radiation and do not depend on the radiation emitted by the object under measurement. This makes them more complex than passive devices. There is a very high data collection rate of around one million points per second. The producers of laser scanners have so evolved their models that they are compacter than previously, more user-pleasant, energy-free, and cheaper. Although there are various scanner models, certain key features to classify them are provided. The main working criterion is the most popular category of scanners. Other categorizations are based on the maximum possible measuring length and the Field of View of the device. Finally, the combination of the laser scanner with moving platforms introduced another form of categorization. This format is based on the type of platform on which the scanner is mounted. In this way, in addition to static ground scanners, dynamic ground scanners and aerial scanners are created, which are two additional techniques for mapping and solving engineering problems, (Van Genechten, 2008).

## 2.3 Artificial Inteligence

Mankind has been fascinated by artificial intelligence for almost 100 years. The first mention of artificial intelligence, although indirect, can be found in the science-fiction drama of the writer Karel Čapek R.U.R. This work dates from 1920, and the term "robot" is used for the first time. This entity is an intelligent, man-made machine capable of performing common activities, in other words, artificial intelligence within a robotic body. Artificial intelligence can be defined in several ways, but for the purposes of this work, we will limit ourselves to the following definition. Artificial intelligence is a term for simulated intelligence in machines. These machines are programmed to think like a human and mimic human or animal behavior. The ideal characteristic of artificial intelligence is the ability to logically evaluate the environment and, based on this evaluation, select an action that leads to the achievement of a certain goal, or to approach that goal('Artificial Intelligence (AI) Definition', no date).

Artificial intelligence helps people at work and assists them in other facets of their everyday lives. Yet a lot of people don't know they're using it, and for some of the artificial intelligence means just humanoid robots from science-fiction movies. However, artificial intelligence is concealed in most technology, including Internet search engines that use artificial intelligence to find relevant results for their users, smartphones with embedded artificial assistants, cars that can use it to identify road obstacles, or smart buildings that use artificial intelligence to minimize energy usage.

### 2.3.1 Definition of artificial intelligence

Artificial Intelligence (AI) is an approach to modeling, recreating, and interpreting cognitive processes and intelligence. This method includes various branches of science and uses a range of logical, empirical, computational, biological, and still mechanical concepts and devices. AI is a central branch of cognitive science. It may be abstract and theoretical as it aims to enhance and expand human understanding of natural cognition, or to prove hypotheses, or to help define the limits of computers. Artificial intelligence, however, can also be very realistic with an emphasis on smart device applications and engineering(Frankish and Ramsey, 2014).

Artificial intelligence can be regarded, from this pragmatic point of view, as the intelligence exercised by computers. In computer science, these intelligent machines can interpret their environment and take the appropriate measures to improve their chances of successfully completing their tasks. People typically use the term "artificial intelligence" in situations where computers mimic cognitive processes, such as problem-solving or learning, which people equate with other human beings and their minds.

### 2.3.2 History of artificial intelligence

The history of modern artificial intelligence starts about at the same time as the evolution of electronic computers. This section of the study, therefore, offers a brief summary of some significant and fascinating events in the history of artificial intelligence since that period. However, it is important to mention two gentlemen at the beginning, before the summary. The first is the American author Isaac Asimov, who described and published three laws on robotics in 1950. These rules are as follows: The first is that "a robot can not harm a human being or, by inaction, cause a human being to come to harm." The second, "a robot must follow the instructions provided to it by human beings except where such orders conflict with the First Law." Third, "a robot must protect its own life as long as that defense does not interfere with the First or Second Rule"(Frankish and Ramsey, 2014). The second is an English mathematician and computer scientist Alan Mathison Turing, who published Computing Machinery and Intelligence also in 1950. This publication introduced the Turing Test, which can be used to test intelligent actions. The original form of the test is the game of imitation. The theory of the game is quite plain. A man and a woman communicate with the interrogator only in written letters. The interrogator is trying to ascertain the sex of his correspondents. The woman encourages the interrogator to make the right decision, but the man tries to persuade the interrogator to make the wrong decision. In computation it operates on the same theory, the only difference being that the artificial intelligence is trying to persuade the human interrogator that it is still a human being.

The first International Joint Conference on Artificial Intelligence (IJCAI) was held in 1969. The conference was held in Washington, DC. Roger Schank's model of conceptual dependence on natural language comprehension was also established this year (Stanford). The model was later developed by Wendy Lehnert and Robert Wilensky, in their Ph.D. dissertations at Yale University, for use in story comprehension, and by Janet Kolodner for use in memory comprehension.

### 2.3.3 Artificial intelligence technologies

Developers use a broad variety of technologies with various approaches to artificial intelligence in their development. The approach chosen should allow a correct solution to the particular problem for which AI is developed, as simple as possible. However, more complicated tasks typically involve a combination of at least two technologies. An example of such a combination is a fuzzy expert system, defined by Mark Kantrowitz, Erik Horstkotte, and Cliff Joslyn (1993) as 'an expert system that uses a set of fuzzy membership functions and rules, rather than Boolean logic, to the reason for data.' This part of the study explains the three fundamental technologies chosen for artificial intelligence. The first technology is an artificial neural network, much of which is used for machine learning through imitation of biological nervous systems. The second technology is an expert framework that is used for decision-making based on experience. And the new technology is a genetic algorithm used to optimize mutations, crossovers, and choices inspired by natural evolution.

1. Artificial Neural Networks:

According to Siganos and Stergiou, "The Artificial Neural Network is an information-processing model that is inspired by the way biological nervous systems, such as the brain, process information." Artificial neural networks are based on the arrangement of a large number of artificial neurons. These neurons are the basic processing elements of the neural networks and are very well connected to each other using multiple interconnections that generate a dense network. Artificial neural networks are typically created for a particular reason(Kwok and Yeung, 1997). The method used to link the collection of neurons is defined as the topology of the network. Various types of network architectures are defined based on topological properties. Both types of topologies must include the output layer of neurons and the input layer of neurons. There are two choices for how the input layer will work. The first choice could be to insert input signals directly into the appropriate interconnection. The second possibility is realized by generating an input neuron for each input signal. These input neurons have a constant value equal to their input signal. Other neurons are then bound to these input neurons, forming a layer known as a hidden layer(Volná, 2013).

2. Expert Systems

An expert system is an intelligent computer program that simulates a human expert's decision-making to solve complex problems. The right judgment is made based on experience rather than based on a traditional form of procedure. Information is adopted by an expert system from a human expert and is specifically stored in a knowledge base. In addition to using the knowledge base, the expert method must gather information on the particular problem, and the information obtained must be processed by the inference engine. The collection of information by the expert system generally simulates a way for a human expert to collect information, which means that the expert system uses dialogues. These dialogs typically take the form of simple questions from the expert system and simple answers from the user. However, the first downside of expert systems is to collect input from the user. This drawback is because expert systems are not able to detect when the user is lying, which may result in incorrect system performance(Liebowitz, 2019).

Expert systems are made up of two primary elements, the knowledge base, and the inference engine. Awareness of a specialist in the field is stored in the knowledge base and the inference engine enables the knowledge to be applied during a consultation for a specific case. Other components of expert systems are a database for a specific situation, a justification framework that allows the system to explain the chosen method in the rationale of the system, and a user interface for contact with the user. An example of a traditional expert system that uses dialogs with the user is shown in the figure 2.7(Dvořák, 2004).

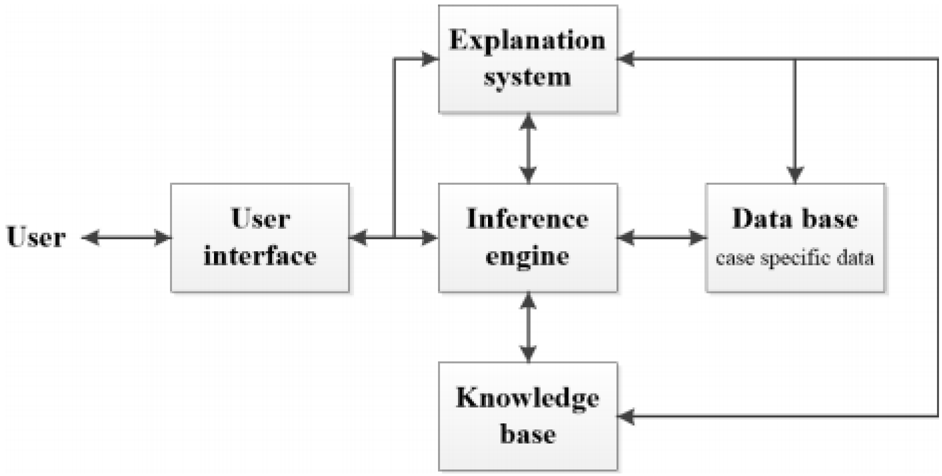



**Figure 2.7:** Scheme of an expert system

Expert systems can be divided according to a type of the solved problems into diagnostic and planning expert systems. Diagnostic expert systems attempt to determine which hypothesis from the specified set of hypotheses corresponds with the data of the specific case. On the other hand, planning expert systems solve tasks where are initial state and the result known. In these tasks, the system attempts to determine the entire procedure which will lead to that result(Dvořák, 2004).

