T.C.
ISTANBUL GEDİK UNIVERSITY
INSTITUTE OF GRADUATE STUDIES

THE AUTOMATION OF CRITICAL PATH METHOD USING MACHINE LEARNING: A CONCEPTUAL STUDY

MASTER'S THESIS

Othman Adnan Ibrahim AL-JUMAILI

Engineering Management Master in English Program

AUGUST 2021

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Thesis Advisor: Assist. Prof. Dr. Ahmet GÜLLÜ

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DECLARATION

I, Othman Adnan Ibrahim AL-JUMAILI, do hereby declare that this thesis titled as "The Automatıon of Crıtıcal Path Method Usıng Machıne Learnıng: A Conceptual Study" 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. (12/08/2021)

Othman Adnan Ibrahim AL-JUMAILI

DEDICTION

To my Mother, father, and my whole family for their unconditional love and support

To those who are working day and night to improve people's lives around the world

To my wounded country, the Cradle of civilization and history

To all my friends who gave me hope, help and advice through this journey

To all my teachers in and outside studying classrooms who contributed to lighten my life.

PREFACE

At the end of this research, I am pleased to thank my parents for their unlimited support along with my academic career. I thank my friends for every support and encouragement they gave along they gave during this work. I am pleased to extend my thanks to anyone who helped, advised, guided, or contributed to this research by giving me the references and resources I needed at any phase of the research. I especially thank my supervisor (Assist. Prof. Dr. Ahmet GÜLLÜ) for support and advisement. I also thank the university, the head of the department, and the discussion committee members.

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TABLE OF CONTENTS

Page

PREFACE ..... **v**
TABLE OF CONTENTS ..... **vi**
ABBREVIATION ..... **viii**
LIST OF TABLES ..... **ix**
LIST OF FIGURES ..... **x**
ABSTRACT ..... **xi**
ÖZET ..... **xii**
1. INTRODUCTION **1**
1.1 Background 3
1.2 Context 4
1.3 Purpose 4
1.4 Research Scope and Objectives 6
1.5 Thesis Outline 7
1.6 Survey Form 7
1.7 Validity of the Questionnaire Test 8
1.8 Statistical Methods Used in the Analysis For Analysis Data 8
2. CRITICAL PATH METHOD **9**
2.1 Background 9
2.2 Development of the Critical Path Method 10
2.3 Growth of CPM Usage 10
2.4 The Critical Path Method Mechanism 11
2.5 CPM Compression Techniques 14
2.5.1 Fast tracking 14
2.5.2 Crashing 15
2.5.3 The use of fast track and crash 15
2.6 Resolving Practical Constraints in CPM 16
2.6.1 Resource leveling/Allocation 16
2.6.2 Challenges in resource allocation algorithms 17
2.6.2 Time-cost trade-off analysis 19
3. MACHINE LEARNING **21**
3.1 Introduction to Machine Learning 21
3.2 Learning in Machines 23
3.3 Machine Learning Relation With Other Disciplines 25
3.3 Machine Learning Techniques 27
3.4.1 Supervised learning 28
3.4.1.1 Example 28
3.4.1.2 Regression 29
3.4.1.3 Classification 29
3.4.1.4 Algorithms for supervised learning 30
3.4.2 Unsupervised learning 35
3.4.2.1 Algorithms for unsupervised learning 35

3.4.3 Cluster identification 36
3.4.4 Semi-supervised learning 36
3.4.5 Reinforcement learning 37
3.4.6 Deep learning 37
3.4.7 Deep reinforcement learning 38
3.4.7.1 Unexploited opportunities of deep learning 38
3.4.8 What is required for achieving more using deep learning? 38
3.4.9 Deep learning - disadvantages 39
3.4.9.1 Computationally expensive 39
3.4.9.2 Duration of development 39
3.4.9.3 Black box approach 40
3.4.9.4 Amount of data 41
3.4.9.5 Validation and evaluation 41
3.4.10 Applications of machine learning algorithms 42
3.4.10.1 Automatic recognition of handwritten postal codes 42
3.4.10.2 Computer-aided diagnosis 45
3.4.10.3 Computer vision 46
3.4.10.4 Auto-driven cars 47
3.4.10.5 Face recognition and security 48
3.4.10.6 Speech recognition 49
3.4.10.7 Text mining 49
3.4.10.8 Where text and ımage data can be used together? 50
3.4.11 The present and the future of machine learning 51
3.4.11.1 Thinking machines 51
Smart Machines 53
4. RESEARCH DESIGN 58
4.1 Methodology and Research Design 58
4.2 The Community of the Study 58
4.3 Exclusion Criteria 59
4.4 Designing the Questionnaire 59
4.5 The Questionnaire 60
5. FIELD STUDY PROCEDURES 62
5.1 Field Study Planning 62
5.2 Study Population 62
5.2.1 Distribution of the sample members according to personal variables 62
5.3 Statistical Methods Used in the Study 65
5.3.1 Data reliability test 65
5.3.2 Descriptive statistical methods 66
5.3.3 Median estimation method 66
5.3.4 Likert scale intervals 66
5.3.5 Analyze the study sample data 66
5.4 Evaluation of Study Variables 67
6. ANALYSIS, CONCLUSION AND RECOMMENDATIONS 77
6.1 Discussion on the General Results of the Survey 77
6.2 Conclusion 79
6.3 Recommendations 83
REFFERENCES 85
RESUME 92

ABBREVIATION

AI	: Artificial Intelligence
ANN	: Artificial Neural Network
CIO	: Chief Information Officer
CP	: Critical Path
CPM	: Critical Path Method
DC	: Direct Cost
DL	: Deep Learning
DRL	: The Deep Reinforcement Learning
FF	: Finish-to-Finish
FS	: Finish-to-Start
IT	: Information Technology
KDD	: Knowledge Discovery in Database
LOB	: Line of Balance
LSM	: Linear Scheduling Method
ML	: Machine Learning
MS project	: Microsoft Project
OCR	: Optical Character Recognition
P	: Primavera
PERT	: Program Evaluation and Review Techniques
RFID	: Radio-Frequency Identification
SAS	: Statistical Analysis System
SF	: Start-to-Finish
SL	: Supervised Learning
SPSS	: Statistical Package for Social Sciences
SS	: Start-to-Start
TCT	: Time-Cost Trade-off
UL	: Unsupervised Learning

LIST OF TABLES

Page

Table 2.1: Three techniques for Time-Cost Trade-Off analysis comparison 20
Table 3.1: Unlabeled Data Examples along with Labeling Issues 29
Table 4.1: Distribution of the Research Sample According to Personal Variables .. 62
Table 5.1: Likert scale intervals 66
Table 5.2: Respondents' knowledge of Critical path method 67
Table 5.3: Critical path method usage 67
Table 5.4: opinions about the importance of CPM in construction projects 68
Table 5.5: alternatives of CPM 68
Table 5.6: lag in CPM 69
Table 5.7: Modified CPM 69
Table 5.8: Dependency on CPM 69
Table 5.9: CPM need for improvement 70
Table 5.10: Technological support of CPM 70
Table 5.11: Building Information Model 71
Table 5.12: BIM with CPM 71
Table 5.13: AI knowledge 72
Table 5.14: Machine Learning knowledge 72
Table 5.15: ML usage 73
Table 5.16: Mergence of CPM and ML 73
Table 5.17: CPM in planning phase enhancement through ML 74
Table 5.18: CPM in monitoring phase enhancement through ML 74
Table 5.19: CPM in after finalization enhancement through ML 75
Table 5.20: Critical Path auto-detection through ML 75
Table 5.21: CPM automation possibility through ML 75
Table 5.22: CPM logical abuses solution 76

LIST OF FIGURES

Page

Figure 2.1: Forward pass calculations in CPM network 12
Figure 2.2: Backward pass calculations in CPM network 13
Figure 2.3: Schedule 1 that have resource problem 18
Figure 2.4: Schedule 2 after considering resource limits 18
Figure 2.5: The schedule after adding two days to E activity 18
Figure 2.6: The schedule after solving the problem 19
Figure 2.7: Project duration-cost plot 20
Figure 3.1: Different disciplines of knowledge and machine learning 25
Figure 3.2: Different machine learning techniques and type of required data 27
Figure 3.3: Distribution of three classes of objects 31
Figure 3.4: Distribution of objects after using k-NN 31
Figure 3.5: İllustration shows the unknown object 32
Figure 3.6: An xy coordinated plane showing many distributed points 33
Figure 3.7: Simple decision tree flowchart 33
Figure 3.8: SVM classification plot 34
Figure 3.9: Training process in neural network 39
Figure 3.10: How ANN processing a dog image 40
Figure 3.11: Diagram of data growth and processing power growth per year 41
Figure 3.12: Diagram shows the avancement of OCR in Scanoptics company 43
Figure 3.13: An old type of OCR cameras used by US Postal Service 44
Figure 3.14: US humanoids defeat Iran team in football RoboCup final 47
Figure 3.15: Toyota promises driverless cars on roads by 2020 48
Figure 3.16: Top 10 strategic technology trends for 2014 by Gartner 54
Figure 3.17: Top 10 strategic technology trends for 2015 by gartner 54
Figure 3.18: IBM watson logo 55
Figure 5.1: Degree 63
Figure 5.2: Major 64
Figure 5.3: Age 64
Figure 5.4: Experience 65
Figure 5.5: Gender 65

THE AUTOMATION OF CRITICAL PATH METHOD USING MACHINE LEARNING: CONCEPTUAL STUDY

ABSTRACT

This research aims to shed light on the use of machine learning in improving, developing and automating the critical path method, solving its problems, studying this effect and its dimensions, and discussing that from many aspects.

The research is divided into two theoretical and practical parts. The theoretical part is concerned with studying the critical path method and its advantages, problems and challenges, as well as studying machine learning and artificial intelligence and its dimensions, reviewing materials and sources related to this, and then presenting suggestions and future solutions based on this study. As for the practical section, it is a questionnaire that targeted a segment of engineers, in particular, and others who have sufficient experience in both the critical path method and machine learning, and seeking their opinions on both topics.

The result of the theoretical research was 14 theories or proposals that were presented based on the foregoing study. As for the practical questionnaire, a sample of 127 was taken. Through statistical analysis, the results were analyzed and discussed separately, and then a conclusion was drawn regarding them.

Keywords: *Critical Path Method, Machine Learning, Artificial Intelligence*

MAKİNE ÖĞRENİMİNİ KULLANARAK KRİTİK YOL YÖNTEMİNİN OTOMASYONU: KAVRAMSAL ÇALIŞMA

ÖZET

Bu araştırma, kritik yol yönteminin iyileştirilmesinde, geliştirilmesinde ve otomatikleştirilmesinde, problemlerinin çözülmesinde, bu etkinin ve boyutlarının incelenmesinde ve birçok yönden tartışılmasında makine öğrenmesinin kullanımına ışık tutmayı amaçlamaktadır.

Araştırma teorik ve pratik olmak üzere iki bölüme ayrılmıştır. Teorik kısım, kritik yol yöntemini ve avantajlarını, problemlerini ve zorluklarını incelemek, makine öğrenmesi ve yapay zeka ve boyutlarını incelemek, bununla ilgili materyalleri ve kaynakları gözden geçirmek ve ardından öneriler ve gelecekteki çözümleri sunmakla ilgilidir. bu çalışma. Pratik bölüme gelince, bu, özellikle bir mühendis kesimini ve hem kritik yol yöntemi hem de makine öğrenimi konusunda yeterli deneyime sahip olan ve her iki konu hakkında görüşlerini arayan diğerlerini hedef alan bir ankettir.

Teorik araştırmanın sonucu, yukarıdaki çalışmaya dayalı olarak sunulan 14 teori veya öneriydi. Pratik ankete gelince, 127 kişilik bir örneklem alındı. İstatistiksel analiz ile sonuçlar ayrı ayrı incelenip tartışılmış ve daha sonra bunlarla ilgili bir sonuca varılmıştır.

Anahtar Kelimeler: *Kritik Yol Metodu, Makine Öğrenimi, Yapay Zeka*

1. INTRODUCTION

Before we examine the critical path approach, it is necessary to understand how projects are managed, which is essentially planning, scheduling, monitoring, and controlling side by side with corrective measures as required. The primary objectives of a project are to do a certain quantity of work within a specified time period at a predetermined cost while maintaining the required level of quality. Project planning, scheduling, monitoring, and controlling are all critical to achieving those objectives. The three phases of planning, scheduling, monitoring, and regulating are all part of a continuous process (Jayawardena, 2012). There are a variety of project management tools and techniques available, each of which has been utilized at a certain stage of the project based on the characteristics of the project. Critical route method, Program Evaluation and Review Techniques (PERT), Bar Charts, Line of Balance (LOB), Linear Scheduling Method (LSM), Work Study technique, and operation techniques are some of the important approaches used during the planning stage (Jayawardena, 2012). Although techniques such as CPM, LOB, and LSM may be used for project management in the construction industry, the CPM, with its tools for all phases, is the most well-known, powerful, and successful approach that is frequently used in project management, particularly in the construction industry (Jayawardena, 2012). The CPM is a very effective technique of project management for all types of projects. This method provides an accurate calculation policy for the entire process and allows for the rating and evaluation of substitute programs and types of tools by manipulating the durations of the activities individually, as well as the sources and bonds between activities. It also allows for the rating and evaluation of substitute programs and types of tools (Jayawardena, 2012). The working diagram and its associated equipment provided by the CPM provide project managers with precise information about the effect of any modification or lateness in the planned plan, allowing them to identify tasks that need rectification. The use of the Critical Path Method is well-established in a wide range of sectors, and it is even more well-established in the construction industry, as previously mentioned. Evaluation of cost risks may be used for a variety of purposes in a variety of sectors, including but not

limited to: Additionally, it is a logical method for issues in risk reduction on site, in windy environment, and such risks may be achieved via the Critical Path Method, therefore, the cost of the risks can be assessed as well, inserted into, or programmed into the system (Jayawardena, 2012). As a result, the Critical Path Method is a very effective and strong project management technique that should be included in all project management software packages. There are a variety of project management methods available, all of which are based on the CPM framework. Which are required at various stages of the project.

The main objective of the Critical Path Method is to identify each activity in the project, all the resources required for each one, to connect and plan them, and to estimate the time of each activity while taking into account any other constraints. After completing these activities, any project management software may use this information efficiently for project management methods.

The critical route approach has undergone much development and study over the years in an effort to overcome its inherent limitations and improve its effectiveness in project management. Machine learning and artificial intelligence are two prominent subjects that are being researched and used in a variety of areas nowadays. Artificial intelligence and machine learning are based on automating processes and training machines to perform operations and make intelligent decisions in the same way that humans do, thereby facilitating and saving significant amounts of time, effort, and work in a variety of industrial, agricultural, medical, and military fields. It began to grow and spread across the globe in the past few years. This new innovation began growing and improving day by day in terms of its capabilities and uses in many spheres of life. The term "machine learning" refers to a subfield in artificial intelligence. The primary goal of machine learning is to evaluate the structure of data and transform it into readily comprehensible and usable models. These models may be used for a variety of applications. While machine learning is a subfield of computer science, it is distinct from traditional computational techniques. In classical computing, algorithms are a set of plainly written instructions that computers used to calculate or solve problems. On the other hand, machine learning techniques allow computers to train utilizing data inputs and then evaluate them statistically in order to extract output values that fall within a certain range. As a result, machine learning

enables computers to construct models from sample data, automating decision-making processes based on data inputs.

Nowadays, every user of technology has benefited from machine learning. Social networking apps may employ facial recognition technology to assist users in tagging and sharing pictures of friends and family. OCR technology enables machines to transform handwriting or photographs of text to moveable and readable type. Recommendation engines powered by machine learning assist consumers by suggesting movies, episodes, or videos to watch next based on their interests. Autonomous vehicles that rely on machine learning to navigate through streets are another example of machine learning applications that may be extensively used by people in the near future. Machine learning is a discipline that is constantly evolving. As a result, there are a few points to consider while implementing machine learning methods or analyzing the effect of machine learning procedures (Lisa Tagliaferri 2017). Investing in this area to address a variety of issues and difficulties is the current trend among academics and scientists worldwide.

1.1 Background

This study is critical for managers that use the Critical Path Method to manage a variety of different types of projects, including construction, software development, aerospace and military, product development, plant maintenance, research initiatives, and engineering. Any project involving interdependent operations may benefit from the CPM technique of mathematical analysis.

In this age, Time, Cost and Quality are the three elements making the pyramid that is considered as the corner stone of management.

1. **Time** – In construction, time is analyzed to the tiniest detail. The amount of time needed to finish and all the components of a project are calculated. After analysis has been made, those components are divided additionally even into the time needed to finish each task. Therefore, it’s easy to guess the duration of the project and also the workers and equipment needed.

2. **Cost** – All resources need money so they are extremely connected. Cost of a project means what needs to be applied or assigned to finish the project based on money and labor needed to make it possible. Resources can be workforce,

instruments and materials.

3. **Quality** – There are a lot of parts for the word quality. However, specifically interesting one is the scope of a project (usually named as the Scope of Work or Specifications). Which means, the drawings, the contract, and specifications that are being agreed and signed.

When considering that Time, Cost and Quality are the three key parts that form the construction today, it is extremely important that the manager pay good attention for every one of these components. Poor performance in one of the components has consequences to the rest of them. For example, if quality goes wrong during the project process, then the repairing eventually can delay the whole project, and may cost extra money.

The Critical Path method deals with the complex of time, one of the three components that build the modern management structure. Therefore, the development and improvement of the Critical Path method is an important step for the project management field in general.

1.2 Context

This research aims to shed light on investing the machine learning method and its techniques in developing the critical path method and addressing some of the problems and challenges faced by this method. This research is considered the first of its kind in this field, as it discusses the possibilities, problems and solutions that can be applied with the help of machine learning by studying machine learning and its capabilities and then trying to present proposals that may help researchers in future studies and shorten the way to what follows from research

1.3 Purpose

Although there are many studies and researches concerned with development and improvement of the Critical Path method in many of its aspects in terms of accuracy, speed, flexibility and reliability etc., until now the Critical Path method has not been linked to the machine learning (ML) and the artificial intelligence (AI) to study what can this pairing offer in terms of capabilities and uses that may contribute in shaping a breakthrough in the Critical Path Method and in the field of administration in

general and Engineering Management in particular, for this was this research.

This research is considered the first of its kind in this field and it is considered a gateway to what it follows from researches that aims to draw attention to artificial intelligence and its tremendous and promising capabilities and try to invest it in improving and solving many of the problems and shortcomings that the Critical Path method suffers and some of these problems:

Inadequate Planning (before Construction): For the planning phase, Critical Path Method is made basically on two unrealistic assumptions:

1. Resources are unlimited.
2. The project deadline is not restricted.

The project manager should use a variety of methods when it comes to operational concerns, including cash flow management, time-cost trade-off analysis, resource allocation, and resource leveling. These methods address sequentially distinct sub-problems, not concurrently (Hegazy 2002). This range of methods should improve not just Critical Path Method tabling, but also simplify the procedure. Additionally, construction projects often face many constraints, making it difficult to develop a realistic timetable, since resolving one constraint (for example, resource constraints) may clash with another (for example, deadline). This issue renders the CPM and other tools ineffective and relegates them to presentation purposes exclusively. Due to a lack of adequate tools and techniques for resolving these constraints, current software solutions place a premium on technical aspects of the problem, such as online collaboration, rather than on characteristics that address basic engineering and project management problems.

Decision Support inadequacy (during Construction): When a project begins, the schedule serves as a baseline for tracking progress and becomes critical to the proper organization of daily activities. When site events are recorded and properly placed into the project's schedule, Critical Path Method analysis may help project managers in predicting potential problems that may arise later in the project (Gould 2005). Management is able to initiate appropriate corrective actions, such as rescheduling and re-planning, as well as increase the flow of resources, by using the variation between planned and actual progress. This dynamic cycle of predicting future needs and examining the current state of affairs is one of the primary goals of project

control (Ahuja and Thiruvengadam 2004).

Despite the fact that the Critical Path Method is useful for updating activity status, the actual progress data is saved primarily or Schue led as a cumulative percentage for tasks, with no additional details about the problems caused by anything or details about whether the progress was rapid or slow. These issues prevent the Critical Path Method from properly assessing the project's delays. Additionally, the Critical Path Method does not improve decision-making related to determining the most cost-effective corrective measures that assist in recovering lagging plus overflowing.

Inadequate Analysis (Post-Construction): In addition to being a critical technique for scheduling a project, the Critical Path Method is critical for evaluating the final as-built schedules to ensure that any delays occurred throughout the project are quantified. The courts and contract appeal boards have shown their willingness to use critical route method network analysis as a means of identifying the source of delays in building projects (Ostrowski 2006). In any case, the complex features of commercial scheduling software, such as numerous calendar resources, hinder the use of critical route method tables. Among the agents that contribute to the complexity of analyzing Critical Path Method schedules are the use of lead and lag periods in relationships, the complexity of the relationships between activities (Herlod 2004), and an insufficient impersonation of on-site events in critical path method scheduling software. Exact analysis of building schedules is particularly difficult due to the lack of a comprehensive lag analysis technique that takes into consideration several fundamental lines as well as day-to-day events caused by different sections (Hegazy and Menesi 2008).

