CURRENT STUDIES IN BASIC SCIENCES, ENGINEERING AND TECHNOLOGY 2024

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Fatma Zerrin SALTAN
Huseyin ARIKAN
Yusuf UZUN

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About the Book

Dear Readers,

The fields of science, engineering, and technology demonstrate constant progress and innovation in pushing humankind's limits. This work, titled "Current Studies in Basic Sciences, Engineering, and Technology 2024", brings together the most current studies, research, and discoveries in these fields.

Today, research conducted in a wide range from basic sciences to engineering and technology aims to find solutions to the challenges faced by humanity. This book includes studies presented by distinguished researchers in a wide range of fields, from physics to biology, from chemistry to computer science. Each article and chapter aim to provide the reader with in-depth information on the subject.

The content of the book focuses on the challenges, innovations, and discoveries faced by scientists and engineers. In this way, we believe that our readers will not only update their current knowledge but also gain a perspective on the technological and scientific trends of the future.

While preparing this work, we brought together many valuable pieces of content that are the product of intense collaboration between editors and authors. We believe that these studies will foster progress in academia and industry.

Finally, we hope that this book, "Current Studies in Basic Sciences, Engineering and Technology 2024", will increase your interest in the fields of science, engineering, and technology and enable you to gain more in-depth knowledge of these subjects.

We wish you good reading.

December, 2024

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Contemporary Approaches in Osas: Orthognathic Surgery & Crucial Role of Digital Planning

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Introduction

Sleep-disordered breathing (SDB) refers to a group of conditions characterized by abnormal respiratory patterns during sleep, which includes obstructive sleep apnea (OSA) and central sleep apnea (CSA). These conditions can lead to significant morbidity and mortality, affecting individuals of all ages, from children to adults. OSA is the most prevalent form, primarily caused by direct physical airway blockage. In contrast, CSA is caused by a lack of respiratory effort due to failure in the central nervous system's respiratory control centers. CSA is often associated with various comorbidities, including heart failure, opioid use, and neurological disorders (Foldvary-Schaefer & Waters, 2017; Sateia, 2014).

Obstructive Sleep Apnea Syndrome (OSAS) is a clinical condition marked by repeated episodes of complete (apnea) or partial (hypopnea) blockage of the upper airway during sleep, each lasting more than 10 seconds, despite ongoing thoracoabdominal movements. Apnea episodes lead to improper nocturnal alveolar ventilation, resulting in decreased oxygen saturation and increased blood pressure. Consequently, this condition disrupts sleep, causes hypoxia, and leads to a range of cognitive, behavioral, and metabolic consequences (Sateia, 2014).

The diagnosis of OSAS primarily relies on polysomnography (PSG), considered the gold standard. Comprehensive sleep evaluations and follow-ups are essential for accurate diagnosis.

The management of OSAS requires a multidisciplinary approach. Treatments for obstructive sleep apnea syndrome include continuous positive airway pressure (CPAP), weight loss, exercise, myofunctional therapy, and various surgical options such as maxillomandibular advancement (MMA) and uvulopalatopharyngoplasty. CPAP remains the most effective and widely recommended treatment, significantly improving symptoms and quality of life. Exercise and weight loss are beneficial adjuncts, particularly for overall health. Myofunctional therapy offers a promising alternative for reducing symptoms, especially for those who cannot tolerate CPAP. Surgical options are available but vary in effectiveness, with maxillomandibular advancement showing the highest success rates. Further research is needed to optimize treatment strategies and explore new therapeutic avenues (Abbasi et al., 2021, Foldvary-Schaefer & Waters, 2017).

Orthognathic surgery (OS) can be performed via Le Fort I osteotomy (LFIO) and bilateral sagittal split ramus osteotomy (BSSRO) with or without genioplasty, which is a highly effective surgical treatment for OSAS. This procedure significantly reduces the apnea-hypopnea index (AHI) and respiratory disturbance index (RDI) scores, high surgical success and cure rates, and long-term improvements in sleep quality and overall health. While MMA is more effective than some other surgical options, its complication rate is higher than that of standard orthognathic surgery procedures. Overall, MMA is a valuable option for patients with OSA, particularly those who are intolerant to CPAP therapy (Gottsauner-Wolf et al., 2018; Spyropoulou et al., 2022).

MMA increases upper airway volume by repositioning muscle attachments, which repositions the tongue and hyoid bone. However, this procedure can cause unesthetic results in patients without maxillary hypoplasia, especially in the paranasal regions. In this context, OS aims to enlarge the airway in OSAS patients while ensuring facial aesthetics. To achieve this, counterclockwise rotation (CCWR) of the maxillomandibular complex is used to treat OSAS patients where maxillary advancement is not required (Caples et al., 2010; Wei et al., 2017).