3. Genetic Algorithms

Genetic algorithms are heuristic optimization or solution-finding procedures. The fundamental concept of genetic algorithms is based on Charles Darwin's theory of evolution and natural selection, which was published in 1859. According to this theory, populations in nature compete for resources, the ability to reproduce, and battle for survival against predators. As a result, the most successful people live longer, have a greater chance of finding a spouse for reproduction, and have more descendants than the least successful people, who will die without having a descendant. Further, these descendants should have the abilities of their successful ancestors, which should make them better adapted for life in their environment, thus, they should be the same or even more successful than their ancestors(Hynek, 2008).

A genetic algorithm by John Holland, who, according to Hynek (2008), was a pioneer in the field of genetic algorithms, uses a direct comparison of the theory of evolution. The basic genetic algorithm and its theory can be interpreted by this genetic algorithm. The algorithm starts by obtaining an initial population. This population's representatives are all searching for an encoded possible solution. The next step is for each person to be tested and given a fitness value. The final step is to build a new population using genetic operators and natural selection as a basis. For several generations, this generation cycle is usually repeated. In each generation, people with a higher fitness value are favored. Furthermore, a population with one or more individuals that match an appropriate or even ideal solution is generated after a certain number of repetitions. Genetic algorithms typically come to an end after a certain number of cycles, a certain amount of time, or when certain conditions are met(Hynek, 2008). Genetic algorithms, on the other hand, are heuristic methods, so it's difficult to guarantee that their results are flawless. These algorithms are universal since they use a wide variety of possible solutions. A simple algorithm developed for a particular problem that uses only one initial solution process, on the other hand, is typically more efficient. Furthermore, it seeks a higher-quality, quicker solution. It makes genetic algorithms particularly well suited to solving problems for which no specialized solution method exists or for which such a method is unknown. However, some extremely difficult problems may necessitate the use of both a genetic and a specialized algorithm, but generally, genetic algorithms are overused today(Mirjalili, 2019).

# 3. METHODOLOGY

## 3.1 3D Laser Scanning

In recent decades, 3D laser scanners have appeared in surveying. The operation of these devices is similar to the operation of geodetic stations that can measure distances without the use of a prism or reflector (reflectorless - prismless total stations). But unlike those that measure individual points, 3D scanners can measure several thousand points per second or even a few hundred thousand points per second. Also, for geodetic stations, it is required to place them in places with known coordinates. Instead, the usual practice with a laser scanner is to place the resulting data (point clouds) at the center of the instrument and the overall image of the area under study by transferring the clouds to the same coordinate system. Of course, in many versions of laser scanners, it is permissible to enter the coordinates of the point where the instrument is placed, which leads to the direct georeferencing of the point points (Manual, 2007).

3D laser scanners can be ground-based static, ground-based (moving on a platform, usually a car) and aerial. Dynamic and aerial scanners work in conjunction with other navigation and positioning systems to be able to know the location of the integrated system at any time. The introduction of scanning technology (laser scanning) in the science of geometric documentation offered new possibilities in existing techniques. Since the use of laser scanners became widespread, the widest acceptance of these devices was expected by an increasing number of the scientific and professional community of geometric documentation engineers of the earth's surface and the human structures found on it. Whether we are referring to surveyors, photogrammeters, surveyors, or even Geographic Information Systems engineers, the integration of laser scanners has expanded the possibilities of the science itself and the applications that each of them serves.

Laser scanners are devices that measure the distance between two points. The first point is the one located in the mechanical center of the scanner and the second is any point located on the surface of the area or object being scanned. To achieve this measurement, most scanners emit a beam of radiation to the object and record the time it takes for the beam to reach the object and return to the device. The time recorded leads to the calculation of the distance between the two points and the latter leads to the calculation of the three-dimensional Cartesian coordinates (x, y, z), concerning the mechanical center of the scanner, the point at which the reflection of the beam took place. Up to this point in the operation, a laser scanner is very reminiscent of the way a geodetic station operates. The main difference between the two devices is the rate at which the above measurement is performed. A geodetic station offers the ability to measure a point every about 1-3 seconds. Laser scanners can measure several thousand points per second. In this way, they create large blocks of data which are called point clouds. That is, a cloud is a set of points, each of which is described by its coordinates in three-dimensional space. The point clouds can be so dense that the points are a few millimeters apart or even shorter(Lerch, MacGillivray and Domina, 2007). Laser scanners and their data (point clouds), in addition to the wide range of applications to which they are addressed, also offer many fields of research. Due to the large volume of data that emerges, great emphasis has been placed on automation techniques for their management and processing. The main categories that pique the interest of researchers and users of laser scanners are:

- Construction monitoring.
- Urban documentation.
- Forest environment.
- Documentation of monuments and archeological sites.
- Aerial scan.
- Sorting and grouping.
- Scanner quality control.
- Other studies.

Since the introduction of laser scanners as a method of imaging, many of their features have changed. The devices have become more compact, they do not need an external power source and also, they do not need to use a computer to work. The software that accompanies modern scanners has become more sophisticated by providing the user with tools for the necessary actions in point clouds and 3D models (joining clouds, creating 3D models, controlling and further processing cloud points and models). But the most important change regarding scanners is the perception of the engineering community about this type of technology. Laser scanner imaging techniques have been widely accepted by imaging engineers and engineers in general. Nowadays, laser scanning is considered as one of the main imaging methods and is applied in many jobs. Sometimes the use of a laser scanner is combined with the parallel use of other imaging and positioning methods. The combination of methods provides more efficient data collection and processing(Liang *et al.*, 2016).

The use of laser scanners in fingerprints provides a wealth of information that is collected. Most scanners collect up to a million points per second. This leads to the possession of a large amount of data that the engineer has to process and export two-dimensional (2D) drawings or 3D models, always depending on the application. Thanks to this large amount of data, laser scanners have become a very efficient method in many applications and scientific fields. The primary data (here we are referring to the data available to the user) of the use of a laser scanner is a 3D cloud of points of interest. Laser scanner measurement belongs to the category of internationally referred to as line-of-sight measurements. This leads to the need for many different shots to obtain cloud spots for the entire object being scanned. Creating "shadows" during the measurements requires the attention of the engineer in the selection of data receiving points.

### 3.3.1 Categorization of 3D laser scanners

Laser scanners are active devices that create groups of points in 3D space. Active devices are devices that, when measured, generate their own radiation and do not depend on the radiation emitted by the object under measurement. This makes them more complex than passive devices. The data collection rate is very high, approaching one million points per second. Laser scanner manufacturers have developed their models to such an extent that they are more compact than before, more user-friendly, energy independent, and affordable to many users. Although the various scanner models are diverse, there are some key features to their classification. The most common categorization of scanners is based on the working principal criterion. Other categorizations are based on the maximum possible measuring length and the Field of View of the device. Finally, the combination of the laser scanner with moving platforms introduced another form of categorization. This format is based on the type of platform on which the scanner is mounted. In this way, in addition to static ground scanners, dynamic ground scanners and aerial scanners are created which are two additional techniques of mapping and engineering problem solving (Van Genechten, 2008).

#### 3.1.1.1 Categorization of 3D laser scanners based on the working principle

The term "principle of operation" refers to how laser scanners generate 3D point clouds. The principle of operation is the main factor that affects the properties of a scanner, the length it can measure and the accuracy it can achieve. In turn, all the above features are the factors that determine the applications in which the scanner will be used. The categorization of laser scanners according to the principle of operation raises three categories. Pulse time-of-flight scanners, phase comparison scanners, and space point scanners using principles from triangulation theory (triangulation scanners). Pulse flight time scanners and phase comparison scanners measure the time interval between two events. The first event is the emission of a laser pulse and the second event is the reception of the corresponding pulse reflected by the object. These two types of scanners are also called time-based scanners.