1.4 Research Scope and Objectives

The goal of this research is to make the first step and the first research that focuses the lights on the investment in the capabilities and enhancements that ML can contribute and make in the improvement journey of CPM, and this was done by dividing the research into two parts:

- The first part is about collecting information about the CPM through previous articles and researches and also collect information about ML and its capabilities and branches and try to make a combination of the two and

summarize that into practical and solid ideas and thoughts that can possible be implemented in further researches and discuss each of them separately.

- The second part is a survey that is made for a wide slice of engineers collecting information about several aspects:

- Engineers' awareness of ML and its abilities.
- the aspects that need to be reconsidered in developing CPM.
- Automation of CPM and what are the aspects that are most needed to be automated than others.
- Is the automation in CPM really needed?
- What other improvements that ML can contribute in developing CPM?

The results after that would be analyzed and discussed one by one.

1.5 Thesis Outline

This research content of five main chapters as follows:

- Chapter one: Introduction
- Chapter two: Critical Path Method.
- Chapter three: Machine Learning.
- Chapter four: Research design
- Chapter five: Field study
- Chapter six: Analysis, Conclusions and recommendations.
- References

1.6 Survey Form

A questionnaire was made in order to gather information required for the analysis, then it was authorized. The scope of the questionnaire is to support the ideas and theories made in this research by a slice of experienced people in both CPM and ML. The included samples are the following categories:

- An elite of engineers with experience in the critical path method, its use, and its pros and cons.
- An elite of academics with experience in both theoretical and scientific fields to fill out the questionnaire as respondents and as well as evaluators.

- A selection of machine learning experts on how it works and its capabilities and limitations so far.

1.7 Validity of the Questionnaire Test

- Virtual honesty: The questionnaire was created and introduced to a panel of specialist academicians and experienced engineers after a study of the literature used for science analysis by the previous theses and the technical skills of the researcher, as well as making several pre-tests to know to which extent the Phrases of this questionnaire were clear and understandable to the responders. After taking the previous authorities' observations and recommendations into consideration, the questionnaire was finalized.
- Content Validity Test: The Cronbach's alpha credibility factor was used to verify the reliability and consistency of the answers of the research sample members, and the statistically acceptable value in this test is 60%.

Alpha Cronbach: is a measure of internal consistency, or how closely linked a collection of components is, and the Alpha Cronbach scale provides a straightforward method to determine whether or not a result is trustworthy. The term "reliability" refers to the amount of actual variation determined by multiplying the observed deviation in the measurement by the amount of real variance. Numerous factors have been proposed for determining dependability from internal consistency, but Cronbach's alpha is the most often used. Alpha Cronbach's alpha coefficient is a commonly used measure of dependability in social and organizational studies.

1.8 Statistical Methods Used in the Analysis For Analysis Data

The questionnaire adopted the SPSS Statistical Program to analyze results

The SPSS Statistical Program is a collection of lists and tools that enable scientists to collect data via questionnaires, interviews, or observations and then conduct statistical analysis (statistical analysis). The statistical system is based on digital information, and the program is distinguished by its exceptional ability to process data. It is equipped with and is compatible with all scientific research techniques.

2. CRITICAL PATH METHOD

2.1 Background

The Critical Path Method (CPM), developed in 1956, has established itself as an efficient and successful method for planning and managing building projects. The critical path method enables project managers to determine the early and late start and end times of each activity, as well as to calculate the float (slack) time of the activities when available, to define critical activities, and to evaluate the effect of changing the durations and logical relationships on the overall duration. The critical path method (CPM) has seen a significant rise in usage across all sectors, including construction, over the past three decades, owing to its advantages and the enormous advancements in computer technology and scheduling software (Liberatore et al. 2001). CPM is critical in construction projects since it allows the contractor to identify and quantify when and how many resources are required, as well as suppliers to estimate when they can supply suppliers and subcontractors to decide when they can begin work. However, the critical route approach has a number of significant drawbacks that have not been addressed. The critical route method's computational efficiency and analytical skills must also be improved in order to meet the changing demands of the construction industry (Ahuja and Thiruvengadam 2004). Construction involves unique conditions, difficulties, and needs not seen in any other industry. Although this sector has a large number of large firms, data indicate that almost three-quarters of construction companies have less than five workers (Halpin and Woodhead 1998). The majority of these small businesses operate as specialist subcontractors for a general contractor. According to Russell and Radtke's study, this kind of business faces the greatest number of failures (1991). The study identified the agents responsible for failure, such as insufficient financial flow, underbidding, a lack of expertise estimating and monitoring expenses, and other outlandish problems. These agents demonstrate an inability to manage projects efficiently, which is partially attributable to faults in the Critical Path Method, most notably the lack of a straightforward mathematical formulation for resolving project

constraints such as resource constraints and deadlines. Although commercial software and professional organizations offer several practical suggestions, many construction specialists, as well as small contractors and tradespeople, use the Critical Path Method and project management tools for little more than creating a tidy schedule to meet contract requirements (Baweja 2006).

2.2 Development of the Critical Path Method

The Critical Path Method was created by researchers at the E. I. Du Pont de Nemours Company in the late 1950s. When the Critical Path Method was originally created, it took the form of a (AOA) or "activity on arrow" diagram, which allowed for just Finish-to-Start relationships between activities. This implies that activities cannot overlap and that previous actions must be completed before the current activity may begin.

With the introduction of the Precedence Diagram Method (PDM), more flexibility in activity connections was introduced, although schedule calculations continued to utilize the Critical Path Method. In precedence-based networks, an activity may be connected from either its start or end, which, in addition to the traditional Finish-to-Start connection type, enables the use of three more kinds of links between project activities (Start-to-Start, Start-to-Finish, and Finish-to-Finish).

Another feature of the Precedence Diagram Method is the ability to specify time intervals between the start/finish of one activity and the start/finish of the subsequent activity. These temporal intervals between actions are referred to as leads and lags.

A lead is defined as the time interval between the commencement of one action and the start of its successor(s), while a lag is defined as the time/delay between the completion of one activity and the start of its successor(s).

The majority of commercial software packages, such as Primavera, Project Planner, and Microsoft Project, allow for the use of not just the traditional kind of connection but also additional sorts of relationships in the event of delays.

2.3 Growth of CPM Usage

Numerous studies have shown an increase in the use of the Critical Path Method in the construction sector over the last few years. (Kelleher 2004) examined data from

three polls conducted in 1974, 1990, and 2003 to determine if the top 400 contractors in Engineering News Record (ENR) use the Critical Path Method. That study revealed a growing use of the Critical Path Method, which reached 98 percent of responses in 2003. Hawkins (2007) discovered that by polling both large and small contractors, not only the major ENR 400 businesses, but also small and mid-size construction firms, use the Critical Path Method for project management. Almost all respondents said that they have utilized Critical Path Method scheduling at least once; 45 percent stated that they used CPM always, while the remaining 40% stated that they used CPM mainly in their job.

CPM was primarily used for planning (before to construction), control (during construction), and claim investigation, according to reports (after construction). The drawbacks of Critical Path Method implementation included extra labor, logic misuse, too much reliance on specialists, a lack of responsiveness, and the need for field workers. These conclusions corroborate survey findings (Galloway 2006): The Critical Path Method did not earn the construction industry's confidence as a project control tool. This is true despite contractor claims of using the Critical Path Method for project management, as stated in Kelleher's (2004) study. They may argue that it is advantageous for evaluating progress and updating activity data, but it is not advantageous for supporting other critical elements, such as resolving execution issues and corrective measures.

2.4 The Critical Path Method Mechanism

In order to implement critical path analysis, firstly identify the activities and tasks that the project is made up of, then the precedence relationships are represented using a project network. According to that network, each activity can be preceded by a group of predecessor activities (predecessors) and succeeded by a group of succeeder activities (succeeders).

After drawing the project network as indicated in Figure 2-1 and Figure 2-2, the next procedure is implemented (Hegazy 2002):

- The early start times (ES) are calculated through forward pass calculations.
- The late finish times (LF) are calculated through backward pass calculations.
- Calculating float.

- Critical activities identification.

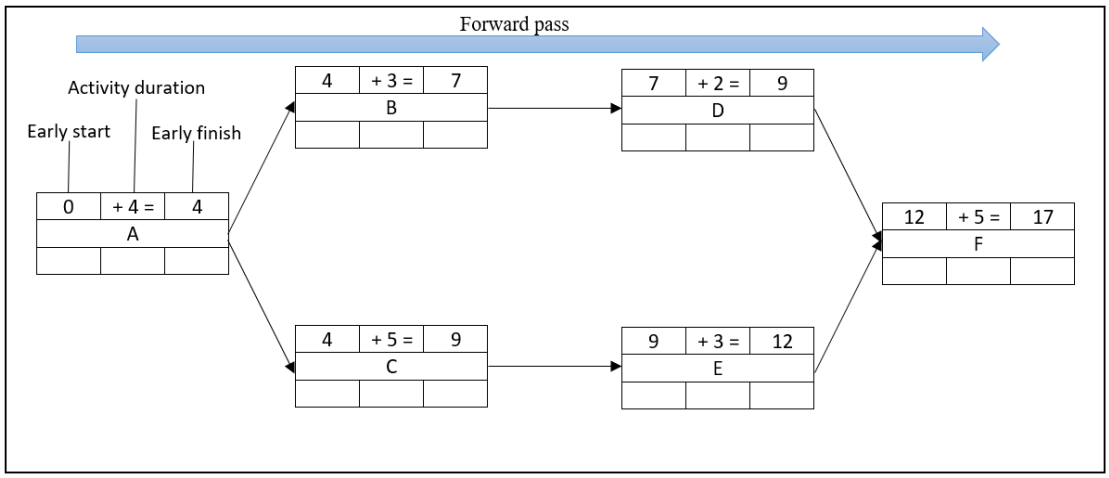


Figure 2.1: Forward pass calculations in CPM network

Firstly, the forward pass which is the calculations that start from the early start of the project and keep moving till the end of the project (from left to right) as shown in figure2-1, the early start time (ES) is usually written on the upper left corner of the node while the early finish time (EF) is usually written on the upper right corner of the node which represents an activity while the number on the upper mid represents the duration of an activity. The calculations start from the first mission in the schedule (the first mission starting from left) which its early start time is zero always (0), then the activity time (4 days or weeks depending on the time unite used in the project) is being added to the first early start time (0+4) resulting an early finish time of (4) at the end of that activity. The network shows that both of the activities **B** and **C** can start as soon as the activity **A** has finished. The next step is to transfer the EF time of the predecessor activity to the ES time of the successor activity. Then each ES time of activities must be added to the duration of activity which produces the early finish time of that activity for both **B** and **C** (7,9) as shown in figure2-1.

If more than one activity was predecessor to an activity, one of the activities having the highest EF is selected to be written into the successor activity. As explained with **F** activity in figure2-1, since the largest EF of the two predecessor **D** and **E** was (12) and not (9), it was chosen as the early start time of the successor activity **F**. through summing duration (5) to ES (12), EF resulted for the final activity (17) which represents also the time by which the project must finish.

Then comes the backward pass, which is calculated the same as the forward pass but on the opposite direction, since it starts moving from the end of the project to the beginning as explained in figure 2-2.

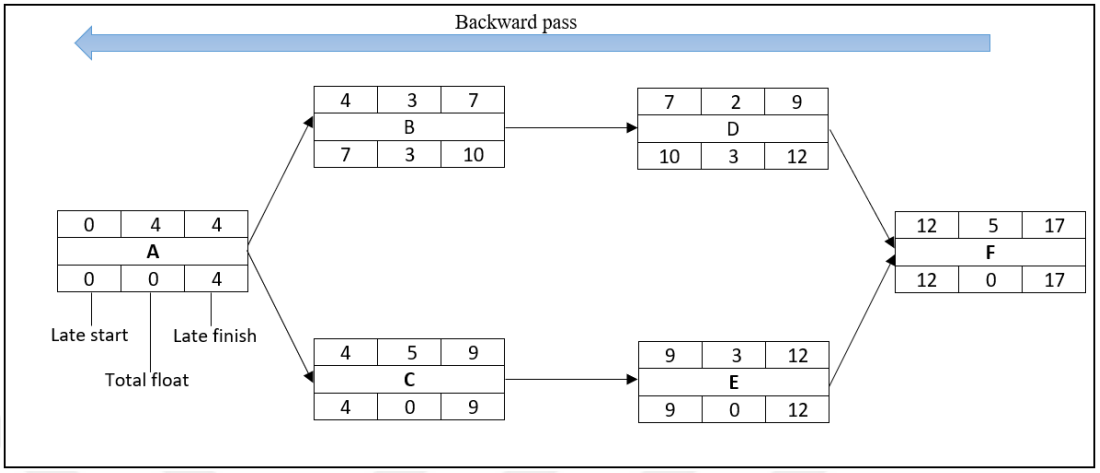


Figure 2.2: Backward pass calculations in CPM network

The late start (LS) is usually written on the lower corner on the left of the node while the late finish (LF) is usually written on the lower corner on the right of the node, the lower middle part represents the total float of the activity which refers to the available time for an activity to be delayed beyond its own specified time which is usually zero in critical activities. The calculations start from the farthest activity to the right in the network which is the last activity, the early finish time of this activity now becomes the late finish. when the activity's own duration is subtracted, late start now computed (12). Now heading backward towards the predecessors of the last activity, the last activity's late start considered as late finish of its predecessors, then it's subtracted of the duration of each activity as shown in figure 2-2.

When more than one successor activity goes back towards one a single activity, activity chosen with the shortest late start to be the late finish of predecessor activity, as it happened with the activities **B** and C with the predecessor activity **A** in figure 2-2.

After calculating the forward pass and backward pass, total float (**TF**) is then calculated, which represents the difference between the late finish and the early finish or the difference between the late start and the early start of each activity as expressed in the mathematical formula:

$$\text{Total float} = LF - EF = LS - ES$$

The total float is calculated for each activity, it's also called the total slack, its important because it determines the flexibility of an activity: how much time can an activity be delayed.

Critical activities are activities with zero float, they're critical because any delay in these activities cause delay in the whole project. Those critical activities form a continuous path that moves throw the whole project from its beginning to its end.

This path is called the critical path and it's the tallest path (in duration) in the project. Such as the critical path (**A-C-E-F**) shown in figure 2-2 as bolded activities.

2.5 CPM Compression Techniques

Compressing a schedule provides couple significant tactics in indexation of time for projects to be accomplished in the specified date for it. The correct investment for these techniques and the proper implementation for the way of implementation in the compression of projects is helpful in both big and small types of projects. Schedule compression are working methods utilized in the time that a project manager is willing to minimize a project duration with no shifting in the project's scope. It is mostly employed in the scenario when a project is falling after the schedule and it has to keep up with it or to the case when the project has to be finished earlier than what is planned.

Fast tracking and **Crashing** are two methods could be used to minimize the duration of a project but keeping it is scope.

2.5.1 Fast tracking

Fast-tracking is a method when the tasks that are intended to be done alternatively one after the other according to the schedule are implemented in parallel. Simply, fast tracking a project refers to the method of working on the activities on the same time or concomitantly rather than waiting for every task to be done individually. But fast tracking has one condition to be used which is whether the tasks of project have the ability to be overlapped. while considering for a schedule to be compressed, Fast tracking is the first choice on the list rather than crashing, since fast tracking basically will not imply any cost. It is based on reordering the tasks in the schedule. Despite that fast tracking does not involve increasing financial cost, it causes

increasing the risk, simply, because activities now are implemented on the same time, in parallel in other words, which can cause the whole project to be rescheduled or rearranged. Thus, rearranging a project would lead to further loss in time. Project managers have to consider the positive and negative effects of this tool to decide whether it would be worthy for accept this risk raise.

2.5.2 Crashing

Crashing is the technique used as a second choice when fast tracking cannot save the enough required time on the schedule of the project. Using Crashing increases resources that used in the project with the least cost feasible. This technique is implemented by analyzing cost and schedule tradeoffs to calculate how to achieve the maximum compression with least additional fee. Crashing is an expensive technique since it has to add more resources to the project and any additional resources simply, means extra cost. Crashing technique first studies and classifies each activity according to the lowest crash cost possible for the time saved. This allow the team responsible for the project to be able to specify the activities that are capable of giving the highest value with least additional cost. The outcomes obtained from analyzing crash generally submitted in a graph to explain them to other members in the administration of the project. Activities that have the flattest slope are regarded before other activities, because they make an equal degree of time being saved with less cost increase. Crashing can be used only when the additional resources will attain earlier completion of the project.

2.5.3 The use of fast track and crash

The need to handover or complete project, service, or result earlier than what originally planned, project manager is will have to compress the project schedule. Schedules are always changing duo to outer circumstances or many other factors; usually, schedules taking longer time rather than taking shorter time than scheduled, which will have negative effect on the basic schedule since the project would not be completed in the period available.

Fast tracking or crashing non-critical activities is useless, since minimizing such activities would not affect or shorten the time of the project.

2.6 Resolving Practical Constraints in CPM

Critical path method has no consideration for resources since it resources are not included in processing both forward passnor backward pass. Additionally, Critical Path Method structure does not include any deadline which will restrict or limit time specified for the project (Hegazy 2002). So, other methods have to be implemented independently after finishing the analysis to handle the deadlines and limited resources. Anyways, implementing those methods may cause many other problems, as explained below. As well as, solving one of the restrictions, for example, resource limits, maybe breach the solution for another solution, for example, the deadline.

2.6.1 Resource leveling/Allocation

While the Critical Path Method assumes that the resources required to complete the tasks are limitless, in most real-world situations, the available resources are restricted in quantity, particularly when those resources are used for several tasks or even numerous projects (Lu and Li 2003). The issue is that when scheduling considers resources, accuracy for total float computations is lost (Bowers 1995, Fondahl 1991, Kim and de la Garza 2003). As previously stated, total float is defined as the time allowed for an activity to be delayed without affecting the project's completion date. Typically, critical activities or critical tasks with a total float of zero are regarded as critical activities or critical tasks in Critical Path Method calculations. These essential activities help define the project's crucial route on the schedule or calendar. Total float is important in construction scheduling and management because it motivates the contractor to prioritize vital activities over those with zero total float. Additionally, the total float of the activities is critical in the delay analysis that is conducted to determine the impact on project completion time caused by any lags/inching progress. To resource-constrained applications, the Critical Path Method's backward pass computation may result in incorrect total float timings, since the serialization of some operations is determined not only by logical linkages, but also by resource dependencies (Kim and de la Garza 2003). When the traditional Essential Path Method is used, resource-critical activities cannot be defined, resulting in the creation of a fake critical path.

2.6.2 Challenges in resource allocation algorithms

Several researches have concentrated on the issue of discovering the real total floats in resource-constrained projects (like: Wiest 1964, Woodworth and Shanahan 1988, Bowers 1995, Kim and de la Garza 2003, Lu and Li 2003). These researches used the way of making resource-constrained bonds among the activities plus the basic logical bonds in the original Critical Path Method table. Anyways, the techniques suggested in the researches does not present changing properties for the resource bonds which can show changings in the schedule (Kim and de la Garza 2005).

(Lu and Lam 2008) searched the scheduling in resources tools for Primavera (P3) computer software. P3's constraints based on the employment of SF (Start to Finish) bonds or relationships through resource limitations were specified as: exaggerated total floats are resulted, and invalid dates are made. Trying to solve these constraints, (Lu and Lam 2008) displayed a modern policy in calculating the total float in every task by monitoring impact of expanding duration for every task on the period of the project. Whatever, this way is not accurate also as it takes into account only one kind of task lag. A task can be delayed because of either disability to initiate or bad advancement (raise in duration). Every reason of them has a variant effect on the project and also on the total period of the project. Whenever a task slowed or postponed because of slow advancement, for example or, decreased productivity, the resource will still be consumed by that task, and the contractor will not be able to use the resource in another task till the present task ends. Nevertheless, postponing the beginning of a task frees the meagre resource so that the contractor would be able to use it to perform another task so that he can decrease the impact of that delay on the total duration of the project.

MS Project (Microsoft Project) is one of the most well-known and widely used software bundles among construction managers (Galloway 2006; Liberatore et al. 2001), and thus Microsoft Office Project Professional 2019 was used to shed light on the issue of calculating a false critical path in resource-constrained projects.

Figure 2-3 depicts the timetable for a six-day program comprised of seven events. Each task in this research needs two employees on a daily basis; the issue is that no more than four workers may be used on any one day. The contractor changed the beginning times of both A and F activities (by throwing a delay option for the

activities) to resolve resource over-allocation. After revising the timetable, the project's length increased by two days.