Virtual surgical planning (VSP) has revolutionized orthognathic surgery, particularly in treating patients with skeletal-dental abnormalities and OSAS. Computed tomography (CT) based VSP illustrates the postoperative outcomes in a three-dimensional plane before the operation. It allows the surgeon to analyze these data to optimize facial aesthetics and functional outcomes by exploring and simulating different surgical options without risking the patient. Therefore, it provides accurate and predictable movements of the maxillofacial skeleton (Alkhayer et al., 2020; Chen et al., 2021).

VSP based on patient-specific 3D reconstructed CT scans allows for the identification of anatomic sites of obstruction, aiding in determining the extent of airway obstruction and the necessary advancements and impactions during skeletal surgery for OSA. Moreover, VSP can assist in establishing target endpoints for distraction procedures, such as mandibular distraction, by enhancing precision and reducing complications (Ha et al., 2023; Resnick, 2018).

Customized surgical treatment planning is essential for patients with OSAS, considering diverse skeletal-dental and soft-tissue patterns to achieve favorable changes in facial esthetics and sleep function. Integrating VSP with maxillofacial surgery has significantly improved surgical planning for patients with OSAS, enabling more accurate and predictable postoperative outcomes. Additionally, VSP has been shown to decrease surgical time and increase surgical accuracy in various medical fields, including maxillofacial surgery (Hua et al., 2019). By utilizing VSP, surgeons can perform complete virtual planning for operations, leading to simplified and more accurate surgical procedures (Klasen et al., 2022).

In conclusion, VSP is crucial in enhancing surgical planning and outcomes for patients with OSAS. Its ability to provide precise preoperative simulations, individualized treatment plans, and improved surgical accuracy makes it a valuable tool in modern healthcare, benefiting patients and healthcare providers (Ha et al., 2023).

This chapter focuses on the impact of digital planning on the success and aesthetic outcomes of orthognathic surgery in patients diagnosed with OSAS with/without dentofacial deformities.

Obstructive Sleep Apnea Syndrome (OSAS)

OSAS is a severe and widespread condition that affects both adults and children with a higher prevalence in men and the elderly, leading to significant cognitive, psychological, and physiological consequences. It is characterized by repeated episodes of upper airway obstruction during sleep, causing disrupted sleep, intermittent hypoxemia, and impacting daytime functioning and cognitive abilities (Sforza & Roche, 2012; Vaessen et al., 2015).

This condition's prevalence is on the rise due to increasing obesity rates and improved diagnostic tools. Common symptoms include snoring, difficulty breathing during sleep, and excessive daytime sleepiness in adults, while children may exhibit hyperactivity and behavioral problems (Lyons et al., 2020; Prajsuchanai et al., 2022).

OSAS leads to intermittent hypoxia, triggering oxidative stress and inflammation, which contributes to cardiovascular and metabolic health issues. Furthermore, the condition is linked with increased risks of hypertension, cardiovascular diseases, and overall mortality. Cognitive impairments associated with OSAS, particularly in attention, working memory, episodic memory, and executive functions, are partially reversible with treatment, but some residual impairments may persist. It is also worth noting that there is a significant overlap between OSAS and psychiatric comorbidities, especially depressive symptoms and anxiety disorders (May & Mehra, 2014).

Effective diagnosis and treatment are crucial, with CPAP being the most common therapy. However, a multidisciplinary approach encompassing lifestyle changes and alternative treatments is often necessary to manage the condition and improve patients' quality of life (Randerath et al., 2021).

Airway Anatomy in OSAS and Dentofacial Deformities

The respiratory system, consisting of the airways, lungs, and associated structures, plays a vital role in gas (O2 & CO2) exchange. Understanding the intricate details of airway anatomy and physiology is critical to comprehending respiratory health and diseases (Strohl et al., 2012).

Mechanical forces acting on the airways are also pivotal in airway physiology. They influence airway development, health, and disease, showcasing the profound impact of the mechanical environment on airway structure and function. Moreover, airway compliance, cartilage, and smooth muscle collectively contribute to the overall mechanical properties of the airways, influencing their responsiveness and ability to uphold patency (Abramson et al., 2010).

OSAS patients have higher upper airway resistance, which is correlated with anatomical variables such as the length of the soft palate and the position of the hyoid bone, also lung cancer has been reported (Sircu et al., 2023).