- **Pulse flight time scanners**

Pulse flight time scanners use devices that can and do measure rangefinders with a high degree of accuracy. Pulse-based pulse-based time-scanners use a timekeeper to calculate distances. A source, placed in the device, generates a laser pulse and emits it to the object under capture. The pulse beats on the surface of the object and is reflected from it. Finally, the reflected pulse is received from the device. The time between the emission of the laser pulse and the reception of the reflected pulse is measured using high-precision clocks(Petrie, Toth and Shan, 2009). Figure 3.1 explains the operation principles of this type of scanners(Van Genechten, 2008).

By measuring the time interval t and knowing the speed of the radiation in the air, the scanner is able to calculate the distance D between the mechanical center and the point where the pulse is reflected from the surface of the object. The calculation of the distance is possible given the equation 3.1(Van Genechten, 2008):

$$D = 0.5\, c.t \qquad \textbf{3.1}$$

The desired distance is calculated by dividing in half the distance covered. The fact that pulse flight time scanners emit each subsequent pulse waiting for the previous reflector to return makes them slower to measure points than phase comparison scanners. The low point count rate is in the order of thousands or tens of thousands of points per second. The integration of devices that can transmit more than one pulse at a time has significantly improved the point-and-shoot rate. Pulse flight time scanners measure distances of a few meters and hundreds of meters for ground applications and distances of kilometers and hundreds of kilometers for aerial and satellite applications respectively(Petrie, Toth and Shan, 2009).

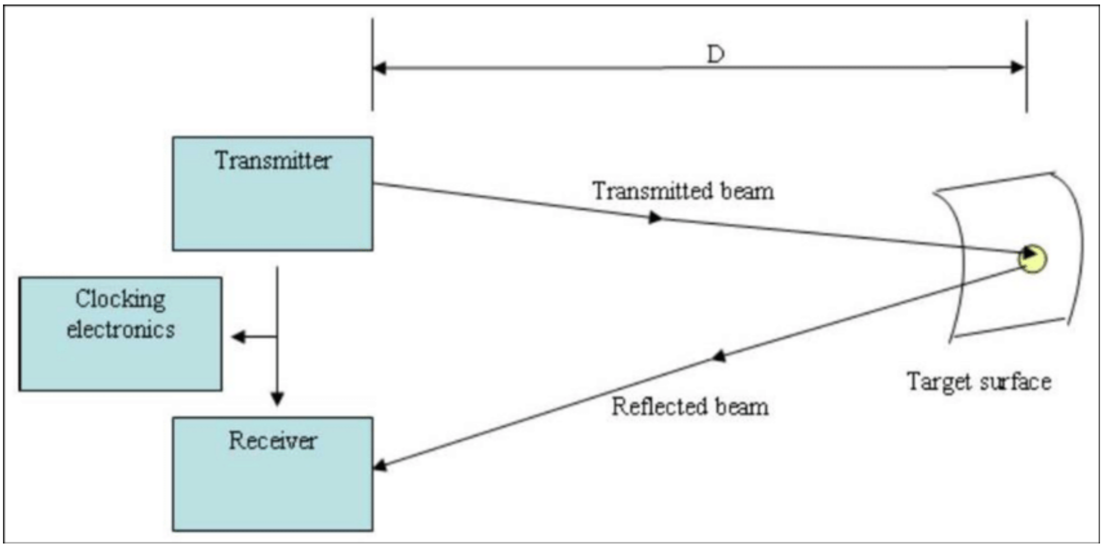



**Figure 3.1:** Principle of operation of time-of-flight scanners

- Phase comparison scanners

Phase comparison scanners emit laser radiation as a continuous wave(Petrie, Toth and Shan, 2009). These types of scanners also rely on time measurement, but differ from pulse flight time scanners in that they measure the time between transmitting and receiving the reflected pulse. These devices compare the phase of the emitted wave with that of the wave received after reflection and calculate the phase difference. Then the time interval is calculated from equation 3.2(Petrie, Toth and Shan, 2009).

$$t = \frac{\Delta\varphi}{2\pi f} \qquad \textbf{3.2}$$

Phase comparison scanners have a shorter length measurement limit than pulse flight time scanners, but have a higher point measurement rate. Phase comparison scanners are widely used in ground applications that require distance measurements of up to 100 meters. The measurement rate is about one million points per second.

- Laser scanners that measure points in space using principles from the theory of triangles (triangulation scanners)

The last category of laser scanners, regarding the principle of operation, are the scanners that use the method of triangles to measure points in space (triangulation scanners). Like the other two classes of scanners, they use a device that emits laser radiation. The difference with other scanners is that there is no timekeeping. The transmitted pulse strikes the surface of the object and the point at which the reflection occurs is recorded by a CCD device. The distance D between the transmitter and the engine is known. The angle α, which is formed from side D and the direction of the emitted radiation, is also known. Finally, the angle β, formed between the side D and the direction of the reflected radiation towards the camera, can be determined by detecting the radiation in the field of view (Field Of View) of the camera. Taking into account the above parameters, the remaining elements of the triangle "transmitter-point on the object-CCD machine" can be calculated. Triangular scanners have the lowest distance measurement limit. Applications made with this type of scanner require distance measurements of less than 10 meters. Some alternative methods use pointless emitting devices. Lines, simple or more complex patterns can be used to cover the whole object Due to the limited range, scanners based on the triangle method are not used in topographic and mapping applications.

#### 3.1.1.2 Categorization of 3D laser scanners based on the field of view (Field of View)

The classification of laser scanners based on the field of view refers to static ground laser scanners. The best-known classification of terrestrial laser scanners was made by (Staiger, 2003) and divides scanners into three categories.

The simplest category is that of camera-type scanners. This type of scanner has a limited field of view (approximately 40ox$40^o$). They do not contain any mechanism of rotation on any axis. In contrast, hybrid scanners allow unrestricted movement around one of the axles (usually horizontal movement is allowed). Regarding vertical movement, it is limited due to the use of mirrors around $60^o$. Finally, panoramic scanners allow movement on both axes. The horizontal field of view covers a circle ($360^o$) and the vertical is limited only by the instrument and the tripod on which it is mounted. In this way, it allows a field of view that in many cases reaches $270^o$.

#### 3.1.1.3 Categorization of 3D laser scanners based on measuring range-range

The measuring length of a terrestrial laser scanner depends on its principle of operation. The method used to operate the device defines the limits and applications in which it will be used. According to the measuring range, scanners are divided into short-range, medium-range, and long-range laser scanners(Petrie, Toth and Shan, 2009). Short-range laser scanners are either pulse flight time scanners or phase comparison scanners, but in most cases fall into the second of these categories. Phase comparison scanners provide higher accuracy than pulse flight time scanners, but are limited to applications that require length measurements from a few meters to a maximum of about 100 meters. They are panoramic scanners and that is why they are very useful for indoor applications. Also, outdoor applications are required which require short distance measurement.

Medium range scanners measure distances of approximately 150 to 350 meters. They are exclusively pulsing time scanners and thus have a slower data collection rate than short-range laser scanners(Petrie, Toth and Shan, 2009).

#### 3.1.1.4 Categorization of 3D laser scanners based on their placement platform

The latest classification of laser scanners that are being investigated, separates the scanners according to the platform on which they are placed during their operation. According to this criterion, there are three main types of scanners. The first type is static ground laser scanners. Static scanners are mounted on tripods during measurements. It is the most common scanning technique and, in many cases, has replaced the traditional topographic and photogrammetric techniques. It is the most suitable technique for interiors such as the documentation of buildings, monuments, and mines. Their use is also widespread in industrial applications, terrestrial and marine, which require high precision and complete modeling. The second type of scanners, always according to the type of platform, is the dynamic ground scanners. These scanners operate mounted on a moving vehicle. Dynamic ground-based scanners were initially implemented by research institutes and later made available for commercial applications. The use of a dynamic scanner raises the need for continuous geo-reporting. Continuous knowledge of the position of the moving vehicle is provided by the integration of GPS receivers and inertial systems (Inertial

Navigation System-INS). Although they are ground-based methodologies, dynamic scanners have more in common with over-the-air scanning systems than ground-based static scanners. This is due to the movement of the vehicle and the constant need to regain its position(Petrie, Toth and Shan, 2009).

The latest category of laser scanners, according to the measurement platform, are aerial scanning systems. Similar to dynamic ground-based scanning systems, there is a need for continuous knowledge of the location of the vehicle in which the scanner is mounted (helicopter, airplane). For this reason, it is necessary to integrate GPS and INS systems. Different airborne scanning systems use different standards to scan the surface of interest. Some models are serrated or sinusoidal in shape. Also, some systems use an elliptical pattern or lines parallel to the flight direction (Petrie, Toth and Shan, 2009).