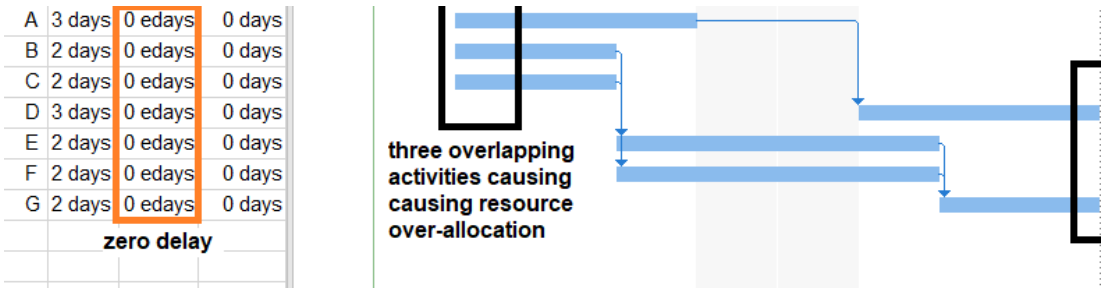


Figure 2.3: Schedule 1 that have resource problem

As displayed in Figure 2-3, activity E now having total float of two days calculated by Microsoft Project program. Days of total float imply that whether E activity had to be extended by two more days, the duration of the whole project will not be impacted. Anyways, when increasing the duration of E activity two days more, as illustrated in Figure 2-5, the number of labors on days five and six would be over-allocated, which means that the whole project then will need to be scheduled again in order to fulfil resource-limits for this special case. After modifying the schedule, the project duration would more increase from 8 to 9 days or units, as displayed in Figure 2-6. Therefore, the activity E should not be referred to as having two float days because this activity is defined as resource-critical. These 2 float days are called by (Kim and de la Garza 2003) the “Phantom Float”.

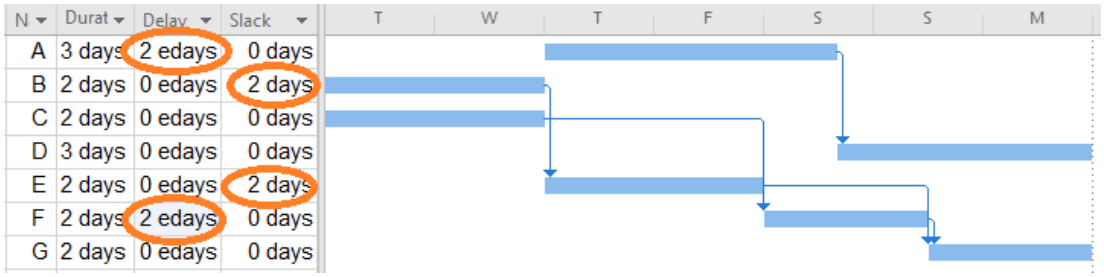


Figure 2.4: Schedule 2 after considering resource limits

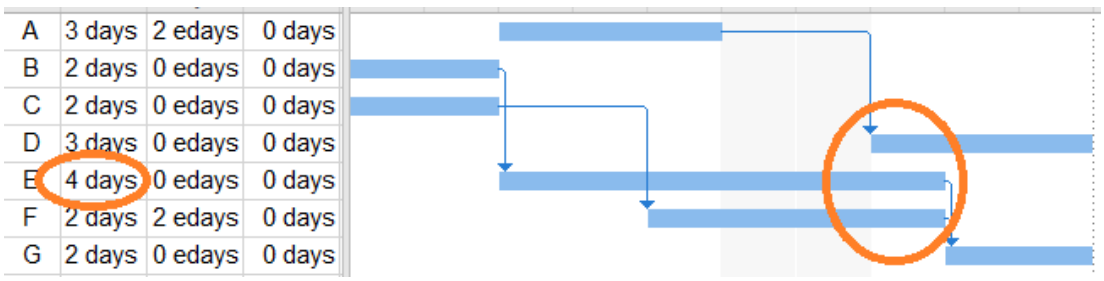
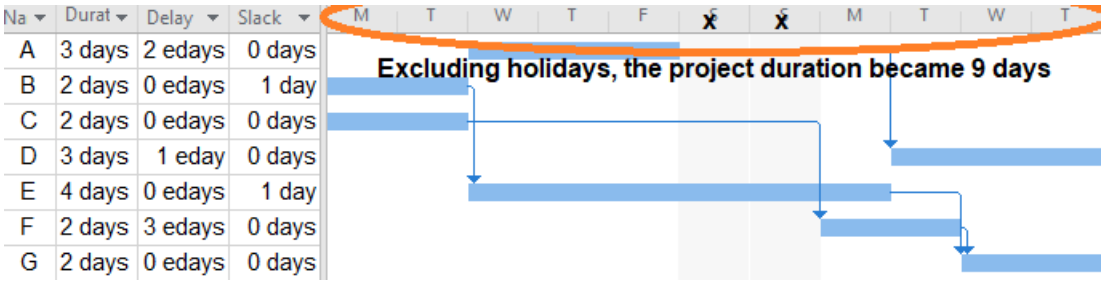


Figure 2.5: The schedule after adding two days to E activity



Na	Durat	Delay	Slack
A	3 days	2 edays	0 days
B	2 days	0 edays	1 day
C	2 days	0 edays	0 days
D	3 days	1 eday	0 days
E	4 days	0 edays	1 day
F	2 days	3 edays	0 days
G	2 days	0 edays	0 days

Figure 2.6: The schedule after solving the problem

This case study reveals the fact that the total float calculation in Microsoft Project is made basically on precedence links between the activities without taking into consider the resource depending relationships between them, which leads into wrong total floats and, therefore, wrong critical path.

2.6.2 Time-cost trade-off analysis

Time-Cost Trade-off (TCT) analysis can be defined as a technique employed for overcoming Critical Path Method's shortage of ability to limit the schedule to an exact period. The main goal of the analysis is to decrease the basic CPM period of a project to satisfy a selected deadline with the least cost (Chassiakos and Sakellaropoulos 2005). TCT analysis is a significant management instrument, the reason is it can be used to accelerate a project so that lags would be solved and skimmer harms averted. Projects mostly, can be quickened via adding resources, for example, laborers or materials, or by adding more working-time to make crash for critical tasks or activities. So, minimizing the duration of project will cause raise in direct costs (DC), for example, the cost of extra equipment, materials and labor. The raise in DC spending, nevertheless, can be warranted in the case of the indirect costs, for example, costs for supervision and management, decreased or in case a reward is gained (Gould 2005).

TCT analysis implies choosing critical activities for trying to minimize their duration by using a quicker building technique, although the additional costs. various formulations of building techniques for the activities can then be made, every one of them causing a certain direct cost and project duration. To calculate the best TCT rapporteur in the project, curves of direct and indirect costs drawn separately so, adding these two curves together makes the total cost curve, displayed in Figure 2-7. Lowest point in curve of total cost marks the best composition of building techniques for the case of activities. whatever, in projects which have a considerable count of

activities having different building choices, identifying the best TCT results gets very hard and time consuming (Zheng et al. 2004).

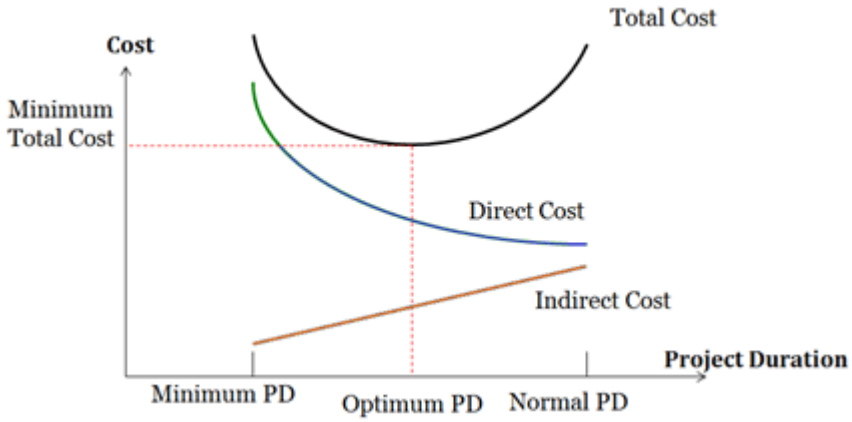


Figure 2.7: Project duration-cost plot

Source: Time Cost Trade Off - info heed

Three master approaches have been employed for fixing TCT issues: heuristic approaches, mathematical programming models and genetic algorithms. The next table shows a comparison between the three made by Hegazy (2002).

Table 2.1: Three techniques for Time-Cost Trade-Off analysis comparison

Heuristic approaches	**Mathematical Programming Models**	**Genetic Algorithms**
Brief: slight laws of thumb	Integer Programming, Linear Programming, or Dynamic Programming	improvement search procedures that mimic natural evolution and reproduction
Positives: - Easy to understand - Provide good solutions - Used for large projects	- May provide optimal solutions	- Robust search algorithm - Can use discrete relationship for time /cost - Applies for large problems
Negatives: - Lack mathematical rigor - Do not guarantee optimal solutions - Mostly assume linear, rather than discrete relationship between time and cost	- Tough to formulate - Gradient-descent approach that often terminates in local minimum. - Applies to small problems only - Mostly assume to be linear, instead of discrete relationship for time/cost	- Random search that is time consuming - Cannot tell when or if an optimal solution is obtained
Examples: Prager 1963 Siemens 1971 Moselhi 1993	Kelly 1961 Liu et al. 1995 Chassiakos et al. 2000 Moussourakis and Haksever 2004 Chassiakos and Sakellaropoulos 2005	Feng et al. 1997 Li et al. 1999 Lu and Li 2003 Senouci and Eldin 2004 Zheng et al. 2004 Jaskowski and Sobotka 2006 Eshtehardian et al. 2008 Rogalska et al. 2008 Zahraie and Tavakolan 2009

3. MACHINE LEARNING

3.1 Introduction to Machine Learning

Since their inception, humans have used a variety of diverse materials to accomplish a variety of different objectives. The human brain's inventiveness resulted in the creation of many devices. These machines simplified human existence by enabling people to fulfill a variety of living needs, including building, transport, computing, and industry. Despite rapid advancements in the machine sector, intelligence remained the critical distinction between people and robots in achieving their objectives. The human senses gather data from the surrounding world; the human mind analyzes this data and then makes suitable choices depending on the information or data. Machines, on the other hand, are not naturally intelligent. Machines lack the capacity to analyze data and make decisions. For instance, when considering a machine, it is unlikely that the machine would comprehend the story of Sinbad, fall in love, or communicate with other machines through a sophisticated language. The era of intelligent machines started in the mid-twentieth century, when Alan Turing considered the idea of a computer thinking. Since that time, artificial intelligence (AI), a subfield of computer science, has developed rapidly. Humans aspired to create robots as intelligent as humans. Numerous science fiction films have attempted to interpret these visions, including AI; Her; I, Robot; Ex Machina; and The Machine. The history of artificial intelligence started in 1943 with Walter Pitts and Waren McCulloch's development of the first neural network model. In 1950, Alan Turing made the second fundamental contribution to the development of Artificial Intelligence by asking the now-famous question, "can computers think?" Additionally, he pioneered the development of B-type neural networks and the idea of intelligence testing. Oliver Selfridge suggested using computers to do pattern recognition in 1955. In 1956, Marvin Minsky, John McCarthy, Nathan Rochester of IBM, and Claude Shannon organized the United States of America's inaugural summer Artificial Intelligence conference. During the second meeting, the phrase "artificial intelligence" was first used. The term "cognitive science" arose in 1956

during a presentation on information science at the Massachusetts Institute of Technology (MIT). In 1957, Rosenblatt invented the first perceptron. After that, in 1959, John McCarthy developed the LISP programming language. In 1962, David Hubel and Torsten Wiesel suggested that neural networks be used for computer vision. "Eliza," created by Joseph Weizenbaum, was the first intelligent system capable of diagnosing a disease based on its symptoms. In 1964, the United States of America's National Research Council (NRC) created the Automatic Language Processing Advisory Committee (ALPAC) to promote research in natural language processing. Following then, the study was halted due to slow progress and expensive costs. Seymour Papert and Marvin Minsky's 1969 book Perceptrons discussed the limitations of neural networks. As a result, funding for groups doing research on neural networks was discontinued. Between 1969 and 1979, there was a surge in research on knowledge-based systems. The two programs Dendral and Mycin were developed as a result of these studies. Paul J. Werbos proposed an effective model for backpropagating neural networks in 1979. In 1986, Geoffrey Hinton, Ronald Williams, and David Rumelhart coined the term "backpropagation" to refer to a technique that enables a network to learn how to discriminate between nonlinear separable classes. In 1986, Charles Rosenberg and Terrence Sejnowski developed NETTalk, an artificial neural network for voice detection. In 1987, Arthur W. Burks and John H. Holland developed a learning-capable adaptive computer system. Dean Pomerleau presented the ALVINN (autonomous land vehicle in a neural network) three-layered neural network for road following in 1989. Garry Kasparov, the global chess champion, was beaten in 1997 by IBM's Deep Blue chess computer. In 2011, an IBM-developed computer called Watson beat Ken Jennings and Brad Rutter, the television game show Jeopardy! champions.

Since 1997, rapid advancements have been made in natural language processing, reinforcement learning, computer vision, computer hearing, emotional comprehension, image processing, pattern recognition, cognitive computing, and knowledge representation, among other areas. These approaches aim to provide computers with the capacity to gather data through senses analogous to human senses and then process it using machine learning and computational intelligence technologies to make predictions and judgments on a par with people. The term "machine learning" refers to the process of allowing machines to learn without

having to be programmed. Generally, machine learning has six well-established methods:

1. Supervised learning.
2. Unsupervised learning.
3. Semi-supervised learning.
4. Reinforcement learning.
5. Deep learning.
6. Deep reinforced learning.

The objectives of machine learning are:

- To enable machines to make predictions
- To perform clustering
- To perform extract association rules
- To make decisions from a given dataset

3.2 Learning in Machines

Learning is a personal experience for us. Will Durant pose the following question in a chapter titled "Is Man a Machine?" in his book (The Pleasures of Philosophy): Consider it cautiously and bravely raising itself to a vertical dignity for the first time; why would it wish to stand and walk? Why should it quiver with hungry interest, touching and tasting, watching and listening, manipulating and experimenting, learning and wondering, and growing—until the globe is weighed and the stars charted and measured?

However, humans are not the only animals capable of learning. Additionally, even the smallest organisms such as paramecium and amoeba learn. Indeed, even plants demonstrated intelligence. Only non-living things are excluded from learning. As a result, life and learning seem to coexist. It is incapable of learning for naturally nonliving objects. Is it feasible to transfer the process of learning to nonliving objects created by humans and dubbed machines? Inventing robots capable of learning in the same way as humans is a goal; fulfilling this ambition may end in machines gaining their own autonomy.

Machines do not come pre-programmed with intelligence. To begin, machines were created to do particular tasks, such as regulating traffic flow, operating on railroads,

excavating deep trenches, and even firing at moving things. When compared to people, machines can execute their jobs far more quickly and with a greater degree of precision. They make life much easier than it was before. The fundamental distinction between people and robots when they are at work is intelligence. The five senses provide information to the human brain. This information is sent to the brain through the neural system for processing, comprehension, and action. The brain organizes and recognizes data during processing by comparing it to previously stored events in the memory, as previously stated. As a result, the human brain makes a decision and then directs the bodily parts to interact in opposition to that activity. After completing the experience, it will be saved in the memory for future use. Machines are incapable of intelligently managing the data they gather. They lack the ability to classify data, make use of prior events, and store new experiences in memory units; in other words, machines cannot learn from experience. Though machines are capable of performing mechanical and mathematical tasks much faster than humans, it is not expected that a machine can comprehend a novel about crime and punishment, jump across a street barrier, make friends, communicate with other machines via a common language, recognize and warn of dangers and then learn how to avoid them, diagnose a disease based on its symptoms, or perform laboratory tests. The challenge is to teach non-living robots how to behave appropriately in such circumstances. Given that robots are primarily designed to help people in their everyday activities, it is critical for machines to think and comprehend in order to solve issues and make appropriate decisions in the same way that humans do. In a nutshell, we need intelligent machines. Indeed, the term "smart machine" refers to a machine that is capable of successfully learning and storing such knowledge for future use.

Alan Turing, a British mathematician, raised the issue of whether a computer can think for the first time in 1955, laying the groundwork for the narrative of artificial intelligence. Alan was the first to propose a test for determining a machine's intelligence via its performance. Computers are also devices that follow pre-programmed instructions in order to complete tasks and help people with everyday life problems. For machines, the human brain is comparable to a CPU capable of solving equations. Assume we are attempting to locate the biggest number in an unordered list of numbers. We are capable of doing this job quickly. Diverse

individuals are capable of doing the same task in a variety of ways. This implies that different individuals may use distinct algorithms to accomplish the same job. In essence, methods or algorithms are a series of instructions that are followed in order to go from one state to the next and produce an output from an input. If several algorithms are capable of doing the same job, the proper question is which algorithm is the best. For example, if two programs are created using two distinct algorithms for finding the largest number in an unordered list, then when both programs are run on the same machine and use the same list of unordered numbers, the program's speed can be used to determine its efficiency. Another metric that can be used is the program's minimum memory usage. Thus, space and time are often used to evaluate an algorithm's efficiency. For some circumstances, time and space may be linked; that is, a decrease in memory consumption can result in a faster algorithm. For instance, an efficient method that enables a program to process all input data in cache memory would also result in a quicker program execution.

3.3 Machine Learning Relation With Other Disciplines

Machine learning is a subset of artificial intelligence that focuses on the efficient performance of machines via the use of intelligent software. Because statistical learning methods are mainly used to enhance machine intelligence, they form the backbone of intelligent software. Due to the fact that machine learning algorithms need data in order to train, this branch must be connected to the database branch. Similarly, terms like Knowledge Discovery in Databases (KDD), pattern recognition, and data mining are often used interchangeably. One may question how to depict this connection graphically. SAS Institute Inc. is a software development firm best known for its Statistical Analysis System (SAS). To illustrate the relationship between machine learning and other disciplines, we will use an SAS example from a 1998 SAS data mining course.

Figure 3.1: Different disciplines of knowledge and machine learning

Source: SAS website

In a 2006 paper titled "The Discipline of Machine Learning," Prof. Tom M. Mitchell described machine learning as follows: "Machine Learning is a natural outgrowth of the intersection of Computer Science and Statistics." We might say that the practical challenge confronting Computer Science is, 'How can we develop computers capable of solving tractable/intractable issues in and of themselves?' Additionally, the issue that may define Statistics is, 'With what degree of confidence may inferences be made given data and a set of modeling assumptions?' Combining the two previous questions yields the defining question for Machine Learning. While Computer Science was mainly concerned with teaching humans how to program computers, Machine Learning is focused with teaching computers to program themselves (through experience and some initial structure). While Statistics is mainly concerned with the conclusions that may be derived from data, Machine Learning also tackles the following questions:

- What computational structures and techniques can be used to gather, store, index, retrieve, and integrate this data more efficiently?
- How can many subtasks of learning be accomplished in a bigger system?

Certain activities we do easily or with some effort, but we are unable to describe how we do so. For instance, we may easily identify the speech or sound of our family or friends, but when asked how we know voices, we find it very difficult to describe. Due to our lack of knowledge of such phenomena - in this instance, voice recognition - we are unable to develop algorithms for such situations. Machine learning algorithms may assist in closing this knowledge gap. That is a pretty basic concept. We are not interested in understanding the passive mechanisms that aid in learning; rather, we develop computer algorithms that enable computers to learn and perform jobs such as prediction. The goal of learning is to develop a model that can take in data and generate the desired output. At times, we may comprehend the model, but at other times, it might be incomprehensible, with no obvious indication of its function. The model may be thought of as a close approximation of the process that we want machines to emulate. While it is possible that we may encounter mistakes for certain inputs in this scenario, the model will often give accurate responses. As a consequence, another performance parameter for a machine learning algorithm (along with speed and memory use) would be outcomes accuracy.

3.3 Machine Learning Techniques

Machine learning developed step by step as shown in the below diagram.

- At the beginning, scientists started developing Supervised Learning.
- Then unsupervised learning followed, where computers were capable of learning with no need for oversight or labelled data.
- researchers after that discovered additionally the following: it is feasible insight for rewarding a machine after performing a task in a right method that it is expected and that was the birth of the Reinforcement Learning.
- Soon, the data increased in vast amounts after the explosive usage of internet around the globe and the huge spread of social media platforms, its availability, and its easy access these days that the classic techniques that were used failed to analyze this massive amount of data and make use of it.
- Thus, Deep learning came in, in which, the man mind was mimicked within ANN made using computers.
- Machines now learning on its own without supervision using the elevated computing force of computers and the huge data provided per-day.
- Till now, it is noticed that DL did resolve various of the divergent issues that have not been solved yet.
- Deep learning is much more advanced now through awarding the machines with computational incentives which is a new technique that is called DRL.