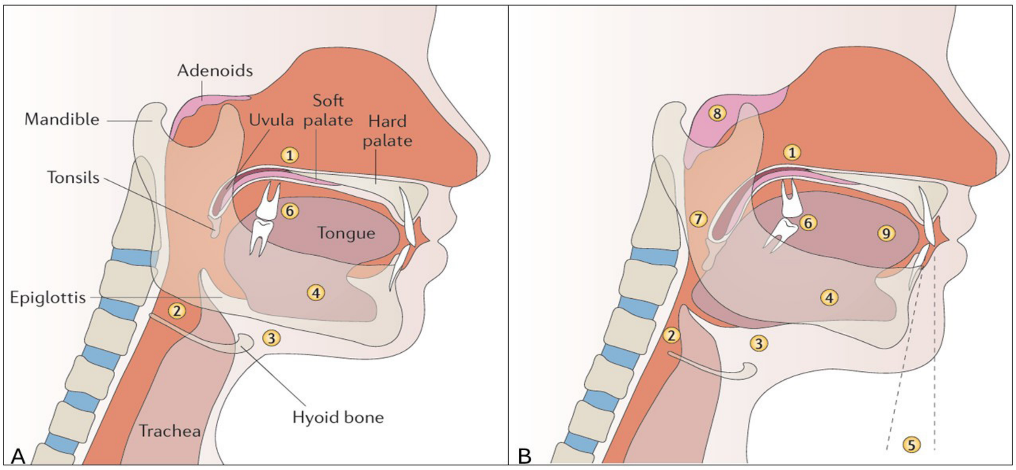
Obstructive sleep apnea (OSA) and other sleep disorders are often present with various oral health issues, including gingivitis, periodontitis, dry mouth, halitosis, and recurrent throat infections. The Mallampati classification, which evaluates the visibility of the soft palate and uvula, is commonly used to assess the risk of OSA and for pre-anesthetic evaluation, particularly when intubation may be necessary. Bruxism (teeth grinding) is often an early indicator of sleep apnea. This grinding can result in tooth attrition and wear facets on the incisors, suggesting the patient may be pushing the mandible forward to help open the airway during sleep. Clenching can damage teeth, leading to regressive changes in tooth structure, gingival inflammation, recession, and an increased risk of dental caries due to weakened enamel (Jokubauskas et al,2017).

Tongue crenulations, or scalloped borders, indicate that the patient is habitually pressing the tongue against the mandibular teeth, possibly to improve airflow. This can also result in anterior or lateral open-bite relationships between opposing teeth. Additionally, dimpling on the functional cusps and the lingual or palatal surfaces of the teeth can indicate gastroesophageal reflux disorder, which is associated with OSA. Other oral features linked to OSA include orofacial pain, reduced jaw size, and erythema in the larynx and pharynx due to snoring and mouth breathing (Padmanabhan et al., 2020).

In OSA patients, the most common physical examination finding is narrowing of the oropharyngeal airway, with or without soft tissue deposition. Other factors that contribute to airway narrowing include retrognathia, micrognathia, tonsillar hypertrophy, macroglossia, and an inferiorly displaced hyoid bone (Biradar et al., 2023; Deegan & McNicholas, 1995).

Figure 1

Maxillofacial and Soft Tissue Changes Occurring in OSAS



a. Normal anatomy. B. Typical anatomical changes in obstructive sleep apnea syndrome (OSAS): a long soft palate and enlarged uvula (1); a reduced retroglossal pharyngeal airway space (2); an increased distance between the hyoid bone and the mandible (3); a shorter and more vertical mandible (4); a retro-position of the mandible, which is measured by the angle (retrognathia) (5); dental overbite or loss of normal dental occlusion (6); tonsillar hypertrophy (7); adenoid hypertrophy (8); and macroglossia (unusual large tongue) (9). (Lévy et al., 2015)

Mandibular hypoplasia and vertical growth patterns are strongly linked to airway obstruction, particularly in the oropharyngeal and hypopharyngeal regions. Recent Computed Tomography (CT) studies have shown that individuals with mandibular hypoplasia exhibit narrower pharyngeal airways compared to those with Class I skeletal relationships. Additionally, longitudinal studies confirm that these patients maintain smaller airway volumes throughout pre- and post-pubertal periods. Key anatomical features of mandibular hypoplasia, including mandibular retrognathia, a shortened mandibular corpus or ramus, and posterior mandibular rotation, contribute to nasopharyngeal and oropharyngeal narrowing. This narrowing can lead to improper tongue positioning and respiratory issues such as snoring, increased upper airway resistance, and a heightened risk of obstructive sleep apnea (OSA) (Jung & Kim, 2015; Kurbanova et al., 2021).