### 3.2 Pipe Image Pre-Processing

Analyzing and identifying these pipe photos presents a number of issues. The first challenge is creating a mathematical model for each object of interest, which is simple for conventional, well-known structures like joints and laterals but much more difficult for random, irregular holes and joints. Then there's the issue of the background, which is frequently patterned and busy, resulting in erroneously identified edges. Finally, there's the issue of low contrast, especially between tiny fractures and the background. As a result, using digital picture data usually necessitates some preprocessing, such as geometric correction, image enhancement, and feature selection, (Rosenfeld, 1982). Geometric correction, for example, entails reorienting image data to specific parameters [8], allowing for precise crack feature spatial assessments and measurements. Picture enhancement aims to improve image data by suppressing undesired background distortions or enhancing certain image elements (such as fractures) that are useful for subsequent processing. The main goal of picture pre-processing is to transform an image into something that is better suitable for a given purpose than the original. The word Fspecific_ is significant because it establishes right away that the approaches covered in this section are primarily problem-solving techniques.

### 3.2.1 Bayesian classification

A pattern classification issue can be used to determine the boundary between things and their environment (Pratt and Wiley, 1978). It is specifically desired to classify a pixel as to whether it came from the same item or the nearby background. A color pixel $x_c = (r, g, b)^T$ can be characterized as a crack in a Bayesian framework if its a posteriori probability P(Crack|x) is greater than the corresponding a posteriori probability P(Back|x) for the surrounding pipe background. Bayes' Rule can be used to derive the associated a posteriori probability if the class-conditional probability densities p(x|Crack) and p(x|Back) are known.

### 3.2.2 Segmentation of buried pipe images

Pipe joints (a horizontal dark straight line), pipe laterals (a circular dark object), surface fractures (randomly shaped thin dark lines), and pipe backdrop must all be distinguished in our suggested automated pipe analysis (highly patterned). Pipe joints, laterals, and cracks are all dark, therefore segmenting them will plainly require some discrimination based on geometry and shape. For extracting joints and laterals, a morphological segmentation approach based on set-theoretic principles of shape is proposed in (Abutaleb, 1989) study. The major goal of this method is to remove the pipe joints and laterals from the image, allowing the minor surface fractures to be removed more easily by a subsequent filtering step.

Although the literature [48] has a great number of segmentation algorithms, the literature on segmentation of concrete pipe flaws is quite sparse. Maser's technique [17] suggests using a histogram thresholding approach, although it's unclear how the threshold value is generated. Chen et al. [47] used a segmentation approach introduced by Kittler et al. [48] to segment pavement photos, however the method's efficiency is unknown. Mohajeri and Manning (Hasni *et al.*, 2017)use directional filters to categorize the objects in a method for recognizing segmented pavement distress photos. The entropy-based strategy, which establishes a bilevel threshold to maximize entropy criteria, did not improve the photographs of the pavement surface. A large degree of inaccuracy was recorded in the cluster classification method, which assigns a particular object to one of several groups by comparing typical traits from each group.

### 3.2.3 Mathematical morphology

For image analysis, smoothing, segmentation, edge detection, thinning, form analysis, and coding, mathematical morphology is a commonly used methodology. Mathematical morphology is a rapid, reliable method for analyzing the geometry of an image directly in the spatial domain, based on a formal mathematical foundation. We provide a morphological strategy for segmenting underground pipe images in this part, which comprises describing object sizes in a pipe image, thresholding the image into a binary image, and then classifying the segmented image.

### 3.2.4 Morphological segmentation

The following classes are of common importance in underground pipe picture segmentation: pipe joints (horizontal dark straight lines), pipe laterals (circular dark objects), surface cracks (irregularly shaped thin dark lines), and pipe backdrop (anywhere from a smooth to a highly patterned surface). The purpose of our study is to segment pipe joints, laterals, and cracks based on their geometric variations, particularly morphology. The morphological method is based on the idea of distinguishing objects based on their shape. The key idea of this method is to use two parameterized structuring elements: a circular structuring element (SC) of radius r, and a horizontal structuring element (SH) of varying length l and fixed width w = 3. With the canonical shapes being thin and wide, large and round, and small and irregular (cracks, holes), the key idea of this method is to use two parameterized structuring elements: a circular structuring element (SC) of radius r, and a horizontal The choice of these two elements is clearly designed to match the geometry of the laterals and joints to be extracted, as the impact of an opening is to remove those features that are small compared to the structural element S while maintaining features greater than S. The essential principle is that by conducting a succession of opening procedures based on structural parts of varied sizes, we may separate objects of a certain size. The greatest structuring element (measured in terms of radius r or length l) that can be inscribed in the item is then specified mathematically as the object's size. Note that, aside from the general shape of the structuring element, we make no specific assumptions about the shape of the object being measured; thus, this definition of size is quite general and will be useful in measuring the sizes of cracks, irregular laterals, and other objects that would otherwise be difficult to characterize.

### 3.3 Visual Inspection Techniques

For pipe inspection, visual inspection techniques such as closed-circuit television (CCTV) are often used. On a tractor, a CCTV normally consists of a camera and a lighting device. The CCTV device moves along the inside pipe wall during the examination and broadcasts the inspection video to an external monitor on the ground. When the inspector comes across a pipe defect or a pipe lateral, the unit is stopped and the camera is zoomed into the anomalous section to see if there are any potential flaws. The inspector must review the collected photos or videos after the inspection to determine the defect kind and location. Such manual interpretation of inspection photos or videos is time-consuming and labor-intensive, with subjective and erroneous findings, (Cheng and Wang, 2018).

A recent trend has been to use computer vision to automatically evaluate inspection photos or videos. Traditional computer vision techniques, on the other hand, necessitate the creation of complicated feature extractors, as well as extensive preprocessing of images used for training. Furthermore, the training procedure is time-consuming and ineffective. Deep learning has shown promise in numerous computer vision applications, such as image categorization and object recognition, in recent years. When compared to traditional computer vision techniques, deep learning-based systems are capable of extracting image features automatically and do not require extensive image preprocessing, which greatly improves accuracy and efficiency. As a result, this study proposes an automated defect identification strategy for identifying and locating pipe problems from CCTV images based on a faster convolutional neural network (AlexNet), which is a deep learning model for object detection.

A high number of inspection photos or videos are generated during the examination as a result of the widespread development and implementation of visual inspection techniques for infrastructure, such as CCTV robots and unmanned aerial vehicles (UAVs). In order to acquire inspection results, manual interpretation is required, which is inefficient and ineffective. Computer vision is the ability of a computer or machine to perceive digital images or movies in the same way that humans do. As a result, computer vision techniques have the potential to overcome the limitations of manual interpretation of photos or videos from visual inspections of civil infrastructures. Edge detection and morphological operations are two image processing approaches that have been extensively researched earlier, (Kalfarisi, Wu and Soh, 2020). Despite the fact that noise reduction approaches (Jeong, Lee and Ju, 2019) have been researched, image processing still requires prior information of the images, which is difficult, especially with photographs collected in varied environments. Picture pre-processing, image segmentation, feature extraction, object recognition, and structural analysis are some of the uses of traditional computer vision algorithms, (Spencer Jr, Hoskere and Narazaki, 2019). For civil infrastructure inspection, various vision-based tasks have been investigated, including automated detection and dimension measurement of concrete cracks , recognition of damage pattern changes and 3D visualization of cracks, (Ren *et al.*, 2020), and precise crack extraction with low model computation cost. In addition, using UAV photos, 3D reconstruction of road surface distresses and power line paths, as well as automatic obstacle recognition, were examined. Computer vision techniques, such as segmentation and classification of sewer pipe pictures to get joints, laterals, and faults for condition evaluation, have also been used for effective underground sewer pipe inspection. The automatic detection and segmentation of cracks is another application of image processing techniques for underground utility inspection. Dealing with photos with poor resolution and noisy data, image distortion and structural motion, and the influence of illumination and shooting distance were all encountered and analyzed.

However, one of the major drawbacks of the most common computer vision approaches used in the studies is the necessity to develop complicated feature extractors that are only suitable for a single task. Another issue is that generating the training dataset necessitates a significant amount of picture preprocessing, and the training process is time-consuming. Furthermore, past research has mostly focused on the automated detection and location of single problems, such as tree root incursion and water penetration, which can have serious effects, (Cho, Yoon and Yoon, 2016).