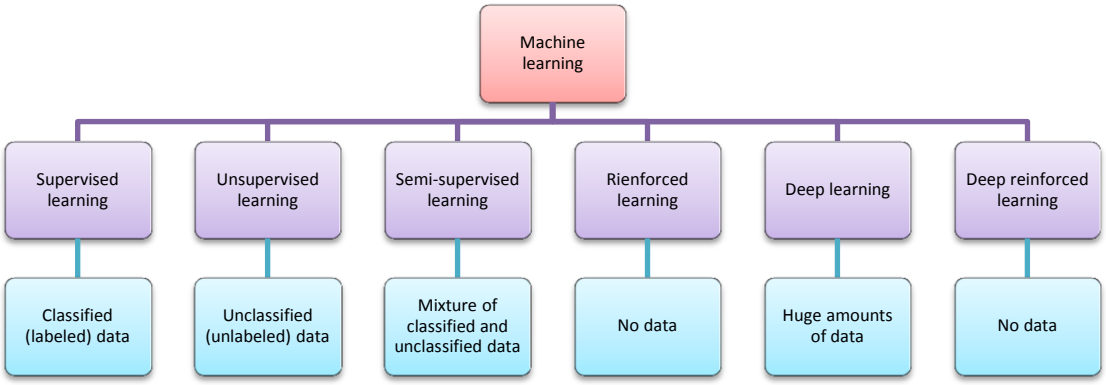


Figure 3.2: Different machine learning techniques and type of required data

3.4.1 Supervised learning

The objective of supervised learning is to infer a technique or mapping from labeled training data. Training data is comprised of an input vector X and an output vector Y containing tags or labels. A label (or tag) in vector Y represents the interpretation of the corresponding input sample in vector X. The combination of X and Y data constitutes a training example. That is, training data is made up of training examples. If no labeling or tagging exists for input vector X, this indicates that X contains unlabeled data. Why is this kind of learning referred to as supervised learning? The training data contains an output Y vector with labels for each training sample. The supervisor submits the produced vector labels. While supervisors are often people, such tagging may also be performed by computers. Human judgements are much more costly than machine judgments, since the greater mistake rates in data labeled by machines attest to human judgment's superiority. Manually labeled data is a very trustworthy and valuable resource for supervised learning. However, in certain instances, machines may also be employed to do accurate labeling.

3.4.1.1 Example

Below are some instances of unlabeled data types that may be labeled according to different standards. The column on the left of the table, headed (Example judgment for labeling), has a viable yardstick for each kind of data included therein. Additionally, the column discusses possible captions once the choice is applied. The last one indicates if any of the performers is qualified to serve as a supervisor on other columns. For the rows 1 to 4, as described in Table 3-1, machines are capable of being used, but their decreased percentages of accuracy make their use untrustworthy. While emotion analysis, voice recognition, and picture recognition technologies have advanced significantly over the past thirteen years, there is still much need for improvement before we can compare computers to human judgment. However, in instance number 5, the lump searches, ordinary humans lack the capacity to classify the X-ray data, necessitating the use of expensive specialist services. The term "supervised learning" refers to two distinct groups or types of algorithms. They are as follows:

Table 3.1: Unlabeled Data Examples along with Labeling Issues

	Unlabeled Data Example	Example Judgment for Labeling	Possible Labels	Possible Supervisor
1	Tweet	Sentiment of the tweet	Positive/ negative	Human/machine
2	Photo	Contains house and car	Yes/No	Human/machine
3	Audio recording	The word football is uttered	Yes/No	Human/machine
4	Video	Are weapons used in the video?	Violent/nonviolent	Human/machine
5	X-ray	Tumor presence in X-ray	Present/absent	Experts/machine

3.4.1.2 Regression

In the supervised learning case, computer is given significant pre-solved examples. Where for specific feature value x1 its output is y1, the same with x2 it is y2 and so on. According to the given data, the computer automatically finds an empirical relationship between x and y (model). As soon as the machine finishes training in with a sufficient amount of data, the machine is then tested to predict Y value based on a given X. The Xs and Ys values that are used for testing are already well known to the user so that the predicted value can reveal whether the machines model is correct or not. Once the machines results are satisfying which means that the machine now can perform the prediction with a required level of accuracy (like 80% or 90%), its accepted to stop further training the machine. The model after testing becomes ready to be used for real, unknown predictions. One of the most famous examples for explaining this, is the house price prediction model which is built by training the machine using previous data then given some information about specific house so that the machine predicts its price.

3.4.1.3 Classification

In classification algorithms, the machine classifies similar objects based on some features into groups. For example, 100 students have to be classified based on their heights into three categories or groups short, medium, and long. After getting the measure of each student, each student will be placed in one of these three groups

according to his height. Now, when we want to register another student, we will categorize him based on his height and find the suitable group for him based on that measurement. By training the machine to distribute and classify students according to this feature -height-, the machine will have the ability after that to classify any unknown new student correctly. Again, it's important to use a testing data to make sure that the machine has learned the required technique of classification before using the constructed model in production. That technique seems easy to be done without the help of machine, but if we use many features combined on the same time it will be very difficult or maybe impossible to do that manually. Supervised Learning is considered as the place where the journey of AI really began. This technique was used successfully in many real-life cases. Several algorithms have been developed for supervised learning.

3.4.1.4 Algorithms for supervised learning

There are many algorithms made in the case of supervised learning. And some of the most known and used on a large-scale of algorithms are:

- k-Nearest Neighbors
- Logistic Regression
- Decision Trees
- Support Vector Machines
- Naive Bayes

k-Nearest Neighbors

The k-Nearest Neighbors, it is basically called k-NN which is a statistical algorithm that is utilized for helping with classification and regression problems. For example, for classifying three classes of points using k-NN. Assume that the allocation of objects is as shown in the Figure 3-3 given below:

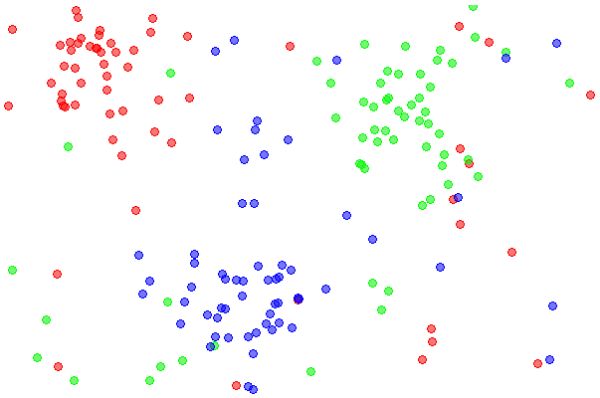


Figure 3.3: Distribution of three classes of objects

Source: Wikipedia

The Figure 3-4 shows three classes of objects, shown as blue, red, and green. When using the k-NN classifier for classifying this dataset, boundaries will be drawn for every class of objects and will be noticed in Figure 3-4:

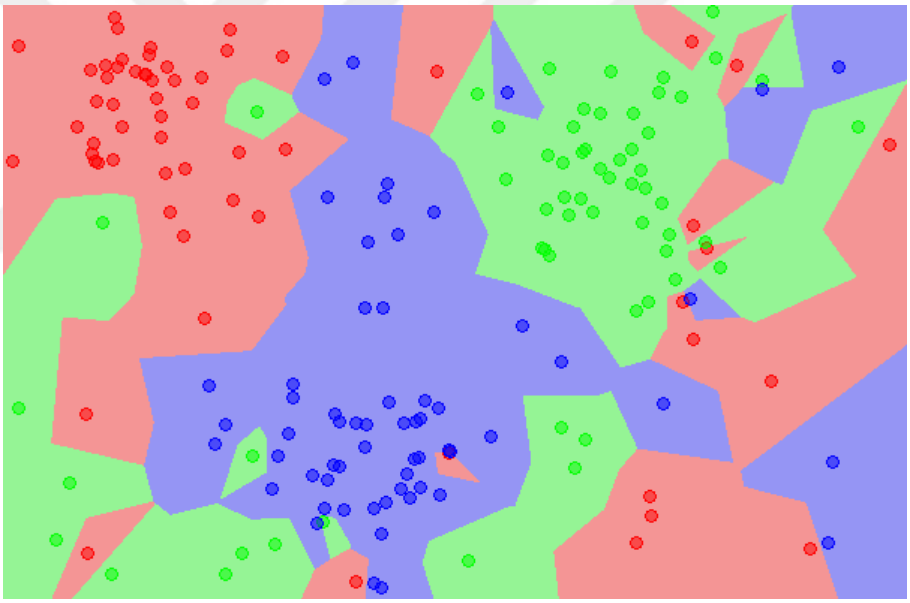


Figure 3.4: Distribution of objects after using k-NN

Source: Wikipedia

Now, let's consider an unknown object that we want to categorize it as red, green or blue. This is illustrated in the Figure 3-5 below:

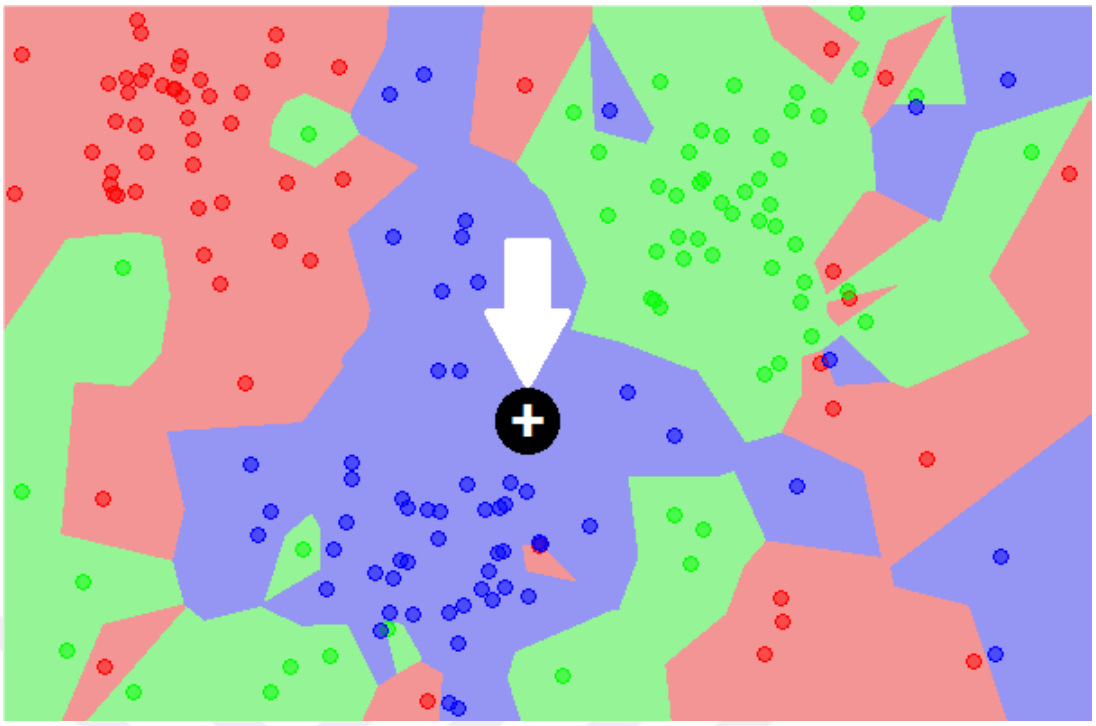


Figure 3.5: İllustration shows the unknown object

The unknown point visually belongs to the blue class. This result is mathematically deduced by calculating the distance between the unknown location and every other point in the data set. After doing so, we'll see that the bulk of adjacent spots are colored blue. Clearly, the medium distance between the green and red dots is much greater than the medium distance between the blue points. As a result, this unknown point must be classified as blue.

Additionally, the k-NN method may be utilized in regression situations. The k-NN method is included in the majority of machine learning packages.

Logistic Regression

The below demonstrates the allocation of data points on the XY plane.

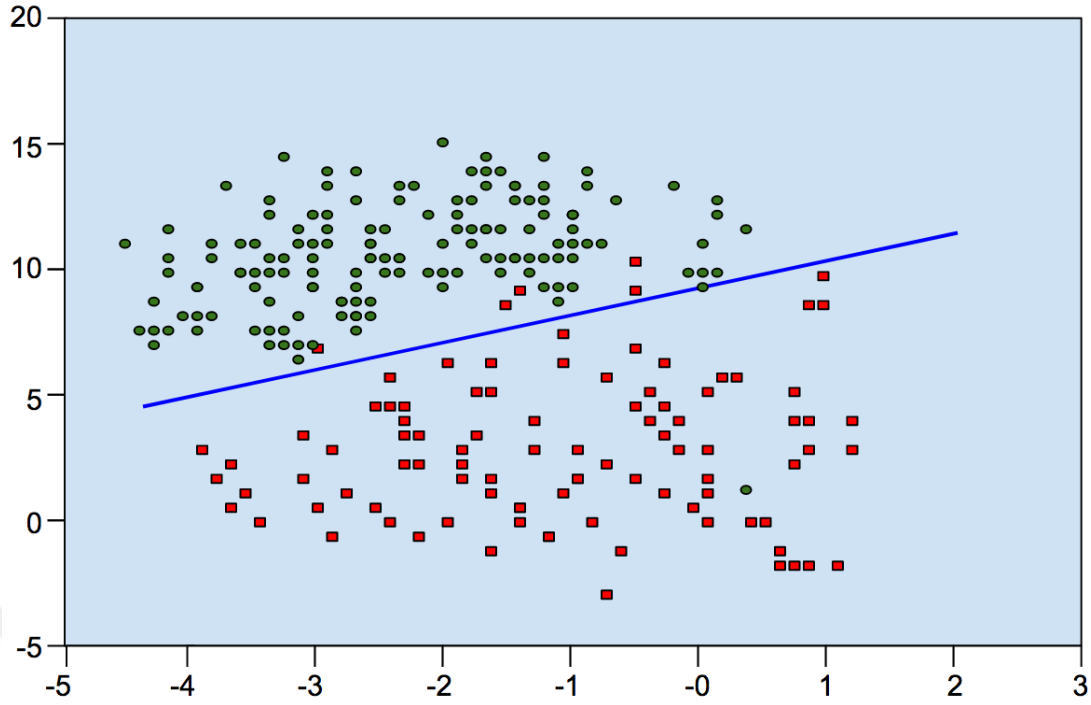


Figure 3.6: An xy coordinated plane showing many distributed points

After seeing the Figure 3-6, we can optically expect where the separating line between red and green dots can be placed. we might draw a bordering line to discrete these two classes of dots. After that, for classifying any new different point, we will have to identify on which hand of the separating line the point lies.

Decision Trees

A simple example of decision tree through flowchart format is shown in the Figure 3-7:

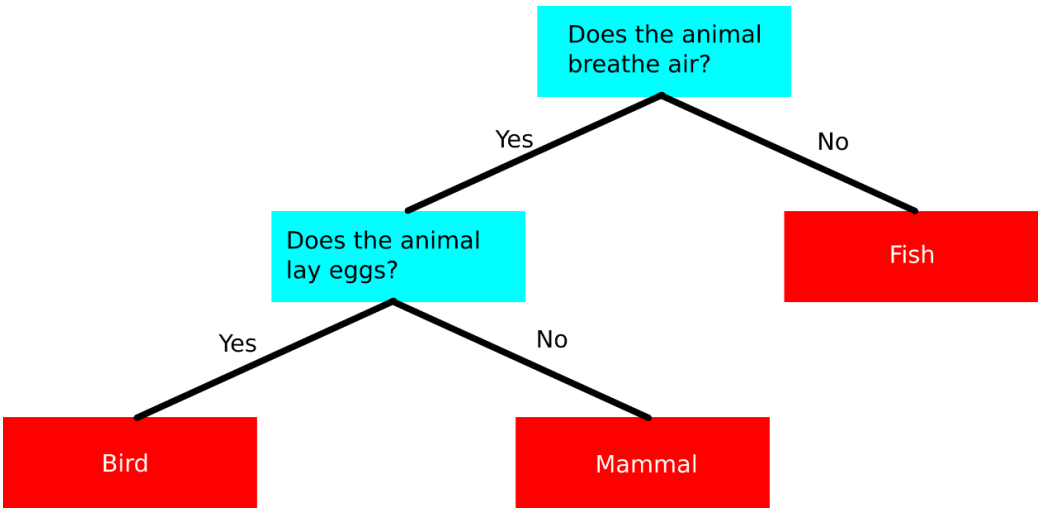


Figure 3.7: Simple decision tree flowchart

Source: Charlie Bickerton

The flowchart is simple, intuitive, and easy to understand. For the case in the above flowchart, obviously it is used for classifying animals based on specific features.

Generally, in practical environments, the decision trees are way larger and more complex. There are many algorithms existing for creating and expressing these trees.

Support Vector Machines

In the blow distribution of data shown in the Figure 3-8. There are two types of data that cannot be separated using linear methods. The boundaries as shown are curves and non-linear. In this kind of cases, finding a suitable equation for the curve is not an easy job.

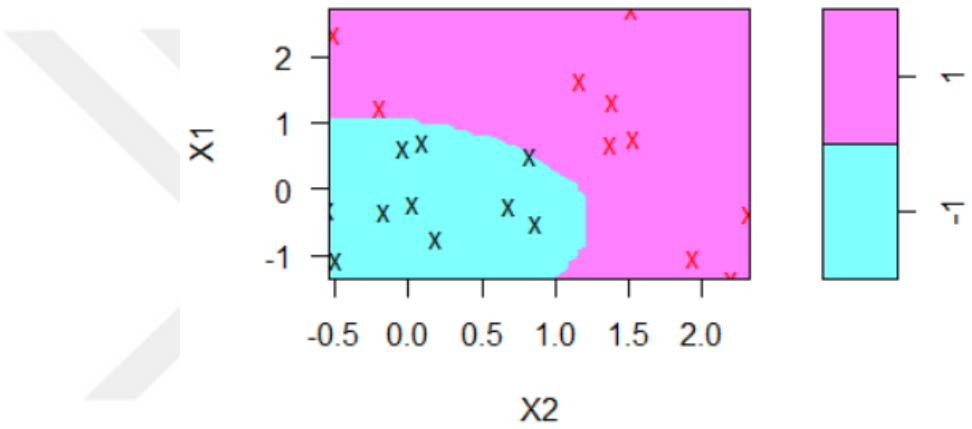


Figure 3.8: SVM classification plot

Source: SVM Classification Plot in R - Stack Overflow

The Support Vector Machines (SVM) is very useful method for identifying the separating boundaries for such cases.

Naive Bayes

Naive Bayes algorithm utilized for building classifiers. In case we want to categorize different kinds of fruit in a fruit plate. we can use characteristics like shape, color, and size of a fruit, like, any fruit colored with red, rounded in shape and is nearly have 8 cm diameter can be recognized as an Apple. So that in order to train the model, these characteristics are used to check whether the possibility that a given feature is similar to the specified fruit. The probabilities for the various characteristics are then collected till reaching a probability that reveals whether a given fruit is an Apple or not. Naive Bayes in general works with small counts of training data used for classification.

3.4.2 Unsupervised learning

There is no requirement for supervision or data training in unsupervised learning. In other words, only unlabeled data is utilized. The idea is to look for an unnoticed structure in the data. There are a variety of reasons why the data does not have a label. It may be due to a lack of money to pay for human labeling, or it could be due to the data type itself. Data may now be gathered at an unparalleled pace because to the proliferation of data collecting devices. Big Data is viewed and evaluated on the basis of its variety, velocity, and volume. It's critical to extract anything useful from this data without involving the supervisor. Today's problem for machine learning researchers is this. This scenario, as described in Alice's famous book about her experiences in Wonderland, published in the 1980s, is similar to the one described in Alice's famous novel about her adventures in Wonderland, when Alice was searching for someplace to go while talking to the cat.

- She asked: can you tell me, please, which way I should use to go from here?
- That is depending a good deal on where you want to get to.
- I don’t care.
- Then it doesn’t matter which way you go.
- So long as I get somewhere.
- You’re sure to do that if you only walk long enough.

Clustering (an unsupervised learning technique) is comparable to the cat's suggestion to "walk long enough." Finding regularities in the input is equivalent to Alice's "somewhere."

3.4.2.1 Algorithms for unsupervised learning

Now we'll go over the most commonly used classification method in unsupervised machine learning.

k-means clustering

In 2000 and 2004 Presidential elections occurred in USA, the results were very close. The major percentage of votes for one of the candidates was 50.7% and the other candidate got 47.9%. In case some of the voters chosen the other candidate, the whole results of that election would have been something else. There are tiny clusters in machine learning language- of voters who the ability to change the history, despite

the fact that they are very small percentage of the whole population. Some questions come to the mind; how can we locate these groups of citizens? How can we implore them using a finite budget? Clustering can be the solution.

How can that be possible?

1. First, information must be collected about those people with or without their approval: any kind of information that may give certain insight about the things that can affect their vote and how to touch their needs or expectations.
2. Then the collected information can be used into a certain type of clustering algorithm.
3. Next, for every group or cluster (choosing the biggest ones first is the right decision) we formulate or arrange a suitable message that will appeal to these voters.
4. Last thing, is to make the campaign and check to see whether it is working or not.

Clustering is a kind of unsupervised learning technique that can automatically shape clusters of identical objects. It is sort of automatic classification. It is possible to cluster nearly anything, and the higher similarity of the items in the cluster, the more preferable the clusters are.

3.4.3 Cluster identification

Cluster identification is equivalent to telling a computer, "Here is some unlabeled data." put similar things together and then report on the outcomes of these groups". The primary distinction between classification and clustering is that with classification, we know precisely what we're searching for. Although this is not the proper method to cluster.

Clustering is sometimes referred to as unsupervised classification due to the fact that it produces comparable outputs to classification but without the benefit of pre-labeled data or categories.

3.4.4 Semi-supervised learning

This kind of learning uses a mixture of classified and unclassified data. This mix of labeled and unlabeled data is utilized to develop a data classification model that is suitable for the data. While labeled data is limited in most cases, unlabeled data

abounds (as mentioned previously in unsupervised learning). The objective of semi-supervised classification is to build a model that is more predictive of future test data classes than data generated by a model that just utilizes labeled data. Humans acquire knowledge in a way similar to semi-supervised learning. Both are given to the developing brain of a child:

1. Data from the environment that hasn't been labeled. In the early years of life, children's environments are typically filled with unlabeled data.
2. Data that has been labeled by the supervisor. A father, for example, educates his children about colors and item names (labels) by pointing to them and saying their names.

3.4.5 Reinforcement learning

The reinforcement learning technique makes use of the data gathered from the environment's response to take measures that increase the reward or decrease the danger. Reinforcement learning is used to create intelligent programs (also known as agents) by following the methods below:

1. The agent examines the condition of the input.
2. A decision-making function is employed to compel the agent to take action.
3. The agent gets reinforcement or a reward from the environment after completing the activity.
4. Information about the award is kept in the action concerning the state pair.
5. Using the information that was saved, policy for a certain state depending on action may be fine-tuned, allowing our agent to make better decisions.

3.4.6 Deep learning

Deep learning is a machine learning technique that is based on Artificial Neural Networks (ANN), more specifically Convolutional Neural Networks (CNN). Deep learning employs a variety of network architectures, including deep neural networks, recurrent neural networks, deep belief networks, and convolutional neural networks.

Deep learning using such networks have been used effectively in participating in the solution of many problems in computer vision, drug design, speech recognition, medical image analysis, natural language processing, bioinformatics, and games.

There are many different areas in which deep learning is also implemented. The deep learning needs massive processing power and giant amount of data, that is conveniently available in this era.

3.4.7 Deep reinforcement learning

DRL is a combination of deep and reinforcement learning techniques. To build a strong DRL model, reinforcement learning techniques such as Q-learning are now coupled with deep learning. This approach has been very successful in a wide range of fields, including robots, finance, video games, and healthcare. Following the creation of DRL models, a number of previously diametrically opposed problems were resolved. Numerous researches have been performed in this field, and companies and investors closely monitor them.

3.4.7.1 Unexploited opportunities of deep learning

After seeing the enormous success that deep learning applications have achieved in a variety of disciplines, individuals begin to investigate additional areas where machine learning has not been applied before. Deep learning algorithms are successful in a wide variety of disciplines, and they may also be used in a wide variety of other sectors. The following are some examples:

1. Agriculture industry is one of the most related fields to people's daily needs, people could use deep learning techniques to enhance and also improve the production.
2. Financially, machine learning is able to assist in making an early detection for scamming and also help in analyzing customer's capability to pay.
3. Deep learning is also used in medicine to develop new medicines and to provide a patient with a customized counter.

When talking about the Deep learning, the possibilities are unlimited and one must keep anticipating the new ideas and developments frequently.

3.4.8 What is required for achieving more using deep learning?

For using Deep learning, super-computational power is an obligatory condition. we need memory as also the CPU superiority to enhance deep learning models. Thankfully, nowadays we have the Facilitated High Performance Computing power.

So, the evolvement of the Deep learning applications is becoming reality these days and, maybe in the near future we will be able see the implementations in other unexploited fields come true.

3.4.9 Deep learning - disadvantages

Some of the important notes that one must consider before deciding whether he can use deep learning or not, they are included below:

1. Computationally Expensive
2. Duration of Development
3. Black Box approach
4. Amount of Data

3.4.9.1 Computationally expensive

To train a neural network, many times the computing and processing capacity needed for other traditional methods is required. Training a Deep Neural Network in a practical manner may take many weeks.

On the other hand, traditional machine learning algorithms often require just a few minutes or hours to train. Additionally, the total amount of computing power needed to train a Deep neural network varies significantly depending on the quantity of the available data and the network's depth and sophistication.

3.4.9.2 Duration of development

The operations of training a neural network have the shape of processing circle like the diagram below:

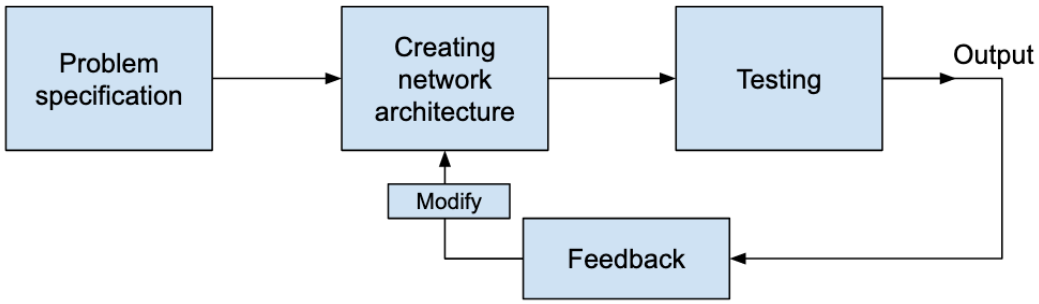


Figure 3.9: Training process in neural network

It can be specified in this sequence:

1. Defining the problem that needs to be solved.
2. Creating specifications for the problem.
3. Choosing the features of the input.
4. Making a design for the network.
5. Deploying the network.
6. Testing the output.
7. If the outcomes are not as expected, take this as feedback to rebuild the network.

3.4.9.3 Black box approach

A neural network is analogous to a Blackbox. It is provided with an input and then generates an output depending on these inputs. The accompanying graphic illustrates one such application, in which you input an animal picture to a neural network, which identifies the image as being of a dog.

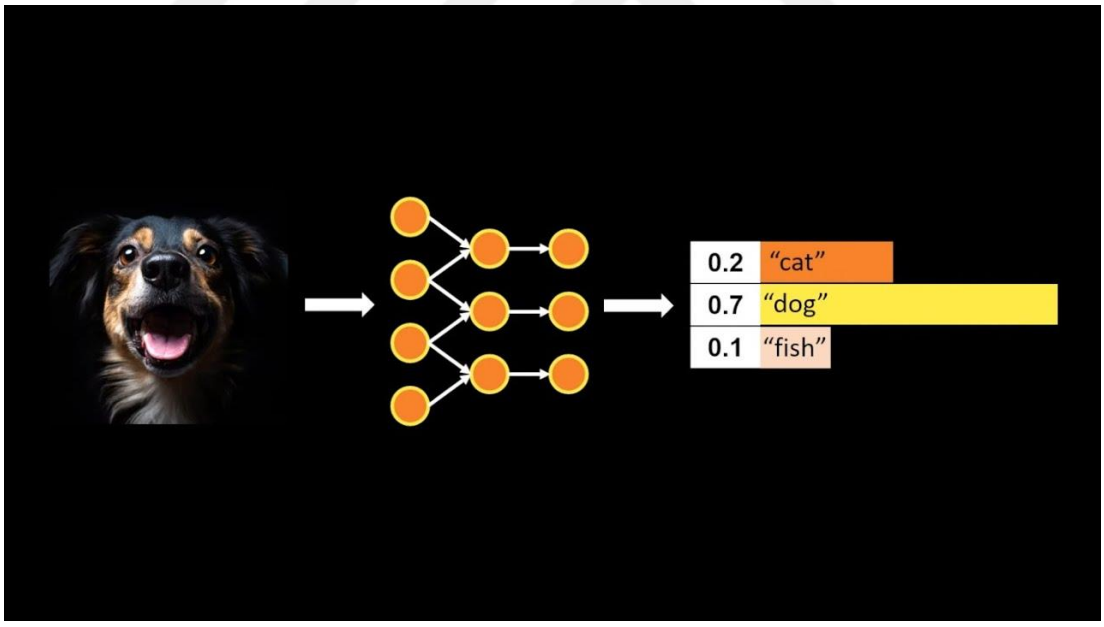


Figure 3.10: How ANN processing a dog image

Source: Deep Learning Networks Prefer the Human Voice

It is called Blackbox because it only gives results without specifying how does those results were concluded, for our example, we do not know how the dog image was concluded by the network? For explaining the negative side of this, let us take a banking application as example where the bank needs to say whether the credit of a

client is worthy or not. The network will answer this question. But the real question here is how to clarify this to the client? Banks have to make it clear to their clients.

3.4.9.4 Amount of data

Deep learning networks, in general, need a large quantity of data to be trained, while traditional machine learning methods may be effectively employed with just a few hundreds or thousands of data points, depending on the situation. Gladly, data massiveness is growing by 40 percent every year, while CPU processing power is increasing by 20 percent every year, as shown in the graph below:

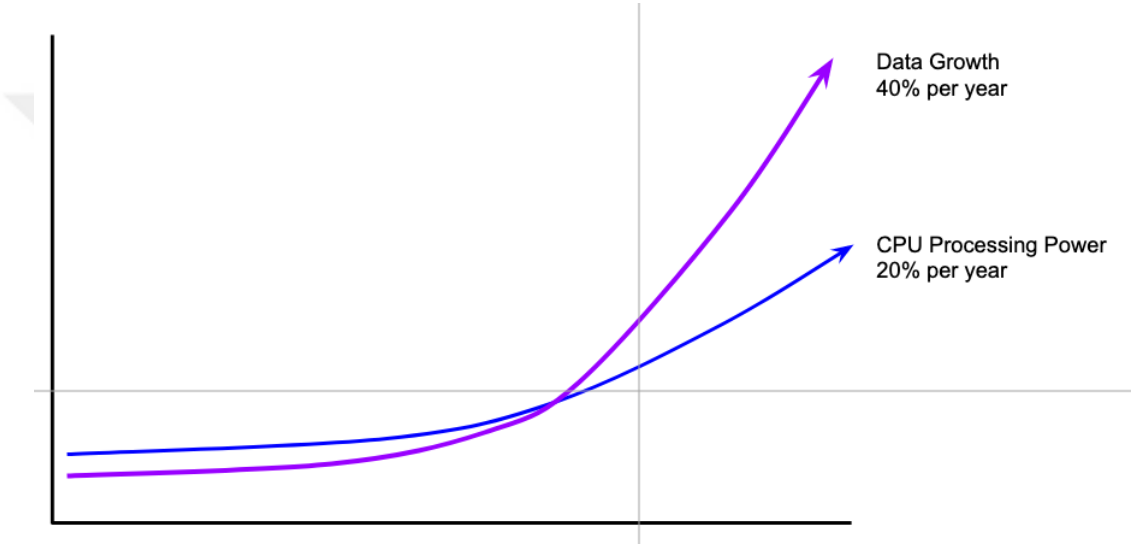


Figure 3.11: Diagram of data growth and processing power growth per year.

Source: Machine Learning - Deep Learning

3.4.9.5 Validation and evaluation

Validation and assessment are required to determine if a model learned using a machine learning method is good or not. For example, if someone says that a function works well for a particular set of training data, this is insufficient for the machine learning community. They'll instantly inquire about the function's performance on test data. It is necessary to evaluate and analyze a function that fits perfectly on training data. When using different labeled data to test them, the phenomena of overfitting may provide the greatest results on training data, but when using other labeled data to test them, they will fail miserably. To prevent overfitting, it is standard practice to split the labeled data into two sections:

1. Data from the training

2. Data validation

The training data is used to create the model, and the testing data is used to verify the model that was previously built. It is anticipated that during testing/validation, a portion of the data be kept for testing. The model is trained on a significant part of the data, and the model's test scales are tested on the remaining data.

3.4.10 Applications of machine learning algorithms

Machine learning has proved to be the solution or answer to a variety of real-world problems, however there are still a number of issues that need a breakthrough in machine learning. Bill Gates, Microsoft's cofounder and former chairman, recognized this need and expressed it in the following words:

Ten Microsofts would be worth a breakthrough in machine learning.

Following this foundation, the following part will cover various machine learning applications with some examples.

3.4.10.1 Automatic recognition of handwritten postal codes

In today's world, we communicate through a broad variety of digital devices and tools. The postal service, on the other hand, is still in operation, assisting us in delivering our mail, presents, and other important papers and documents to the people who need to receive them. To demonstrate how machine learning has helped a specific sector, take a look at the example of the United States Postal Service (USPS). Beginning in the 1960s, when machines were successfully used to automatically read the city-state-ZIP code line from printed addresses, the United States Postal Service started experimenting with the possibility of machine learning for other purposes. The technology of optical character recognition (OCR) was able to properly explain the postal address in question thanks to the employment of a machine learning algorithm and a learning algorithm. "The pictures that are created from handwritten or printed information that has a language that people can understand," according to the author. When it comes to making this kind of text content readable by machines, the use of optical character recognition technology may be beneficial. Text documents that have been scanned into a visual format, such as a bitmap, are nothing more than a representation of the text that has been recorded. Through the use of optical character recognition software, the picture is analyzed to

see whether any alphabetic letters or numeric digits can be identified in it. The software recognizes a character and converts it into machine-encoded text once it has been properly identified. In addition, this machine-encoded text may be used as an entry point for applications such as text mining, text-to-speech, and automatic translation, among others, since it can be electronically compressed, searched, and changed. Due to the advancement of accurate optical character recognition (OCR), data entry has become easier, faster, and less costly.

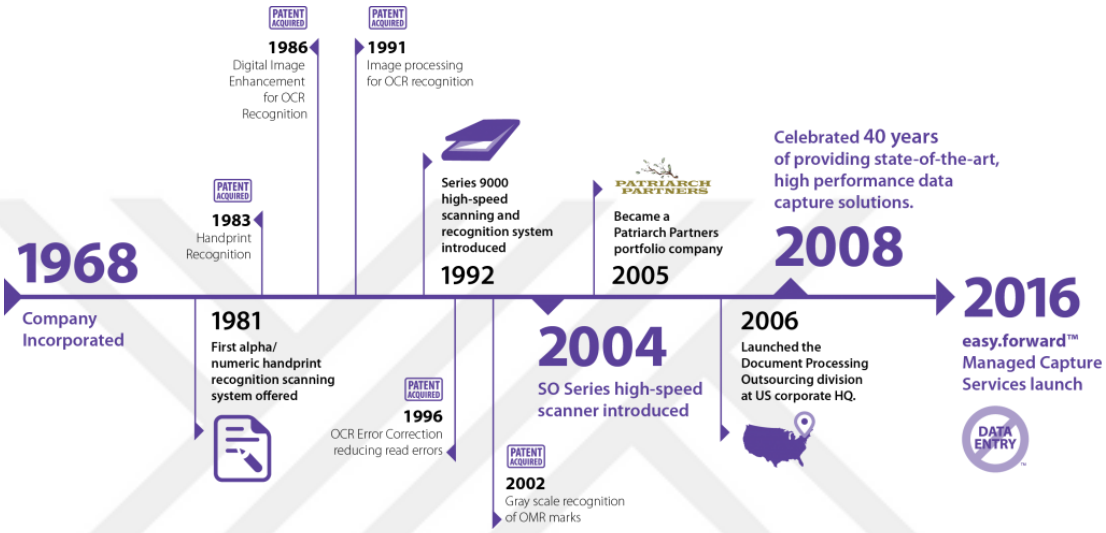


Figure 3.12: Diagram shows the avancement of OCR in Scanoptics company

Source: History – Scanoptics – Intelligent Data Management

In 1900, the United States Postal Service delivered 7.1 billion letters each year. All of these packages were transported without the use of automobiles or sophisticated machinery. In 2006, the United States Postal Service processed and delivered more than 213 billion pieces of mail, accounting for over 40 percent of the world's total volume of mail and exceeding the total amount of mail handled by any other postal administration on the planet. The United States Postal Function (USPS) provides this very valuable service with the assistance of automation. The success of OCR in bringing about a new revolution in the efficiency of the postal system is well documented. The use of an optical character recognition (OCR) camera, such as the one shown in Figure 3-13, assisted in making the link between physical mail and the information system that guides it to its destination feasible. Advanced optical character recognition (OCR) technology, in conjunction with other mail processing services, is now capable of increasing the efficiency of different nations' postal systems.

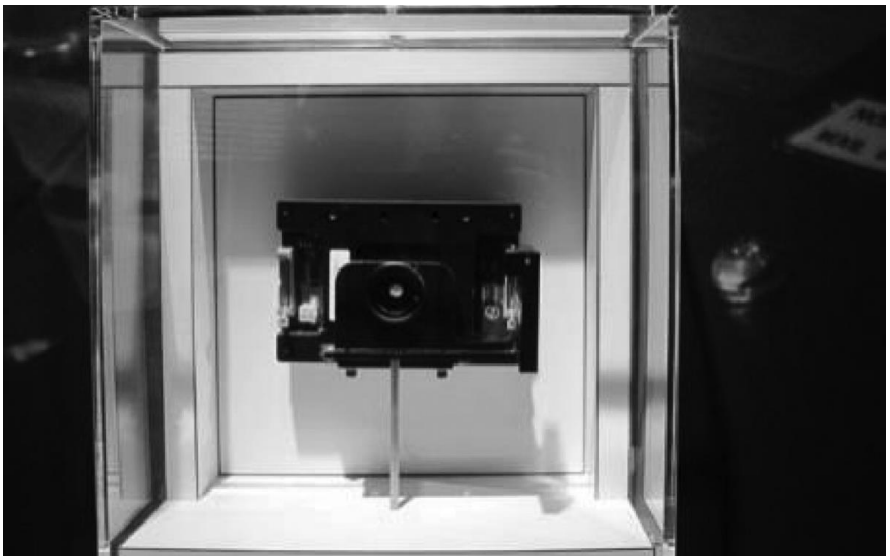


Figure 3.13: An old type of OCR cameras used by US Postal Service

According to the United States Postal Service's online page, "the Postal Service is the finest and the leader in the world in OCR technology, with machines that can read almost 98 percent of all hand-addressed letter mails and 99.5 percent of machine-printed letters. " Google has now made a free tool available for turning text images into text documents in more than 200 languages and more than 25 writing systems, according to the company. Google was able to do this by using hidden Markov models and considering the input as a whole sequence, rather than initially attempting to break it up into parts as it had previously done. On the Google website, you may see a list of the languages that are supported. The complexities inherent in this kind of work are easily comprehended by everyone. The issue of identifying or recognising language is a straightforward one. If a language is processed, it is already widely understood that the language has already been learned. If the language is incorrectly recognized, it is clear that we should anticipate poor or suboptimal performance when utilizing OCR technology to recognize it. OCR technology is a practical application for one of the many applications of pattern recognition, which is, incidentally, a branch of machine learning in and of itself. The primary use of pattern recognition is the detection of patterns and other types of regularities in data. Text, voice, picture, and other types of data may be used to represent the information. The OCR method is the one in which the data that is utilized as input is in the form of an image (as opposed to text). Another use of pattern recognition is in the field of computer-aided diagnostics, where picture data is used to diagnose patients.

3.4.10.2 Computer-aided diagnosis

In computer-aided diagnosis, the algorithms of pattern recognition may assist physicians in explaining medical pictures in a shorter amount of time than they would otherwise have. Patient's health condition may be determined by examining medical images acquired from various medical tests such as ultrasound, X-rays, and magnetic resonance imaging (MRI). A radiologist is responsible for the ability to analyze and evaluate the outputs of these medical test findings, which are presented in the form of a digital image. Because of the limited amount of time available, the radiologist must be aided by a machine. For the purpose of detecting suspicious structures in a picture, computer-aided diagnostics employs pattern recognition methods derived from machine learning. How is it possible for an algorithm to assign these ambiguous shapes? This is something that supervised learning is capable of doing. The tagged images are fed into a variety of machine learning techniques, such as artificial neural networks, Bayesian classifiers, support vector machines, and radial basis function networks, which then analyze the data. The classifier that is created must be capable of correctly categorizing fresh medical pictures in a timely manner. Mistakes in this kind of diagnosis, which is performed using a machine learning algorithm, may result in catastrophe for someone. Such mistakes may be detrimental to a person's financial well-being, and they can even endanger his or her life. As an example, consider the following two sentences:

1. Assume that the classifier incorrectly determines that a patient has breast cancer while in fact the patient does not have the illness. The patient's psychological well-being will suffer as a consequence of these outcomes. Further testing is required to validate the classifier's results, which may result in financial loss for the patient.