### 3.4 Neural Networks

Neural networks are looked at as intense interconnections of basic computational elements known as perceptrons that are simplified versions of neurons found in the human brain. This model is based on the biological nervous system according to our understanding. In addition, neural networks have been described as highly parallel networks made up of several computational elements that are prearranged in parallel and then cascaded to other elements in various layers. To express the similarities to the human brain, any introduction to neural networks includes a simple nervous composition. Pattern recognition, speech processing, and multi-dimensional signal processing are all areas where neural nets have a lot of promise. These programs are usually looking for high parallelism and low computational costs. In recent years, neural nets have been used to solve a variety of engineering problems, such as wireless channel equalization and adaptive control.

The creation of the early neural network systems was in progress at the same time that other adaptive signal processing algorithms, particularly the LMS algorithm, were effectively applied to several scientific and engineering problems(Deng and Yu, 2014). Figure 3.2 shows the basic perceptron architecture (Deng and Yu, 2014).

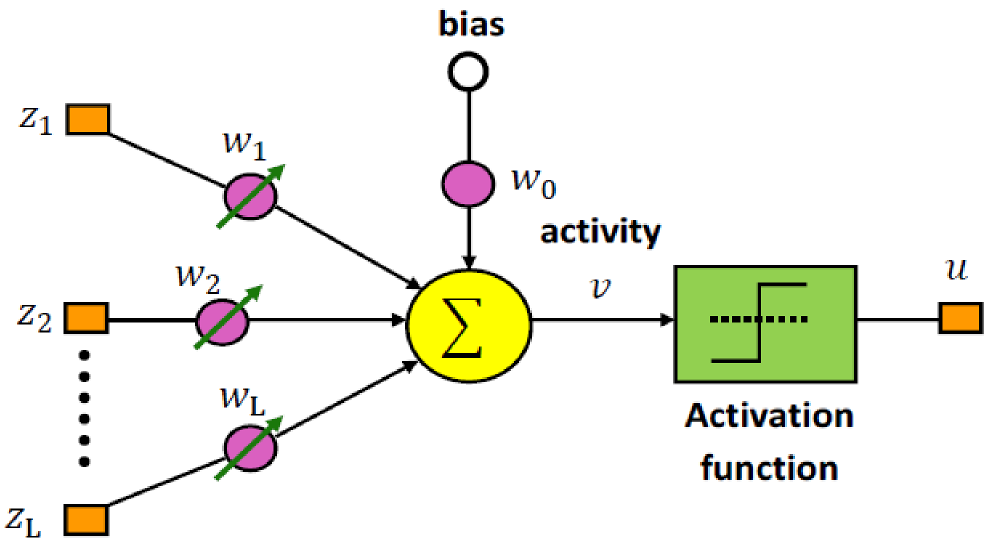



**Figure 3.2:** Basic perceptron architecture

The key benefit of neural nets is their huge parallel distributed composition, which gives the network a lot of computing power. Another distinct benefit is the generalization, which allows neural nets to learn in a more general way. In short, for inputs that were not used during the training phase, a trained network can generate fairly accurate and predicted outputs. As a result, neural nets are capable of addressing complex problems. Many networks are used in certain large and difficult-to-solve problems, each with a particular job to do, so that a suitable structure for each network can be chosen and configured (Simon, 2009). The main features of general neural networks that are briefly given in the following:

- Nonlinearity: A well-known characteristic of neural nets is nonlinearity. While a neural network can be designed to be linear, its distributed nonlinearity is used in applications. Since a linear equalizer cannot effectively equalize nonlinear channels, neural networks have become an important alternative.
- Input-output mapping: supervised learning is the process of adjusting the synaptic connection weights and bias values by providing a set of training inputs or examples and computing the network error using the target output (desired response). If the synaptic weight has reached fixed and stable values with an adequate number of training inputs then the network has formed an input-output mapping for a particular problem. It is an exceptional feature of neural networks that unlike other channel equalization techniques no statistical assumptions are required about the possible input set.
- Adaptivity: neural nets can adapt their synaptic weights according to changes that occur in the inputs or system environment.

### 3.4.1 Network architectures and algorithms

In most neural network architectures, the neurons are linked in a layer structure. In certain designs, neurons in the same layer share the same collection of inputs. Single-layer feedforward networks, as shown in Figure 4.3, have only one layer. Each neuron in the same layer computes an output, which can then be fed into the input of the second layer of neurons, resulting in a two-layer feed-forward network. Multilayer feedforward networks, as shown in Figure 4.4, are created by adding more layers. The new design is called recurrent when the final outputs of the last layer are fed back to the network's input.

The rule for calculating the error $[k]$ at each step or epoch is one of the parameters that distinguish the most recent neural networks, the adaptive method of correcting the weights in each layer corresponding to its error and the choice of using activation function (.). The learning process is divided into two types based on the calculation of output error, supervised learning when the target or expected output is known to the network, and unsupervised or blind learning when required output is not available to the network. The modern neural network architectures that are applied for the problem of channel equalization are similar to the typical architectures used for other applications in the light of the theorem given by (Hecht-Nielsen, 1987) that states "any continuous function in a closed interval can be approximated by backpropagation neural network with one hidden layer."

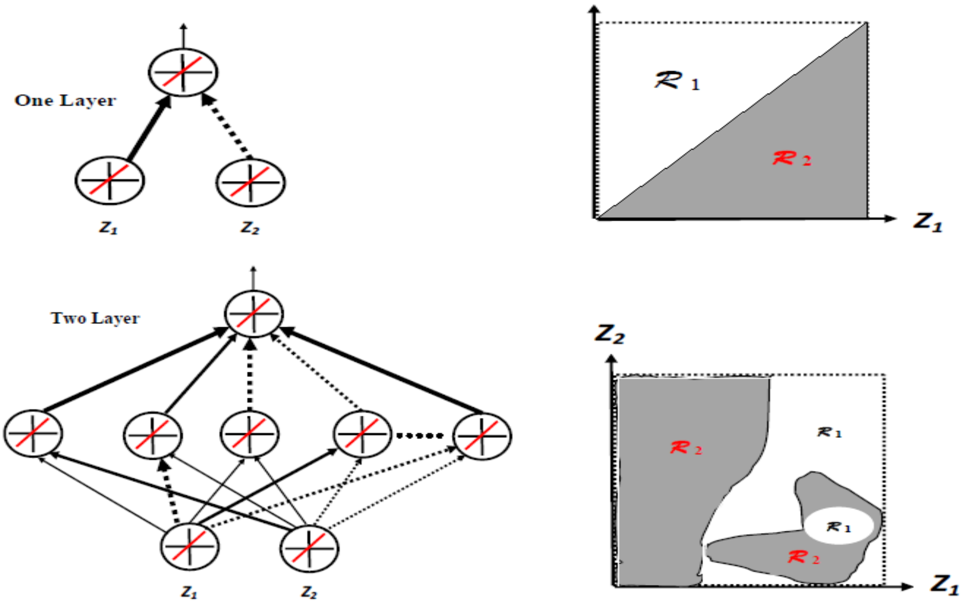



**Figure 3.3:** Decision boundaries for single- and two-layer networks

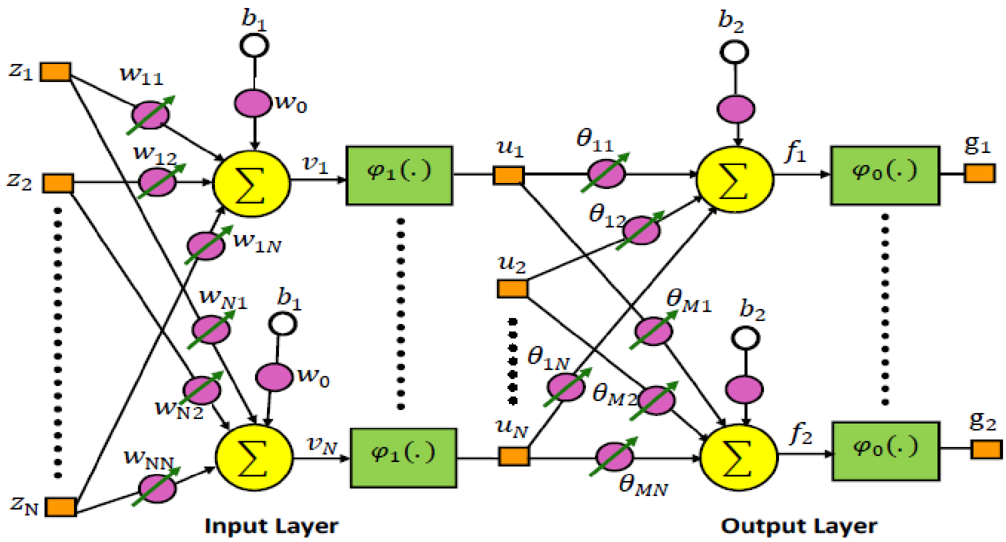



**Figure 3.4:** A multilayer perceptron for layer model with N neurons in the input and M neurons in the output layer

### 3.4.2 The back propagation algorithm

The development of the backpropagation algorithm over recurrent networks is the explanation for the success and popularity of adaptive supervised training of multilayer neural networks. There are two stages to the network's operation. The first phase is forward propagation, in which the current step's output error is calculated using initial synaptic weight values for each layer by the network layer by layer calculations' input to output. The second phase is called backpropagation in which the gradient of error surface concerning synaptic weights is computed for each layer from the output layer backward towards the input layer of the network and then it is used for updating the weights of each synaptic connection neuron to neuron in each layer. It can be concluded that these achievements of the backpropagation method have revived the study and application of neural networks(Rumelhart, Hinton and Williams, 1985).