2. Assume that the classifier was unable to identify breast cancer in the patient who was really suffering from the illness. This will result in incorrect medical treatment, which may put the patient's life in risk in the future. The complete replacement of a biological doctor by technology is not the best course of action in order to avoid making such errors in the first place. The employment of such technology must be complementary, rather than dominant. When it comes to medical images, it is the doctor who should be held accountable for the ultimate interpretation of the picture.

A broad range of diseases may be diagnosed using computer-aided diagnosis, for example. The following are some illustrations:

- Breast cancer
- Congenital heart defect
- Pathological brain detection
- Lung cancer
- Bone metastases
- Colon cancer
- Prostate cancer
- Alzheimer’s disease
- Coronary artery disease

3.4.10.3 Computer vision

We want robots to be able to perceive and behave appropriately after they have grasped the situation. Pictures may be captured by the cameras placed within a robot, but they will not be able to assist the robot in comprehending or recognizing the images. What sort of learning can a robot apply via the use of pattern recognition is unknown? We began by talking about the robot that will be competing in the tournament, which was named RoboCup. To begin with, what exactly is RoboCup? It stands for "Robot Soccer World Cup," which is a robot soccer tournament held throughout the world. Achieving the project's official goal, as declared, is very challenging. Humanoid robot soccer players will win a soccer game by the mid-twentieth century, if they obey FIFA rules. As a result, the winner of the most recent World Cup will be the opponent. It was a global event, with 175 teams from 47 different countries competing in the RoboCup 2015. The team from the United States, which competed in the biggest adult size category of the competition and was formed by Pennsylvania University, defeated the Iranian team by a hard 5–4 score (Figure 3-14). To win the match, the robots must work together with their team mates (who are also robots) in a fast-paced setting that requires teamwork. The robots must classify items and recognize activities in order to complete their tasks. They get input from their cameras in order to carry out these tasks. This kind of job is completely classified in the area of pattern recognition, which is a branch of machine learning that includes a variety of algorithms.

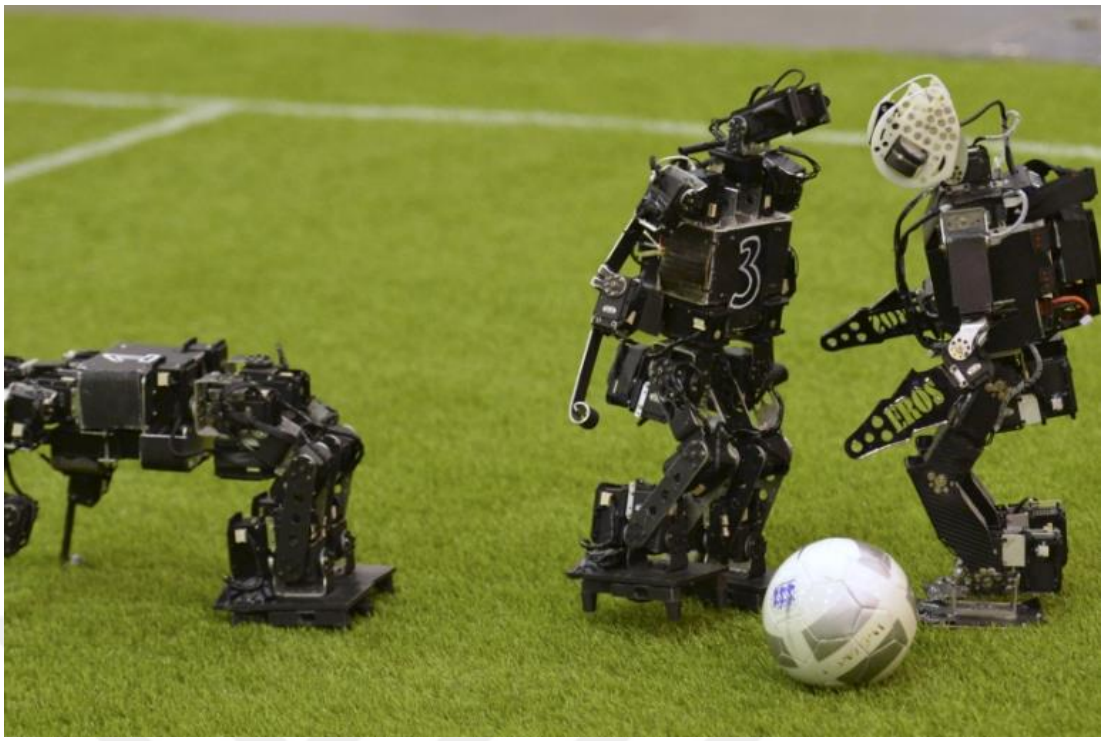


Figure 3.14: US humanoids defeat Iran team in football RoboCup final

Source: US humanoids defeat Iran team in football RoboCup final | Science and Technology News | Al Jazeera

3.4.10.4 Auto-driven cars

One of the applications for which vehicle vision has finally been made feasible by advancements in computer vision technology is self-driving cars without a human driver. Clearly, there is a race to develop autonomous vehicles that can hit the road as quickly as possible in this business. This is a competitive industry. According to a BBC article titled (Toyota pledges to develop autonomous vehicles on highways by 2020), a slew of rivals is getting on the bandwagon and declaring their intentions to create driverless cars. According to the report, Toyota is the latest automobile manufacturer to go forward with ambitions to develop an autonomous vehicle, giving a strong competitive chance for businesses in the Silicon Valley such as Google, Tesla, and Cruise, among others. Employees at General Motors' research and development center in Michigan will be able to take autonomous rides according to a new initiative launched by the company. In addition, Nissan has said that it would begin testing an autonomous vehicle on Japanese roads in 2016.

In reality, Google is currently testing its self-driving vehicles on public roads in the United States. Elon Musk, the CEO of Tesla, said in July that his firm was "nearly

ready" to begin production of its self-driving vehicles, which would be able to travel on major highways and park themselves.

What method will these automobiles use to accomplish this task? The following is how the Toyota announcement is described in the BBC article:

According to Toyota, the vehicle is a hybrid "Detects other vehicles and possible dangers with the use of a variety of external sensors, and selects routes and lanes based on destination. " Computer "drives in a way similar to that of a human driver," according to the data inputs. As seen in Figure 3-15.

Figure 3.15: Toyota promises driverless cars on roads by 2020

Source: BBC

This technique is mostly used in extremely delicate applications. A driverless vehicle accident may be devastating to a family or families. A drone's computer vision technology is also a delicate area. In the event that the algorithms for the drone's vision fail, it is possible for the drone to murder innocent people.

3.4.10.5 Face recognition and security

Images captured by smartphones and CCTV cameras are being generated at an unprecedented pace these days. The pairing of a face picture with the identification of the person who is being recognized is an issue associated with facial recognition technology. Developing a classifier for this assignment is a difficult challenge due to the large number of categories that are involved with a variety of image-related

issues. Face recognition can assist security organizations in using huge amounts of data from a variety of sources in order to automatically discover what is in reality very difficult for people to do manually using facial recognition.

3.4.10.6 Speech recognition

Algorithms and technologies for voice recognition are being developed in order to enable computerized speech recognition. There is no longer a need for stenography, often known as shorthand writing. It has finally made its way into areas such as court reporting and video captioning, where automatic transcription of voice into text is now commonplace. People with impairments will benefit from this technology. In the long run, the accuracy of voice recognition algorithms will improve as well. Voice-activated systems such as Siri on the iPhone, Alexa on the Echo, Google Now and Cortana on Windows Phone do not always understand what we are saying, but this is anticipated to change in the near future as technology advances.

3.4.10.7 Text mining

Until far, the examples we've given have depended heavily on visual or auditory input to aid in learning. There is one more kind of information that may be used for learning, and that is text data. Although it was widely known that the overwhelming majority of the organization's information was kept in text format, the problem was determining how to make use of the collected unstructured data or text. H.P. Luhn's most current definition of business intelligence system, published in the IBM Journal of Business Intelligence, is as follows:

The use of data processing equipment to automate document encoding and extraction, as well as the development of profiles for all of an organization's "action points." Both incoming and generated documents are automatically abstracted, classified according to a word pattern, and then routed to the subsequent action stages in a completely automated manner. Social media is another area where academics may find large quantities of text and unstructured data, which might be useful for their study. For the first time ever, we can see this enormous creation of text data on social media, which is a first in human history. Due to the fact that human experiences were communicated through text, stakeholders such as corporations were able to assess and use this informational resource for their own advantage.

Text mining has a plethora of practical applications in the following fields:

- National security
- Business intelligence
- Life sciences
- Automated placement of advertisement
- Those related to sentiment classification
- Automated classification of news articles
- Spam filter
- Social media monitoring

3.4.10.8 Where text and ımage data can be used together?

To address a particular issue, it is possible that both text and picture data may be required to be utilized. An author identification challenge for a particular textual corpus of data, for example, is a problem that may be addressed in two ways: first, by using a formal author identification system.

1. Handwriting recognition: In this instance, the known writings of handwritten data will be utilized to create a classifier that can evaluate or determine if a document belongs to an author based on a variety of characteristics.
2. Detection of writing style: This kind of issue is categorized as a text mining problem since it involves analyzing text. We're looking for certain characteristics that are associated with an author by examining texts that have been attributed to the same author in the past. Following that, these characteristics will be utilized to create a classifier that will be able to determine whether or not a specific document belongs to that author.

It is also feasible to combine two classifiers to create a third classifier with improved performance for more accurate author identification, if two classifiers are combined. The assessment of undesirable material in a film, such as violence or other inappropriate content, is another area in which this kind of data may be helpful in addressing the issue. We are able to address the issue of identifying undesirable content in two ways: first, we can use a computer to identify the material; second, we can use a human to identify the material:

1. Make use of the movie's still pictures and machine learning methods on the image data to create a model that can detect and remove undesirable content from the video.
2. Use people's comments from social media platforms that are connected to the video to identify the content of the video via the development of a model that can predict whether or not there is undesirable material in the video

Additionally, those two kinds of classifiers may be used in conjunction to improve the overall performance of the system.

3.4.11 The present and the future of machine learning

3.4.11.1 Thinking machines

The British mathematician Alan Turing was the first one who questioned the ability machines to think and even asked that question in 1955, that question was the starting history of the artificial intelligence. He was the same scientist who invented a test to measure the intelligence of machine according to its performance.

In 2014, that test was surpassed by a chatbot, this Turing test was finally passed! (See Article 1 for more details). First of all, a chatbot can be defined as a computer program that is able to emulate a smart conversation with human users. This conversation can be done using either audio or text communication. Article 2 describing another attention event, in this event, one of the magistrates of the yearly Loebner Prize in 2015 talking about the limitations of chatbots.

The chatbots were trained with language paradigm according to the frequent neural network. which means that the answers of the chatbots were not just simply copy/paste answers that are made by chatbots after training on some conversations made by real people and just simulating the patterns. Some of the exciting and professional replays by the chatbot from Google can be found in a research paper have the title “A neural conversational model”. The people who wrote the it acknowledges the lack and extent in the research paper saying that the chatbot was unable to make a realistic chat till now, but though, that chatbot passed the test; in fact, better answers for much more various kinds of questions with no rules can be even more surprising discovery.

Google scientists have programmed a developed kind of chatbot which is able to learn from training data consisting of examples from dialogues. The training data was made of two parts: movie transcript dataset, and IT helpdesk troubleshooting dataset.

Article 1:

Turing Test that was Passed by Chatbot Named Eugene

The Turing test is based on the work of Alan Turing, a twentieth-century codebreaker and mathematician, and his eponymous question and answer game Can Machines Think? This test evaluates whether or not people can tell the difference between speaking with machines and humans. To pass the series of five-minute keyboard chats, the computer must be mistaken for a human more than 30% of the time. Eugene Goostman, a computer program, passed the Turing test for the first time ever in 2014. Turing Test 2014 took place in London on June 7, 2014, and drew hundreds of attendees. When 30 human judges took part in the test, Eugene convinced 33% of them that the object was really a human person.

Article 2:

What Is the Difference Between a Human and a Machine in a Conversation?

There was an article that appeared on the BBC website in the technical section entitled: (AI bots attempting to avoid human judges), and this title described the live coverage of the annual Loebner Prize 2015 that took place. Rory Cellan-Jones, a BBC technology correspondent, served as a judge at the event and was one of the judges responsible for evaluating the intelligence of a chatbot. He was one of the judges who were responsible for evaluating the intelligence of a chatbot. It was possible to listen to the entire recording of his discussion with the winning chatbot Rose on the BBC website. The encounter left Rory feeling like a psychiatric therapist who had just spent more than three hours delving into the deepest thoughts of eight patients, he said afterward. Because of my participation as a judge in the Loebner Prize, I've been thinking a lot about how talks operate and what it means to be a human conversationalist. I immediately began looking for a subtle method for identifying the bot, which was acting in a chaotic manner at the time. Bots are capable of dealing with simple or routine inquiries such as what is your name, how are you, and how old you are. However, when I began talking about the pricing of

homes in London, and what the best method is for dealing with slugs in your park, the bots were outclassed. Their demeanor was to attempt to steer the conversation in a different way while ignoring what I was saying. So, it didn't take more than two or three questions before I realized I was speaking with a bot or an actual person. According to my estimation, it will take some time before a computer can pass the Turing Test. Humans are much more fascinating to converse with than machines.

Smart Machines

For machines to act as intelligent as real people is not near yet for being achieved. Generally, a smart machine to be simply defined: is the intelligent regulation that can use hardware like RFID, Wi-Fi, sensors, or cellular communicating links for receiving data and translate these data to be able to take decisions. These intelligent robots use machine learning algorithms to do jobs formerly performed by humans, thus increasing efficiency and production. Gartner, Inc. is an American information technology research and consulting firm that provides technical foresight to CIOs and IT executives via a variety of means, including Gartner seminars. Gartner seminars draw a large number of industry CIOs. Kenneth F. Brant, a Gartner analyst, established two criteria for identifying a really intelligent system. A really intelligent machine satisfies two criteria:

1. A smart machine is capable of doing tasks that no machine was ever anticipated to perform. By those criteria, a drone that is capable of handling an Amazon delivery qualifies as a smart machine.
2. A machine that is capable of learning. By attempting the second criteria for a really intelligent machine, the amazon drone fails.

However, regardless of how intelligent a delivery drone is, it has a significant impact on production and labor in the shipping sector. Gartner Inc. named smart machines as one of the top ten technologies and trends that were anticipated to be strategic in 2014 and also in 2015.

Figure 3.16: Top 10 strategic technology trends for 2014 by Gartner

Source: forbes.com

Figure 3.17: Top 10 strategic technology trends for 2015 by gartner

They wrote the following in their comments regarding their predictions for smart devices in 2014 and 2015:

- By 2015, there will be over 40 vendors offering commercially accessible, managed services that enable the usage of beneficial smart devices and produced services. By 2018, the cost of acquisition for business processes will be reduced by 30% through the use of smart machines and manufactured services.
- By 2020, the smart machine age will thrive with the widespread adoption of conscious, intelligent personal servants, intelligent consultants (such as IBM Watson), developed global industrial systems, and affordable autonomous vehicles. The era of the intelligent machine will be the most perplexing in the history of information technology.

Figure 3.18: IBM watson logo

Gartner defined three well-known examples of smart machines in 2014 in a study titled (Cool Vendors in Smart Machines). These were IBM's Watson, Google Now, and Apple's Siri. Following that, we'll examine the clever machines described in the preceding forecasts, as well as Deep Blue, an IBM-developed chess-playing computer.

Deep Blue

Deep Blue in May 1997, was the first computer ever that was able to defeat strongest chess player in the world at that time, Garry Kasparov in a match who was the 1st world's champion in chess. The huge force of the processing power in a specialized computer enabled Deep Blue of appraising 200 million moves every second. The 259th most mighty supercomputer of 1997 defeated the world champion in chess playing. It was a historical event in the artificial intelligence society. How could Deep Blue read the case on the board? The answer is written below:

Deep Blue's program of evaluation was facie written in a circulated way, with parameters to be identified (like, the importance of the safety of the king's position as compared with the advantage of occupying the space in the center of the

playground and so on). The best values for these parameters were calculated after that by the computer itself through analyzing big amount of master games. The function of evaluation was divided into 8,000 parts, a lot of them were made for special positions. In the opening book -which is usually used to refer to the database of chess starting plays given as training data to computer chess programs and such games, like computer shogi and so on- there was more than four thousand situations and seven hundred thousand grandmaster previous games. The last game database had several six-piece endgames with five or less piece positions. After than big victory, Deep Blue was a devoted supercomputer to play against living players. Now the research was focused in the chess field on upgrading the efficiency of the software, so that a less powerful computer in hardware is sufficient to do the same task. In 2006, another chess match was held between a chess program called Deep Fritz and world chess champion Vladimir Kramnik. The program was implemented on a normal personal-using computer have two Intel Core 2 doubled CPUs. The program was able to calculate just eight million positions every second versus the two hundred million positions every second for Deep Blue. Again, the computer won 4-2.

IBM's Watson

IBM's Watson is a brilliant machine that is able to answer questions raised in a normal language. Given its name after Thomas J. Watson the CEO of the company. Either we name it as a powerful computer, a smart processing system, or just a question-answering machine, IBM Watson is the most recognized example for artificial intelligence practical machine in use today. Watson acquired its universal popularity from gaining the first prize in "Jeopardy!" the quiz show. With its massive processing and AI force, Watson can help improving various industries through impowering different kinds of practical uses. The industries making use of Watson in Medicare, fiscal, legal, and retail sector.

Google Now

Google Now is another function that contributes to the development of machine learning. A well-known personal assistant who is seen as clever or intelligent is considered by many to be a smart assistant. Google Now's responsibilities include answering queries, making suggestions, and carrying out actions via sending requests

to a variety of online services. Users may use voice commands to create reminders and get assistance with random inquiries by using Google Now. The software first analyzes the users' search habits and uses this information to create predictions about the recommendations that may be useful to them. The program then presents these predictions to them as suggestions.

Apple's Siri

Siri is a well-known and extensively used intelligent personal assistant developed by Apple Inc. Siri is a well-known and widely used intelligent personal assistant developed by Apple Inc. It is a voice recognition and interpretation interface that supports a variety of languages, including English, Spanish, French, German, Italian, Japanese, Korean, Mandarin, Russian, Turkish, and Arabic. It is accessible in a variety of languages, including English, Spanish, French, German, Italian, Japanese, Korean, Mandarin, Russian, and Turkish. Siri, like all other personal assistants, is constantly updated in order to enhance its reaction speed. The capacity to comprehend context is critical. Rather of revealing the location of a specific restaurant where a bad person wants to blow it up, Siri would react to such information by sending a report about the bad person's intentions to numerous security centers.

Microsoft's Cortana

Microsoft's Cortana is another smart personal assistant contesting the previous two, having nearly the same features of Google Now and Siri and improving day by day. Users -one day- will be help people to reserve flying-trips, buying stuff, and also plan their own schedules, through chatting to Cortana.

4. RESEARCH DESIGN

4.1 Methodology and Research Design

First, a theoretical study has been prepared on the capabilities of machine learning and the potential it can offer in improving and developing the critical path method by studying both the critical path method and machine learning separately, as well as asking experts and specialists in each of the two fields and then coming up with results and suggestions It contributes to improving the capabilities of the critical path and is considered as a first step towards the contribution of machine learning to automating the critical path method or improving it significantly and facilitating its use in projects and programs.

Then comes the second section of the chapter, which is a questionnaire presented to a segment of users of the critical path method (mainly engineers), as well as having experience and knowledge of machine learning and its working methods. Then collect information and responses, analyze and categorize them to come up with results that are considered as a solid ground for further future research.

The objective of conducting the questionnaire is to try to identify the problems and shortcomings that the critical path method suffers from the users' point of view in order to try to improve it in the future, as well as to survey the opinions of users and know the problems that need to be addressed more than others, as well as weighting certain types of solutions and treatments over others.

4.2 The Community of the Study

A research community can be defined as a well-defined group of individuals or things that have standard features, characteristics, and the same work added that residents are defined as all the items (things, individuals, and events) that conform to the sample criteria for inclusion in a study (Burns, 2001). The research covers a slice of engineers mainly dealing with the Critical Path Method as well as having the

knowledge about Machine learning and also workers in other disciplines fulfilling the two previous conditions.

The Sample of the Study The researcher relied on sending the questionnaire to the largest number of workers in the study community to obtain the study's data. it involved students, academicians, engineers of different specialties with different years of experience.

The questionnaire was conducted by 127 people, and personal interviews were conducted with many people specialized in the critical path method, as well as specialists in the field of machine learning, and many things that contributed to the establishment of this study were recorded.

4.3 Exclusion Criteria

Exclusion criteria are some of the attributes and characteristics that some respondent lack so that they are not included in them so they were excluded to ensure the results' reliability.

The data was cleaned before analyzed. Many responds were found fake or not related to the critical path method based on the answers, so that, they were neglected and deleted.

4.4 Designing the Questionnaire

To gain the preliminary information and data for this study, the questionnaire which is one of the standard methods of collecting data. It is characterized by the possibility of collecting information from a wide range of people in the study sample and is analyzed to obtain specific results was designed to collect as much information as possible regarding the development of the critical path method by machine learning by measuring the extent of people's knowledge of this method and then studying suggestions and opinions regarding the development of this method from their point of view as researchers or users. After that, asking about artificial intelligence in general and machine learning in particular was addressed in the same way of Critical path method. The users were then asked about the effectiveness of combining the two in different ways in different questions. After that, open questions were

developed to collect the suggestions and opinions of the respondents on the subject in general.

The steps were followed during the process of building the study tool:

- Review of literature related to the studied subject and read what has been written about the Critical Path Method and Machine learning.
- The researcher introduced the primary tool of the study to his supervisor and took his opinions regarding the consistency of the paragraphs with the research in general.
- By applying the supervisor's advices; the following was done:

✓ Delete the paragraphs that the supervisor suggested to be delete.

✓ Editing and paraphrasing the paragraphs to give the intended meaning.

✓ The educational and cultural level of the people participating in the study was considered by avoiding the problematic vocabularies and avoiding embarrassing questions.

- Accordingly, the questionnaire was modified to suit the study community and the study sample, and then the questionnaire was constructed with its final form. It was also written in two languages, Arabic and English, depending on the language chosen and the country that the study will be carried out.

4.5 The Questionnaire

N.	Questions	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1	Do you know the Critical path method?					
2	Do you use Critical path method in your projects?					
3	Do you think that the Critical Path Method is an important tool for construction projects?					
4	Do you think that the Critical Path Method is an important tool for construction projects?					
5	Did you experience any delay on a schedule determined by the Critical path method?					
6	Did you try a modified Critical path method before?					

7	Did you try a modified Critical path method before?					
8	Do you think that Critical path method needs improvements?					
9	Do you think that Critical Path Method needs More technological support?					
10	Do you think that Building Information Modeling (BIM) is an effective tool for projects?					
11	Do you think that linking the Critical Path Method with Building Information Model through Machine Learning is efficient solution?					
12	Do you know what is Artificial intelligence?					
13	Do you know what is Machine learning?					
14	Do you use Machine learning?					
15	Do you think that it is possible to merge Machine learning techniques with the Critical Path Method?					
16	Do you think that Machine Learning could improve the usage of Critical Path Method in the planning phase?					
17	Do you think that Machine Learning could improve the Critical Path Method in monitoring projects?					
18	Do you think that Machine learning could improve the usage of Critical path method in making legal claims in case any financial problem could happen in projects?					
19	Do you think that Machine Learning could improve the auto-detection of Critical Path in Critical Path Method?					
20	With the aid of Machine Learning, the auto-prediction of different scenarios and best crashes or fast tracking have to be made in projects using Critical path method is very likely to be achieved?					
21	With the aid of Machine Learning, the auto-prediction of different scenarios and best crashes or fast tracking have to be made in projects using Critical path method is very likely to be achieved?					

5. FIELD STUDY PROCEDURES

5.1 Field Study Planning

The purpose of doing the field study is to define the elements of this research that aid to achieve its goals and demonstrate its theories by understanding the parts of the research and describing them correctly and explicitly from the sample population as sources of knowledge and methods of collecting it, and then to decide the way it can serve the research.

5.2 Study Population

The community of this research included engineers from different specializations like Civil, Electrical, Dams and water resources and other specializations related to CPM, Mixed of various degrees.

5.2.1 Distribution of the sample members according to personal variables

The survey was adjusted according to personal variables after collecting the questionnaires assigned to the test sample. Then the proportion of variables were measured and distributed in the questionnaire to the listed groups.

Table 4.1: Distribution of the Research Sample According to Personal Variables

Variables	Categories	Frequencies	Percentage
Degree	Bachelor	71	55.9%
	Master	35	27.6%
	Doctorate	21	16.5%
Specialization	Civil	58	45.7%
	Electrical	24	18.9%
	Dams and water resources	8	6.3%
	Other	37	29.1%
Age	From 25 to 37 years	88	69.3%
	From 38 to 55 years	34	26.8%
	More than 55 years	5	3.9%

Table 4.1: (Cont.) Distribution of the Research Sample According to Personal Variables

Variables	Categories	Frequencies	Percentage
Years of Experience	From 0 to 10 years	86	67.7%
	From 11 to 20 years	23	18.1%
	From 21 to 30 years	12	9.4%
	More than 30 years	6	4.7%
Gender	Male	103	81.1%
	Female	24	18.9%

It should be noted in the previous table regarding the educational qualifications of the members that the highest percentage was for the bachelor's degree, and this percentage was (55.9%), which is the largest percentage in the sample. Then comes Master's Degree with (27.6%) and then the Doctorate's with (16.5%) with is considered as typical and realistic distribution for these Degrees in socity in general.

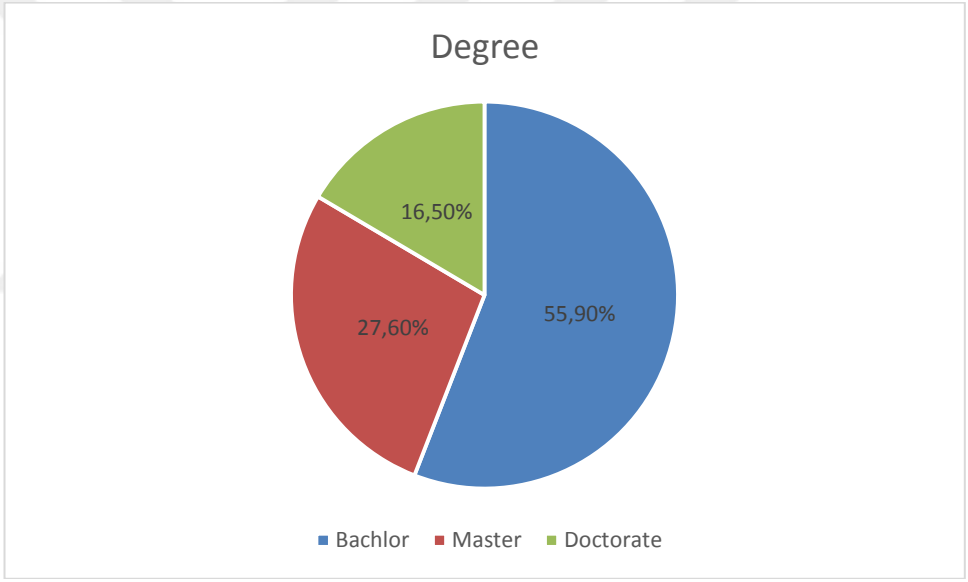


Figure 5.1: Degree

As for the type of work, the largest percentage of workers is in the civil engineering sector with a percentage of (45.7%), then electrical engineering with (18.9%), then dams and water resources engineering in the third place with (6.3%). After that comes other majors from engineering that study or use the critical path method with a percentage of (29.1%).

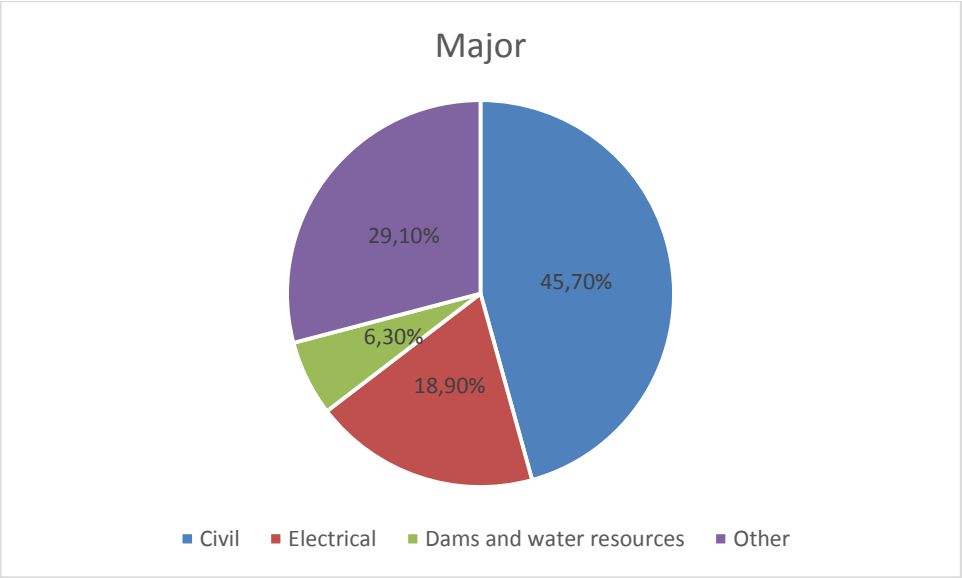


Figure 5.2: Major

The respondents whose ages ranged from 25 to 37 years was (69.3%), while those whose ages ranged between 38 and 55 years was (26.8%). The percentage of participants over the age of 55 was (3.9%).

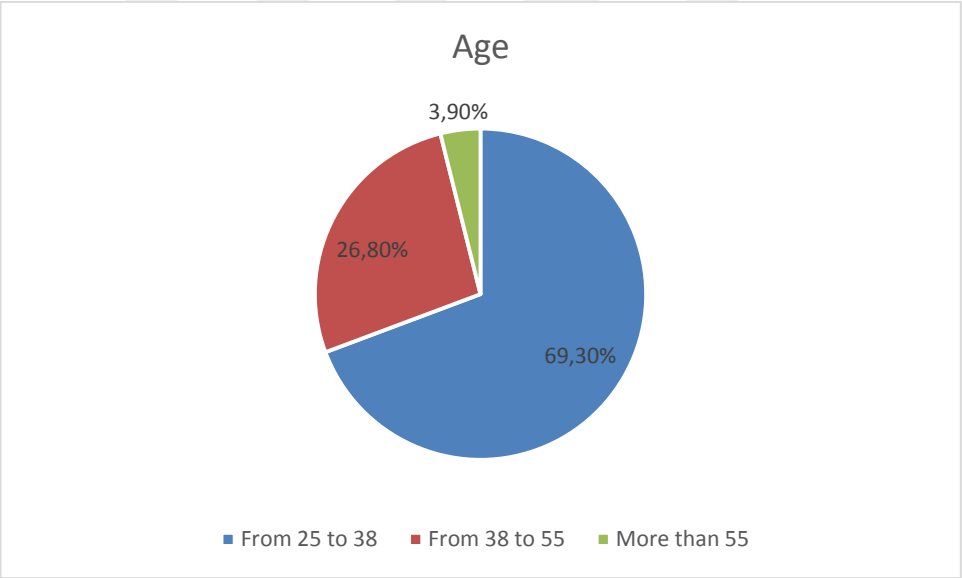


Figure 5.3: Age

As for experience, it was divided into three sections, the first section is from 0 to 10 years, and its percentage was (67.7%), which is the highest percentage for this category. Then the second category, from 11 to 20 years, was (18.1%). The third section is from 21 to 30 years old, and it was (9.4%). As for more than 30 years, it was (4.7%).

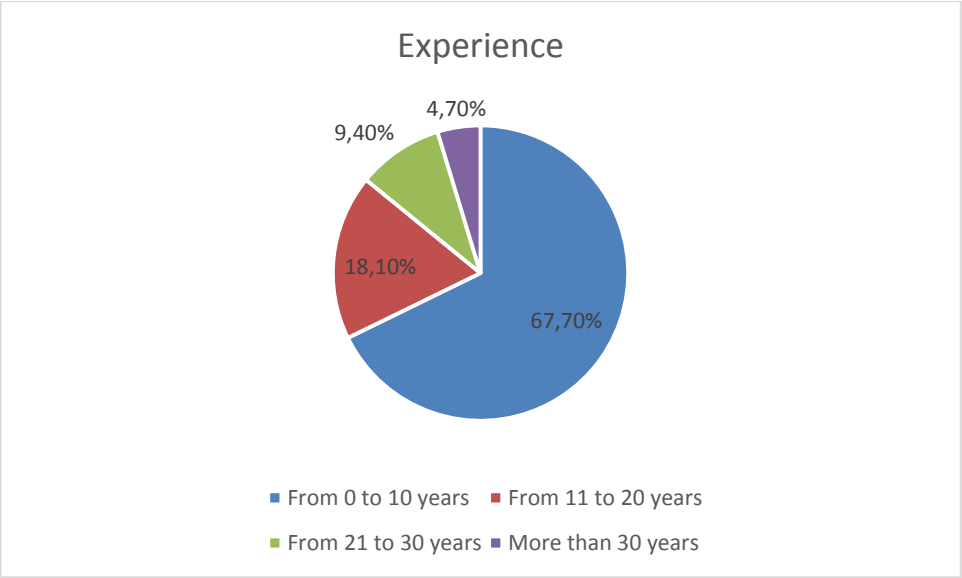


Figure 5.4: Experience

As for gender, males were (81.1%), while females were (18.9%).

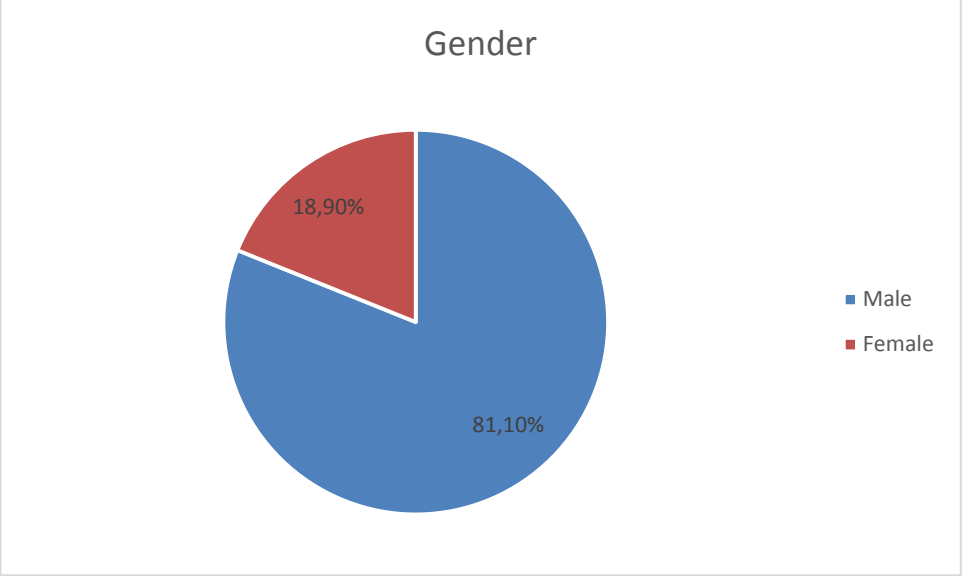


Figure 5.5: Gender

5.3 Statistical Methods Used in the Study

5.3.1 Data reliability test

The responses of the test sample participants were reliable. The responses were collected and Cronbach's alpha or its internal consistency coefficient was measured. The result was after calculating the Cronbach's coefficient for the total sample

(0.865), which is a very high internal consistency ratio for this coefficient, as the sample is considered reliable if the Cronbach's alpha coefficient exceeds (0.6).

5.3.2 Descriptive statistical methods

To get the characteristics of the combination of the study population, the method of repeated distribution of the responses of the individuals of the research sample was used It is a type of descriptive statistical method that assist to have general decisions about the properties and formation of the study population and the method of distribution of the study population and also can show the result of a survey in an ordered and simple way.

5.3.3 Median estimation method

The study made the second part of its results based on the responses of the test survey participants based on the Likert scale.

The five-point (Strongly agree = 5 degrees, agree = 4 degrees, Neutral = 3 degrees, disagree = 2 degrees, strongly disagree = 1 degree). To calculate the most frequent answers.

5.3.4 Likert scale intervals

When starting to analyze data, the average is used to obtain a final result for a given question. Numbers are often obtained with decimals such as (1.5), and such numbers cannot be classified without clear intervals, so Likert scale intervals are used as in the following table:

Table 5.1: Likert scale intervals

Strongly Disagree	[1 - 1.80)
Disagree	[1.80 - 2.40)
Neutral	[2.40 - 3.20)
Agree	[3.20 - 4.00)
Strongly Agree	[4.00 - 5.00]

5.3.5 Analyze the study sample data

The data analysis program SPSS (Statistical Package for Social Sciences) was used in analyzing the questionnaires of the study sample. And this approach is considered as one of the most used systems in sociology for studying information statistics. Nowadays, it is widely used by marketing and finance researches and by

governmental and educational researches too. It is also used in the management and recording of information.

5.4 Evaluation of Study Variables

(Critical Path Method)

This part of the questionnaire focuses on the critical path method and measuring its effectiveness and the extent to which respondents deal with it, as follows:

1. Do you know the Critical path method?

Table 5.2: Respondents' knowledge of Critical path method

Answer	Frequencies	Percentage	Mean
Strongly agree	32	25.2%	3.68
Agree	49	38.6%	
Neutral	25	19.7%	
Disagree	15	11.8%	
Strongly disagree	6	4.7%	
Sum	127	100%	

Through the answers on this question., it gives a clue about the wide spread of the critical path method among engineers in general based on the high rate of the mean for it. This question also is considered as a key question to what is next. It reveals the respondent's knowledge about the critical path method, for that; every Strongly Disagree and Disagree respond will be neglected in the next steps for guaranteeing the accuracy of the results, since the next questions are based on the respondent's knowledge of the critical path method.

Strongly Disagree had 6 responses while disagree had 15, which means, 21 results will be deleted from the whole 127 responses. The left is 106 valid responses.

2. Do you use Critical path method in your projects?

Table 5.3: Critical path method usage

Answer	Frequencies	Percentage	Mean
Strongly agree	15	14.2%	3.51
Agree	40	49.68%	
Neutral	37	34.9%	
Disagree	12	11.3%	
Strongly disagree	2	1.9%	
Sum	106	100%	

After cleaning Data, responses now are seeming more reliable and acceptable. The distribution of the responses is typical from 1.9% for none-usage to 49.68% for the constant users. Then comes the Strongly Agree class which normally, is less than the normal users. It represents the a higher-dependent slice of users on CPM in their daily jobs.

3. Do you think that the Critical Path Method is an important tool for construction projects?

Table 5.4: opinions about the importance of CPM in construction projects

Answer	Frequencies	Percentage	Mean
Strongly agree	27	25.5%	4.02
Agree	61	57.5%	
Neutral	13	12.3%	
Disagree	3	2.8%	
Strongly Disagree	2	1.9%	
Sum	106	100%	

The Reponses here nearly totally agree about the importance of this method in construction projects with high mean rate 4.02. Method with such high rate of importance needs more focus on its development and enhancement.

4. Did you experience a better alternative than CPM?

Table 5.5: alternatives of CPM

Answer	Frequencies	Percentage	Mean
Strongly agree	10	9.4%	2.91
Agree	26	24.5%	
Neutral	23	21.7%	
Disagree	38	35.8%	
Strongly disagree	9	8.5%	
Sum	106	100%	

The mean here shows a Neutral response about other alternatives. In another way, CPM still one of the important tools in construction projects, since, as seen in the above table that there was no clear response for this question as compared with other answers till now.

5. Did you experience any delay on a schedule determined by the Critical path method?

Table 5.6: lag in CPM

Answer	Frequencies	Percentage	Mean
Strongly agree	8	7.5%	3.3
Agree	27	25.5%	
Neutral	20	18.9%	
Disagree	38	35.8%	
Strongly Disagree	10	9.4%	
Sum	106	100%	

The mean of the answers for this question based on Likert scale intervals shows that many respondents already faced delays in while using CPM. Mostly, it's because of the inaccurate estimation of activities duration in projects. This problem can be considerably decreased through the use of Machine learning as its already have been discussed.

6. Did you try a modified Critical path method before?

Table 5.7: Modified CPM

Answer	**Frequencies**	**Percentage**	**Mean**
Strongly Agree	15	14.2%	2.8
Agree	35	33%	
Neutral	31	29.2%	
Disagree	19	17.9%	
Strongly Disagree	6	5.7%	
Sum	106	100%	

Numbers here are showing that there some attempts to enhance CPM but it's still away from what is needed and meets the needs of users. The mean 2.8 lies in the neutral interval which means that yes, there are successful attempts for improvement, but not enough yet to be generalized and widely used.