### 3.5 Proposed System Configuration

As mentioned in the previous section, the current quality assurance system faces various challenges. The current system(Safa *et al.*, 2013), along with the proposed improvements, as shown in Figure 3.3 The area shown in the dotted box shows the stage of quality assurance that will be improved by applying the proposed system. As shown in this figure, the current QA approach requires extensive paperwork. A printed copy of the quality assurance principles and requirements and engineering drawings must be available for use by the certified inspector in the store and in the field. This system also needs QA teams to manufacture stores and field construction of treatment tubes. However, this research mostly focuses on shop manufacturing. The QA algorithm (neural network) includes skilled technicians which well trained and responsible for many qualities assurance processes. In the case of the measurement process, the quality assurance team must come to the store to inspect, measure and test item properties to ensure that they meet the specified requirements. The Quality Assurance Manager / Supervisor is responsible for ensuring that all Quality Assurance (Technical) Inspectors carry out quality assurance activities following established quality assurance requirements.

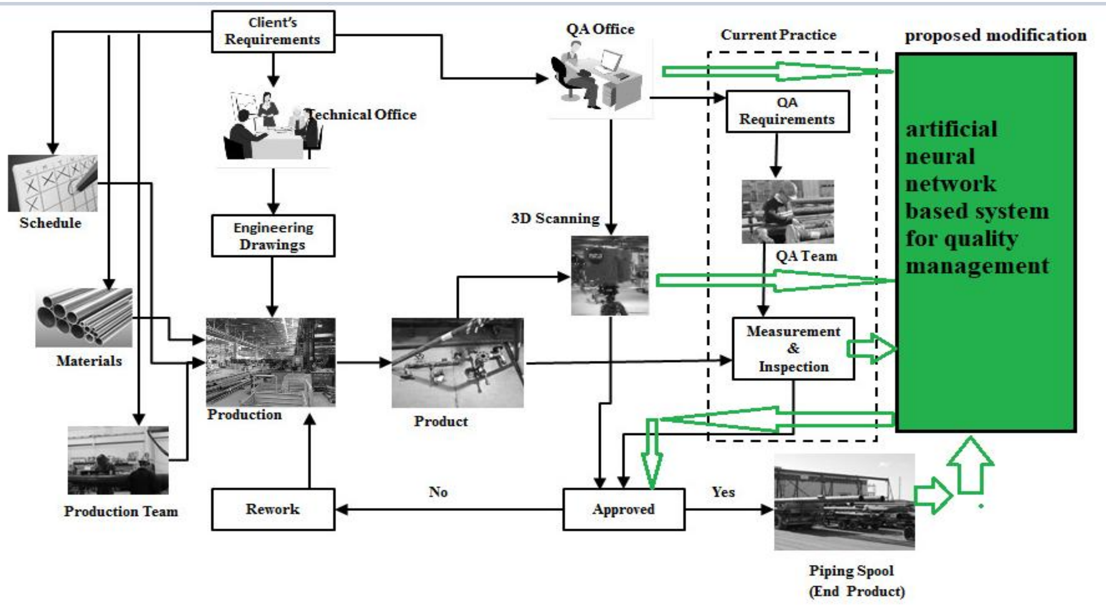



**Figure 3.5:** Proposed modified system

The work is a modification to the system proposed by(Safa *et al.*, 2013). The modification is done by replacing the current practice part shown in figure 3.5 with the green-colored part in the same figure. The work is included with artificial intelligence ( neural network). The ANN is designed and trained with suitable data for product quality management.

### 3.6 Case Study

The proposed system as mentioned in the previous section is a modification of another system. The quality management modification includes some steps to be done starting with: preparing test data and arranged that data in such manner to be used in neural network training, the neural network designed using MATLAB program and Neural networks toolbox. After the training process completed another data applied to the trained system and the the pipes will be classified into two groups " accepted and rejected" depending on the product data entered into the inspection system. The product data as mentioned before is taken from the LASER scanner and formated into a suitable form to be used by neural networks. Simulation results for both the training and testing process are included and discussed in chapter four.

# 4. RESULTS AND DISCUSSION

## 4.1 Neural Network Training

Transfer learning is the used training method to train a deep neural network which is "Alexnet", transfer learning gives the ability to utilize a pre-trained network and update it for another application using an acceptable training dataset and training time.

### 4.1.1 Alexie

The proposed system based on 25-layer Alexnet retrained using the transfer learning method. The neural network layers are shown in figure 4.1.

```
 1   'data'          Image Input                   227x227x3 images with 'zerocenter' normalization
 2   'conv1'         Convolution                   96 11x11x3 convolutions with stride [4  4] and padding [0  0  0  0]
 3   'relu1'         ReLU                          ReLU
 4   'norm1'         Cross Channel Normalization   cross channel normalization with 5 channels per element
 5   'pool1'         Max Pooling                   3x3 max pooling with stride [2  2] and padding [0  0  0  0]
 6   'conv2'         Grouped Convolution           2 groups of 128 5x5x48 convolutions with stride [1  1] and padding [2  2  2  2]
 7   'relu2'         ReLU                          ReLU
 8   'norm2'         Cross Channel Normalization   cross channel normalization with 5 channels per element
 9   'pool2'         Max Pooling                   3x3 max pooling with stride [2  2] and padding [0  0  0  0]
10   'conv3'         Convolution                   384 3x3x256 convolutions with stride [1  1] and padding [1  1  1  1]
11   'relu3'         ReLU                          ReLU
12   'conv4'         Grouped Convolution           2 groups of 192 3x3x192 convolutions with stride [1  1] and padding [1  1  1  1]
13   'relu4'         ReLU                          ReLU
14   'conv5'         Grouped Convolution           2 groups of 128 3x3x192 convolutions with stride [1  1] and padding [1  1  1  1]
15   'relu5'         ReLU                          ReLU
16   'pool5'         Max Pooling                   3x3 max pooling with stride [2  2] and padding [0  0  0  0]
17   'fc6'           Fully Connected               4096 fully connected layer
18   'relu6'         ReLU                          ReLU
19   'drop6'         Dropout                       50% dropout
20   'fc7'           Fully Connected               4096 fully connected layer
21   'relu7'         ReLU                          ReLU
22   'drop7'         Dropout                       50% dropout
23   'fc'            Fully Connected               2 fully connected layer
24   'prob'          Softmax                       softmax
25   'classoutput'   Classification Output         crossentropyex with classes 'Negative' and 'Positive'
```

**Figure 4.1:** Deep neural network layers

### 4.1.2 Image preparing for testing

Each pipe image is firstly resized to [227 227 3] to be acceptable for testing, after that the system classifies the images as accepted or rejected depending on the pipe case. The crack, corrosion, or dimensions errors all those can be used as an indicator for classification. For each test, the neural network must be trained for it.

## 4.2 Graphical User Interface GUI

A simple GUI is designed to be used to select and classify each pipe image. The simplicity is one of the GUI advantages which makes the user use the classification system easily without needing to know how the program inside it is working. Figure 4.2 shows the GUI panel.

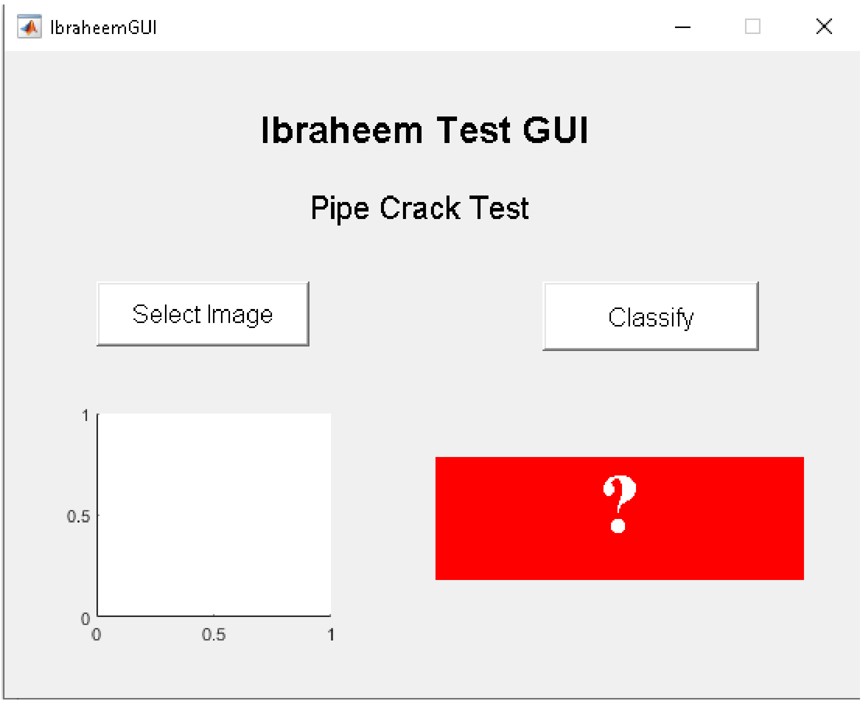



**Figure 4.2:** GUI

```
function varargout = IbraheemGUI(varargin)
% IBRAHEEMGUI MATLAB code for IbraheemGUI.fig
%      IBRAHEEMGUI, by itself, creates a new IBRAHEEMGUI or raises the
existing
%      singleton*.
%
%      H = IBRAHEEMGUI returns the handle to a new IBRAHEEMGUI or the
handle to
%      the existing singleton*.
%
%      IBRAHEEMGUI('CALLBACK',hObject,eventData,handles,...) calls the local
%      function named CALLBACK in IBRAHEEMGUI.M with the given input
arguments.
```

```
%
%        IBRAHEEMGUI('Property', 'Value',...) creates a new IBRAHEEMGUI or
raises the
%      existing singleton*.  Starting from the left, property value pairs are
%      applied to the GUI before IbraheemGUI_OpeningFcn gets called.  An
%      unrecognized property name or invalid value makes property application
%      stop.  All inputs are passed to IbraheemGUI_OpeningFcn via varargin.
%
%
gui_Singleton = 1;
gui_State = struct('gui_Name',       mfilename, ...
                   'gui_Singleton',  gui_Singleton, ...
                   'gui_OpeningFcn', @IbraheemGUI_OpeningFcn, ...
                   'gui_OutputFcn',  @IbraheemGUI_OutputFcn, ...
                   'gui_LayoutFcn',  [] , ...
                   'gui_Callback',   []);
if nargin && ischar(varargin{1})
    gui_State.gui_Callback = str2func(varargin{1});
end

if nargout
    [varargout{1:nargout}] = gui_mainfcn(gui_State, varargin{:});
else
    gui_mainfcn(gui_State, varargin{:});
end
```

### 4.2.1 Select button

Select button function is listed below which does nothing just select the image path and upload the image and display it in a specific place.

```
function Select_Callback(hObject, event data, handles)
% hObject    handle to Select (see GCBO)
% event data  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
global full filename
```

```
[filename,pathname] = uigetfile({'*.jpg';'*.bmp'},'Load image');
%[filename, pathname] = uigetfile({'*.m';'*.mdl';'*.mat';'*.*'},'File Selector');
fullFilename = [pathname filename];
im = imread(fullFilename);
axes(handles.axes1);
imshow(im);
```

### 4.2.2 Classify button

When user click "classify button" the image classification process starts, depending on training data used in training process the image will be classified and the result will be displaied in the result text box. The button backend program is listed below:

```
function Classify_Callback(hObject, eventdata, handles)
% hObject    handle to Classify (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
global fullFilename
I = fullfile(fullFilename);
testData = imageDatastore(I);
load('myNet');
plabel1 = classify(myNet,testData);
if plabel1 == "Positive"
plabel = "Accepted";
end
if plabel1 == "Negative"
plabel = "Rejected";
end
set (handles.text1,'String',char(plabel));
```

## 4.3 Training Process

The training process begins with preparing the neural network, because the transfer learning is used, the first step is to modify "Alexnet". Figure 4.3 shows the training process.

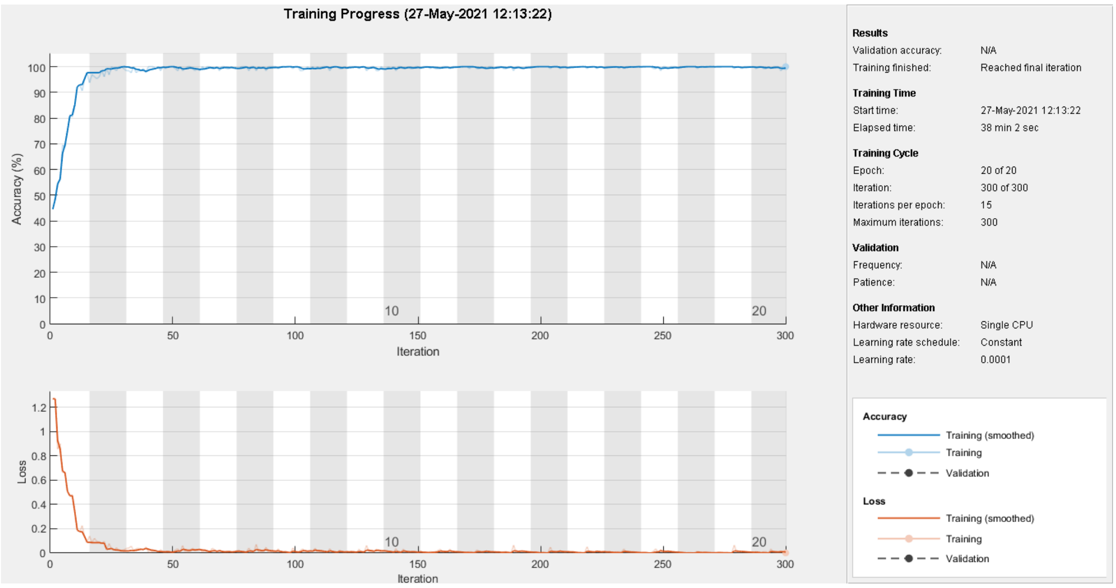



**Figure 4.3:** Training process

While figure 4.4 shows the training details.

```
Training on single CPU.
Initializing input data normalization.
|======================================================================================|
|  Epoch  |  Iteration  |  Time Elapsed  |  Mini-batch  |  Mini-batch  |  Base Learning  |
|         |             |   (hh:mm:ss)   |   Accuracy   |     Loss     |      Rate       |
|======================================================================================|
|       1 |           1 |       00:00:08 |       44.53% |       1.2691 |      1.0000e-04 |
|       4 |          50 |       00:06:28 |      100.00% |       0.0094 |      1.0000e-04 |
|       7 |         100 |       00:12:57 |      100.00% |       0.0036 |      1.0000e-04 |
|      10 |         150 |       00:19:20 |      100.00% |       0.0020 |      1.0000e-04 |
|      14 |         200 |       00:25:33 |      100.00% |       0.0025 |      1.0000e-04 |
|      17 |         250 |       00:31:49 |      100.00% |       0.0017 |      1.0000e-04 |
|      20 |         300 |       00:38:02 |      100.00% |       0.0012 |      1.0000e-04 |
|======================================================================================|

ans =

    0.9969
```

**Figure 4.4:** Training details

## 4.4 Simulation Results

### 4.4.1 Images resizing

To make image size suitable for the input of the deep neural network it must be resized to [227 227], minimum image resolution to be used is: width "227 pixels", hight "227 pixels", horizontal resolution "96 dpi", vertical resolution"96 dpi", bit depth "24", therefore a simple GUI is designed to be used for this process. The image resizing step makes the classification system able to treat with each image with any size. Figure 4.5 shows the image resizing GUI.