7. Do you depend basically on Critical path method in managing your projects?

Table 5.8: Dependency on CPM

Answer	**Frequencies**	**Percentage**	**Mean**
Strongly Agree	15	14.2%	3.32
Agree	35	33%	
Neither	31	29.2%	
Disagree	19	17.9%	
Strongly Disagree	6	5.7%	
Sum	106	100%	

The survey shown that yes, there is a high dependency on CPM in managing projects, since the mean 3.32 lies in the Agree interval, It is evidence of the efficiency and importance of the critical path method, so the automation and

improvement of this method can serve and enhance a large segment of users as project managers in general and engineering project managers in particular, as engineering projects (large ones) require great efforts and high costs to manage them successfully as well as To avoid large losses that can occur as a result of any administrative error; Especially in the project schedule.

8. Do you think that Critical path method needs improvements?

Table 5.9: CPM need for improvement

Answer	Frequencies	Percentage	Mean
Strongly agree	20	18.9%	3.84
Agree	58	54.7%	
Neither	20	18.9%	
Disagree	7	6.6%	
Strongly Disagree	1	0.9%	
Sum	106	100%	

We note here that only one person categorically rejects the idea of the need to improve the critical path method, compared with 20 people who strongly support the idea, which shows that there is a real need to improve this method with high efficiency. As previously mentioned, the proposed solutions are an effective contribution to the critical path method and a qualitative addition, and it needs appropriate technical support.

9. Do you think that Critical Path Method needs More technological support?

Table 5.10: Technological support of CPM

Answer	Frequencies	Percentage	Mean
Strongly agree	34	32.1%	4.08
Agree	52	49.1%	
Neutral	16	15.1%	
Disagree	3	2.8%	
Strongly Disagree	1	0.9%	
Sum	106	100%	

We note here that there is a real need to develop the technical side of the critical path method. The average response period falls heavily, and this is not surprising at all. There have been many small attempts to support the critical path method, but it is not yet sufficient to dispense with manual calculation and expert supervision, as well as to facilitate and reduce the complexity of this method when managing different or large types of projects.

Technical support may be a clear need in all areas, but the results obtained from field surveys are more reliable and also useful for differentiating between the many options that need to be worked on at the same time. Which helps and directs experts to devote their efforts to these issues and not others because of the need and general orientation of users.

(Building Information Modeling)

10. Do you think that Building Information Modeling (BIM) is an effective tool for projects?

Table 5.11: Building Information Model

Answer	Frequencies	Percentage	Mean
Strongly Agree	36	34%	4.16
Agree	53	50%	
Neutral	15	14.1%	
Disagree	2	1.9%	
Strongly Disagree	0	0%	
Sum	106	100%	

The results here indicate almost total approval, as BIM is considered one of the most important modern methods that helped a lot in the development of construction projects, as it enters the phase of analysis, design, planning and implementation. The concept of BIM has been under development at the end of the seventies and was adopted in the early twenty-first century. BIM is considered a promising thing and carries a lot of potential, especially with the great practical progress witnessed by all sectors.

11. Do you think that linking the Critical Path Method with Building Information Model through Machine Learning is efficient solution?

Table 5.12: BIM with CPM

Answer	Frequencies	Percentage	Mean
Strongly agree	24	22.6%	3.9
Agree	49	46.2%	
Neutral	31	29.2%	
Disagree	2	1.9%	
Strongly disagree	0	0%	
Sum	106	100%	

The answers here, as in the previous question, almost agreed. Which prompts us to think seriously about investing in this proposal as an effective solution that could make a shift in the critical path method. The BIM method can embody different

processes and make handling, scheduling and estimating their duration and quantities much easier. Machine learning can help make the process of linking the two easier through supervised learning, which enables the machine to learn and develop in guessing and calculations at an amazing speed compared to other methods.

(Artificial intelligence)

12. Do you know what is Artificial intelligence?

Table 5.13: AI knowledge

Answer	**Frequencies**	**Percentage**	**Mean**
Strongly agree	35	33%	4.1
Agree	44	41.5%	
Neutral	20	18.9%	
Disagree	7	6.6%	
Strongly disagree	0	0%	
Sum	106	100%	

Here, before asking further questions about the Machine Learning, we had to check the responder's knowledge of AI and ML before continuing in order to make sure of the answer's reliability as possible. The mean in this question shown high rate of agreement which reflects good knowledge for responders with AI in general.

Based on the answers of this question and the next, further cleaning for data have to be made, because incase the responses here were negative, they answer for the rest of the survey would be meaningless, and will affect the reliability of the answers.

13. Do you know what is Machine learning?

Table 5.14: Machine Learning knowledge

Answer	Frequencies	Percentage	Mean
Strongly agree	29	27.4%	3.89
Agree	47	44.3%	
Neutral	19	17.9%	
disagree	11	10.4%	
Strongly disagree	0	0%	
Sum	106	100%	

The responses here seem to be nearly the same as the previous question.

Here we'll have to clean data based on the answers of the two questions. Strongly Disagree and Disagree answers of both questions would be cleaned.

There was 7 Disagree answers for the AI question and 9 Disagree for ML question, so the new sample size will be 90.

14. Do you use Machine learning?

Table 5.15: ML usage

Answer	**Frequencies**	**Percentage**	**Mean**
Strongly agree	15	16.7%	3.43
Agree	32	35.6%	
Neutral	25	27.8%	
Disagree	13	14.4%	
Strongly disagree	5	5.6%	
Sum	90	100%	

The average of the answers indicates agreement with the majority, which indicates a good knowledge of the respondents in machine learning and its applications, which gives their answers greater credibility and reliability. Also, this relatively high percentage indicates the extent of the spread of this process and its applications because of the important role it plays in leading the future of humanity towards changing the old systems and automating most of what is operated manually, starting from simple office work to much more complex work such as thinking, analysis and providing solutions such as IBM Watson.

15. Do you think that it is possible to merge Machine learning techniques with the Critical Path Method?

Table 5.16: Mergence of CPM and ML

Answer	Frequencies	Percentage	Mean
Strongly agree	20	22.2%	3.93
Agree	49	54.4%	
Neutral	18	20%	
Disagree	1	1.1%	
Strongly Disagree	2	2.2%	
Sum	90	100%	

As we note here. The average is relatively high and indicates a high rate of approval. This in turn supports the idea of this research in a general way, either in terms of users' need or in terms of possibility based on users' knowledge of the two methods, as the answers showed high rates in both cases, especially after cleaning the data.

16. Do you think that Machine Learning could improve the usage of Critical Path Method in the planning phase?

Table 5.17: CPM in planning phase enhancement through ML

Answer	Frequencies	Percentage	Mean
Strongly agree	24	26.7%	3.96
Agree	47	52.2%	
Neutral	12	13.3%	
Disagree	5	5.6%	
Strongly Disagree	2	2.2%	
Sum	90	100%	

As we already know based on many researches like (Hegazy 2002, Ahuja and Thiruvengadam 2004, Herlod 2004, Gould 2005, Ostrowski 2006, Hegazy and Menesi 2008, Menesi 2010) that CPM has three main uses: in panning phase, monitoring during projects and after finalization. So, this question is asking about the possibility of ML to enhance this use of CPM. General answers show high amount of agreement with this suggestion. Making achievement in this part of CPM can help project managers to be able to plan more accurately and with a smaller number of errors which is unique addition.

17. Do you think that Machine Learning could improve the Critical Path Method in monitoring projects?

Table 5.18: CPM in monitoring phase enhancement through ML

Answer	Frequencies	Percentage	Mean
Strongly Agree	18	20%	3.91
Agree	51	56.7%	
Neutral	18	20%	
Disagree	1	1.1%	
Strongly Disagree	2	2.2%	
Sum	90	100%	

In this phase, CPM helps managers to anticipate problems that can happen in the future through recording day-by-day events so that manager can start corrective actions. So, linking this record to smart schedule supported by Machine learning can help to automatically read situations, anticipate problems and recommend auto-corrections for the schedule. Participants here shown high percentage of agreement with this suggestion which can be considered as agreement with the possibility and realisticity of this solution.

18. Do you think that Machine learning could improve the usage of Critical path method in making legal claims in case any financial problem could happen in projects?

Table 5.19: CPM in after finalization enhancement through ML

Answer	Frequencies	Percentage	Mean
Strongly agree	13	14.4%	3.7
Agree	46	51.1%	
Neutral	24	26.7%	
Disagree	5	5.6%	
Strongly Disagree	2	2.2%	
Sum	90	100%	

Agreement percent for this question is 51.1% which is more than half of participants. In general, High levels of agreement was recorded in these three questions which reflects high possibility of achieving these enhancements in CPM with the aid of ML.

19. Do you think that Machine Learning could improve the auto-detection of Critical Path in Critical Path Method?

Table 5.20: Critical Path auto-detection through ML

Answer	**Frequencies**	**Percentage**	**Mean**
Strongly Agree	16	17.8%	3.86
Agree	50	55.6%	
Neutral	21	23.3%	
Disagree	1	1.1%	
Strongly Disagree	2	2.2%	
Sum	90	100%	

The auto-detection of CP is already made by many programs but not yet made through Machine Learning. It's believed by the researcher that the use of ML can be much better with the continuous learning of machines to tailor projects, find bugs and suggest solutions. The mean for this question is 3.86 which is high agreement.

20. With the aid of Machine Learning, the auto-prediction of different scenarios and best crashes or fast tracking have to be made in projects using Critical path method is very likely to be achieved?

Table 5.21: CPM automation possibility through ML

Answer	Frequencies	Percentage	Mean
Strongly Agree	19	21.1%	3.9
Agree	47	52.2%	
Neither	21	23.3%	
Disagree	2	2.2%	
Strongly Disagree	1	1.1%	
Sum	90	100%	

This question generally contains some potential that machine learning can offer to the critical path method. After collecting and analyzing the different answers of a large segment of professors, engineers and researchers from different groups, the answer is yes, it is possible and strongly. No matter how long it takes to develop and modify, these capabilities will be realized in the future through advanced knowledge of machine learning applications in addition to the critical path method.

21. Machine Learning could solve Logical abuses that can usually happen when implementing the Critical Path Method?

Table 5.22: CPM logical abuses solution

Answer	Frequencies	Percentage	Mean
Strongly agree	11	12.2%	3.69
Agree	47	52.2%	
Neutral	26	28.9%	
Disagree	5	5.6%	
Strongly Disagree	1	1.1%	
Sum	90	100%	

As a sample of the different problems faced by the critical path method, this problem, which was mentioned earlier in this research, was chosen. The average of the answers falls within Agree interval, and this indicates a great potential to solve this problem through machine learning.

6. ANALYSIS, CONCLUSION AND RECOMMENDATIONS

6.1 Discussion on the General Results of the Survey

The questionnaire was formulated in a gradual manner, starting with questions about general issues related to the critical path method, then these questions are gradually specialized until they reach pivotal points related to the effectiveness of the critical path in relation to machine learning. The results were as follows:

1. The survey shown the importance of CPM in managing projects, and thus the importance of improving it as possible.
2. The survey shown that there are several theoretical methods for managing projects, but practically, options used in real projects are limited and CPM is nearly one of the most famous and mostly used methods so improving this method could result in raising the management of projects to higher level.
3. The survey shown that CPM still suffers some problems that needs to be overcome to enhance the reliability and efficiency of this method.
4. The survey shown that despite the massive studies about this method, the practically used modifications are very few which spots the lights on the need of an efficient useful modification for the critical path method which has been answered by this research, Machine Learning is the potential solution.
5. The survey shown that the is a big slice of engineers and managers who depend on the Critical Path Method with their work so improving this method is necessarily needed.
6. Although the critical path method is an effective method, it still suffers from many problems and complications that reduce the effectiveness of this method, which supports the previous point of the need to develop and improve this method.
7. The need to develop the critical path method is definite, and the machine learning method is considered one of the optimal solutions to this. Several

practical proposals have been presented that can be applied in the future, which will contribute to improving this method significantly.

8. One of the very important things is the issue of the need for technical support, which is largely related to the method of machine learning, which falls within this field. There was significant support for this particular issue because of its great importance and contribution, especially in light of the technical development experienced by the administration in general in the era of the speed.
9. One of the practical solutions that were also addressed was Building Information Modeling, which is considered one of the very important methods on which the construction project management world relies heavily. Remarkably efficient work.
10. In the third axis, the topic of artificial intelligence was addressed, and the questions were engineered in the same way as the questions in the previous two axes, where they begin in general and then begin to gradually focus on more detailed points.
11. Before that, the data was cleaned to maintain accuracy and validity, and then topics related to the development of the critical path method by machine learning were discussed, as described in the previous chapter.
12. The third axis is divided into three sections, the first is related to data cleaning and the second discusses the possibility of the effectiveness of machine learning in developing the critical path method in three stages, and they were compared and arranged gradually. planning. The second issue, in order of the percentage of answers, was the effectiveness of machine learning in improving the use of the critical path method in relation to project management. Then the third issue was related to the effectiveness of machine learning in improving the use of the critical path method in relation to the post-project completion.
13. The third section of the third axis discusses some specific issues, such as the automation of critical path discovery, which is complete in the critical path method. The answers were very optimistic, and the topic is very possible after study, research and scrutiny.

14. Three open questions were also asked regarding the subject of the study, but the answers were mostly empty or did not contain information that might satisfy or add to what has been studied in this research so far. This gives additional points to the value of this research, as it directs the attention towards a possible practical investment for machine learning in an important method in the field of project management, which is the critical path method, which is considered a first step for subsequent research.

6.2 Conclusion

After a detailed study of both the critical path method and the machine learning technique, and a review of their sources, previous studies and expert opinions, some theoretical proposals that could be achieved in the future were made regarding the use of machine learning to improve and develop the critical path method based on the capabilities that this technology possesses, which are as follows:

1. Using machine learning for the auto-estimation of projects period: In this case, this achievement can be very useful and a great addition to the critical path method, as it will greatly reduce the time required to estimate the duration of each task of the project, as well as solve the problem of the accuracy of the tasks by having a large database of previous projects in which the machine is trained to have the ability of accurately determining the duration of each task of the projects without the need to higher specialist to perform this task which will consume time and money, the possibility of performing this task will increase the effectiveness of the critical path method and reduce the cost and time required to perform the same process.
2. Using machine learning for the auto-suggestion of any substitutes: The ability to analyze and find alternative solutions in cases of delays or conflicts between the tasks of the project is considered a qualitative addition to the critical path method, and this type of operations machine learning can provide in case it has been programmed in the appropriate way, and in the case of feeding the machine with the appropriate quantity and quality of data for the purpose of training and learning, this type of solution that Any engineer would pay a lot to get since it would facilitate his use of the critical path method in projects.

3. Using machine learning for the auto-detection of the critical path: Finding and specifying the critical path in a correct and accurate manner is one of the most essential and basic tasks when talking about using the CPM, so automatic identification of this path without errors will save a lot of effort, time and money and also solve the problem of needing to audit this path, which will require double money and efforts if this method works with a Certain degree of efficiency. This type of solutions is not currently available due to the lack of data availability (construction database), as well as work and development in this field is still considered in its beginning, but after the availability of the required data and the sufficient experience, this solution will be available.
4. Using machine learning for the auto-suggestion for different scenarios: After fully analyzing the project and determining the critical path for it, the machine can then provide many proposals and alternatives for the way of project implementation and what will result in when implementing any of these alternatives in addition to the automatic review and update of the project after the use of any alternative, this solution can be applied using deep learning techniques that enable the machine to study And then analyze and present alternatives, as well as analyze the effectiveness of using these alternatives.
5. Using machine learning to auto-suggest different and best crashes or fast tracking have to be made: through using artificial intelligence, the machine can study and evaluate both potential "crashes" and "fast tracking" operations, show the suggestions that can be used and determine the best options, with an indication of the advantages and disadvantages of each option, this technology can help a lot as the option to using "crashing" or "fast tracking" is not always easy or clear, And that the use of any one of the methods can affect the success or failure of the project partially or completely since the decision of using any of these techniques is used basically in crucial timings only, so the presence of such kind of solutions is considered an addition of great value and help for users of the critical path method.
6. Solve resources limitation by processing both resources and project duration and tasks at the same time: one of the common problems regarding the

critical path method is not considering the limited resources and this is what prevents many users from using this method at work, artificial intelligence can provide practical solutions to solve this problem, as the machine has a great ability to process and analyze huge amounts of data at a time The same, therefore, charting a critical path while considering both time, resources, and tasks at the same time is an easy process using machine learning assistance, this feature can make the critical path method one of the most used and widespread methods at all.

7. Use the clustering technique for the auto-sorting of tasks, after that decision tree can be helpful for the arrangement of the tasks based on their features: Another practical proposal through which the critical path can be determined automatically and smartly, through using Clustering technique to classify project tasks and then arrange them using the decision tree technique for the purpose of arranging these tasks sequentially to form an integrated project, all within a way to identify fully ready to use projects from Only quickly defining the name, type, and features of the project.
8. Feeding deep learning with many different modifications suggested for the improvement of CPM and try to conclude the best model of them: theoretically this can be efficient method: On the other hand, the deep learning method can be used to develop and improve the critical path method, as the deep learning method is already used in developing, improving and inventing many things in the fields of innovation and development of medicines, crops, devices, etc. Theoretically, this can be done by feeding the machine a lot of Data regarding potential improvements and enhancements, as well as the problems faced by the Critical Path method, the machine will do the rest, since it has the ability to analyze and test feasible solutions. The proposed results can be reviewed and checked whether they are feasible, possible and practical then study of each of them separately.
9. Using machine learning for the auto weather-prediction and making pre-alarms: An additional method is to link the device responsible for the critical path method with meteorology through internet and make accurate analysis and advance alerts for weather for each step of the project, in the event that there is a conflict between the weather condition and certain steps in projects.

For example, rainy weather interferes with concrete works and so on, and also give practical suggestions for each case. Using artificial intelligence, this method can be used effectively, where all the data are analyzed and then alerts and solutions are given in an intelligent way closer to the decisions that a real person can make.

10. Auto-check and alarm in case any problem is made while programing the CPM: Some errors can only be detected late, after continuing to carry out the work or when it is already too late. Such mistakes often have a high cost in terms of time and resources. But the possibility of this can be reduced by using an automatically smart detection of any errors during the project calculations or any errors that may occur during the work, such as illogical errors in the calculations or errors in recording some numbers whose accumulation can lead to errors that are difficult to correct later. This technique previously was dumb and difficult to be done using machines, but after the huge advancement of technology, using this technique with the help if machines now is more promising and useful.
11. Logical abuse solving: One of the problems mentioned frequently in many articles and research is logical abuse, as this problem occurs due to the existence of illogical relationships between tasks, where such relationships can occur theoretically, but they are not feasible from the practical side. Through the use of artificial intelligence, such a problem can be achieved by using specialized tools and algorithms.
12. Reduce specialist's dependency: Among the disadvantages of using the critical path method is its high dependence on specialists, this problem can be avoided in the long run as this can be done by developing and simplifying the use of the critical path method through the use of modern applications and technologies. artificial intelligence plays an important role in this process because of its huge potentials that can be used specifically for solving such problems. If the necessary efforts are made to develop and support scientific research specialized in this field. The dependency on specialists in CPM would be much reduced.
13. Simplifying implementing CPM: Usually, using the critical path method

requires a lot of preparation, work and time, and this is one of the drawbacks related to this method. The ability of artificial intelligence to automate many processes can help save a lot of work and time in order to use the critical path method in general. The ability of artificial intelligence to do many complex and automated tasks, such as driving cars or playing chess, is considered a scientific breakthrough that can be used in.

14. Restricting projects deadlines: When calculating the critical path and determining the duration of each task, the critical path method cannot adhere to the final date of the project or process the calculations based on it, so the project can, during any stage of the calculation, exceed the specified deadline of the project, which leads to re-calculations again, so the solution of such problem is by using inverse computation with the help of artificial intelligence and this can be considered a useful addition to the critical path method.

6.3 Recommendations

1. Create a detailed database for all projects that use the critical path method through the use of a dedicated cloud for this purpose. This work can be done either by doing a periodic collection every specific period (for example) of this data for the purpose of tabulating and analyzing it to develop artificial intelligence and machine learning to simulate procedures and avoid errors that occur in these projects, this can be done by circulating the data collection policy to all companies that specialize in projects in general.
2. Creating a specialized model using deep learning to simulate the structure of real projects in all their details and duration. This model is automatically fed periodically by the database that was made in the previous step, and this will lead to the emergence of remarkable progress after a period of time, so that this model is adopted in the design of projects, assigning them, and making the critical path for them with all its details.
3. Hiring specialists in the field of machine learning programming, as engineering experience is not sufficient. As well as the use of specialists in the field of advanced mathematics as well as advanced statistics for the purpose of completing such a project.

4. The field of machine learning is a deep sea that contains a huge variety of fields and branches, so defining and researching a very specific issue may lead to more effective and accurate results. For example, the topic of automating the critical path method in a practical way, the completion of a master's research or perhaps a PhD in this topic is impossible, perhaps because this topic is very large and contains many complications and branches. Therefore, it is recommended to research the method of estimating the duration of a specific type of activity, for example, it is the subject of an integrated research that will eventually lead to the complete automation of this method in the future.

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RESUME

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