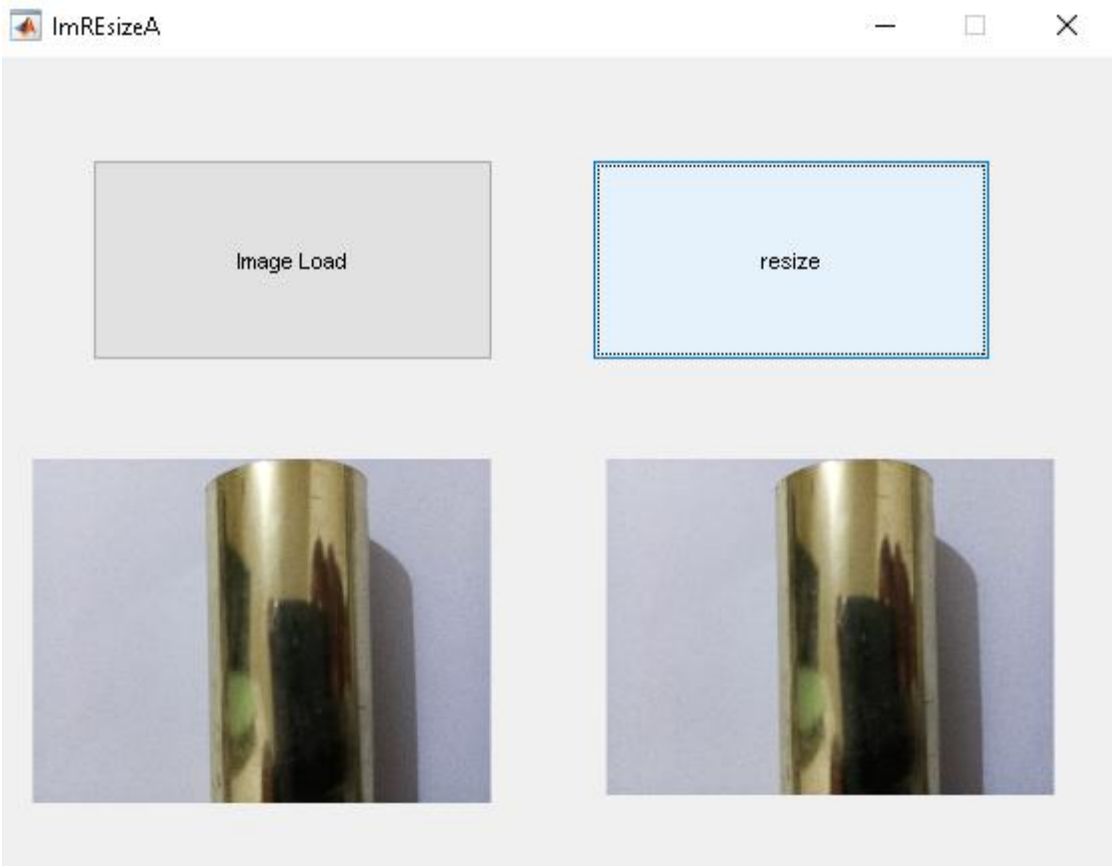



**Figure 4.5:** Image resizing GUI

### 4.4.2 Pipes classification results

Figure 4.6 shows the accepted pipe image under test, also the test result is shown on the GUI. While figure 4.7 is shows rejected pipe image under test.

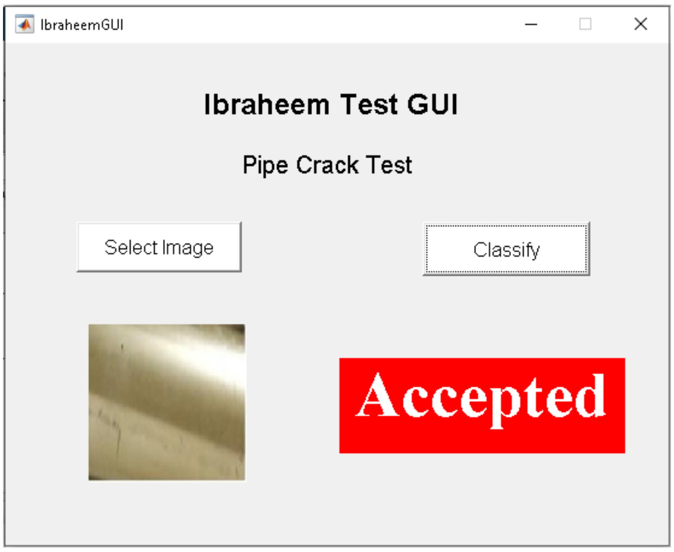



**Figure 4.6:** Accepted image under test

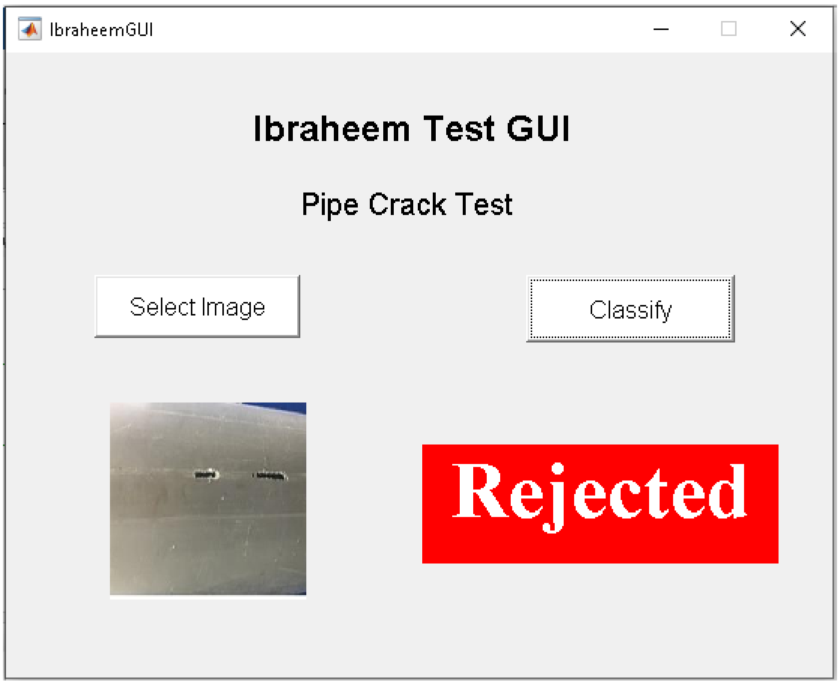



**Figure 4.7:** Rejected pipe image under test

**Table 4.1:** Contains some tested image and their results.

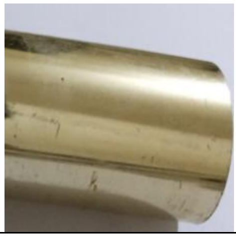
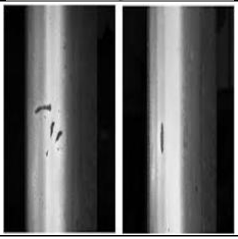
| **Image** | **Result** |
|---|---|
|  | Rejected |
|  | Rejected |
|  | Rejected |
|  | Accepted |

**Table 4.1:** Contunue

| **Image** | **Result** |
|---|---|
|  | Rejected |
|  | Rejected |

# 5. CONCLUSIONS AND RECOMMENDATIONS

## 5.1 Conclusions

Deep neural network-based classification system results show the proposed system is a high accuracy system and it can be introduced as a quality monitor part in the quality management system. Transfer learning training method which is used in the training process of the proposed system in an efficient training method because it needs little training dataset and minimizes designing time and complexity, only 4000 images used for training and validation. Manufactoring error in a range of 0.5 mm diameter can be detected depending on the proposed system, but this can be done only when high resolution images are used. The image resizing step is a very important step that makes the system able to deal with any image size.

Interfacing of artificial intelligence with quality management systems makes those systems more efficient and updated.

## 5.2 Recommendations

The proposed system simulated using camera images to classify the pipes, as a future work it can be used to classify an image of the three-dimension laser scanner. 3D scanner image can give more details for the pipe needed to be classified such as corrosion, length, and diameter more accurately than the normal camera.

Automatic visual surveillance requires the classification of moving objects into semantically meaningful groups. However, due to considerations such as limited object size, huge intra-class changes of objects in the same class due to changing viewing angles and lighting, and real-time performance requirements in real-world applications, this is a difficult problem. With the rapid advancement of video capturing technology, video is quickly becoming a low-cost but crucial medium for archiving information. Due to its considerably expanded automation in public security surveillance, understanding video objects is receiving a lot of attention. Classifying moving objects into semantically meaningful groups is an important task in video surveillance. Typical applications include developing intelligent parking systems for various cars and object retrieval systems from films, among others.

Also, real-time scanning or video-based classification methods may be more efficient in classification methods especially in mass product-based factories because of the high number of pipes produced per unit time. The video-based classification method may need a very complex training method and a higher number of layers than the one used in our application.

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