The position of the hyoid bone in individuals with Class II malocclusion and obstructive sleep apnea syndrome (OSAS) is a critical area of study due to its implications for airway management and treatment outcomes. Class II malocclusion is characterized by a retruded mandible, which can influence the positioning of the hyoid bone and subsequently affect the airway space. Research indicates that the hyoid bone is often positioned lower in patients with OSAS, which can exacerbate airway obstruction during sleep (Anand et al, 2020; Jung & Kim, 2015).

Studies have demonstrated a strong correlation between the hyoid bone's position and OSAS severity, highlighting that a lower hyoid position is often associated with a narrower retro-lingual space and increased airway obstruction due to the tongue base's downward displacement. Inferior hyoid positioning is commonly observed in severe

OSAS cases, suggesting that this anatomical change may result from the disorder rather than being a predisposing factor. Additionally, findings indicate that the hyoid bone tends to sit lower in OSAS patients than in healthy individuals, underscoring a notable anatomical alteration linked to the condition (Cho et al., 2019; Wang et al., 2012).

The interaction between facial morphology and hyoid position further underscores airway compromise risks, especially in Class II malocclusion, where features such as increased facial height and clockwise mandibular rotation contribute to a lower hyoid position. This positioning correlates with a higher apnea-hypopnea index (AHI), indicating its role in exacerbating sleep apnea severity. Moreover, caudal displacement of the hyoid during sleep is a defining characteristic of OSAS, often contributing to impaired swallowing and heightened aspiration risk. In adults, six anatomical factors correlate with OSA severity: the size of the hypopharynx and oropharynx, the inferior position of the hyoid bone, mandibular rotation, sagittal maxillomandibular position, and BMI. Studies indicate that adult OSA patients often have longer airways, shorter skull bases, macroglossia, or elongated soft palates (Kurbanova et al., 2021; Tanellari et al., 2022).

Obstructive Sleep Apnea Syndrome Treatment with Orthognathic Surgery (OS)

OS, particularly the maxillary Le Fort I osteotomy combined with bilateral mandibular ramus sagittal split osteotomy, is widely used to treat OSAS. The combined use of these maxillary and mandibular osteotomies often results in greater advancement of jaw structures, leading to improved outcomes. Notably, Wolford and colleagues emphasized that a counterclockwise advancement of both the maxilla and mandible not only maximizes the posterior airway space (PAS) but also enhances facial aesthetics. Additional procedures such as septoplasty, turbinectomies, nasal reconstruction, and uvulopalatopharyngoplasty can be performed alongside these procedures (Brunetto et al., 2014; Caples et al., 2010).

Maxillomandibular advancement surgery, which advances both the maxilla and mandible, relocates the hyoglossus muscle insert (Sakamoto, 2017) and increases buccopharyngeal volume, leading to the enlargement of the velo-oropharyngeal and hypopharyngeal airways, as well as the advancement of the tongue and hyoid bone. MMA is highly effective in increasing airway dimensions and reducing pharyngeal collapsibility during inspiration, making it the most effective craniofacial surgical technique for treating OSAS in adults. Of the upper airway dilator muscles, the musculus uvulae, tensor veli palatini, levator veli palatini, and palatoglossus are attached to the jaw and comprise the soft palate muscles. These muscles strongly influence the morphology of the velopharynx. Jaw advancement affects the soft palate muscles, and the velopharyngeal space is expanded 3 dimensionally by each of those muscles. The surgery advances the anterior pharyngeal tissues, including the soft palate, tongue base, and suprahyoid musculature, without directly manipulating the pharyngeal tissues. Even without maxillomandibular horizontal deficiency, MMA is effective in patients with hypopharyngeal or velo-orohypopharyngeal narrowing. Especially the advancement of the maxilla results in the maximal expansion of the velopharyngeal space in patients with OSA (Gokce et al., 2014; Okushi et al., 2011).

There is no universally accepted standard for maxillomandibular advancement amount, and no direct correlation has been established between the degree of advancement and the reduction in the apnea-hypopnea index (AHI). However, in most cases, advancements are typically within the range of 5–10 mm for the maxilla and 10–12 mm for the mandible (Patel et al., 2024).

Maxillomandibular advancement surgery may be recommended for OSA patients based on three key criteria:

1-OSA Diagnosis During Orthodontic-Surgical Assessment: When OSA is diagnosed during the routine evaluation of a patient being considered for orthognathic surgery, it may necessitate a change in the surgical plan. This could involve extending mandibular advancement beyond the original plan and including the maxilla in the procedure.

2-Presence of Maxillomandibular Deformities: In patients with OSA and maxillomandibular deformities, orthognathic surgery can be justified to address both the skeletal deformity and the OSA.

3-Failure or Intolerance to Medical Treatments: In cases where patients do not tolerate or fail to respond to treatments such as continuous positive airway pressure (CPAP) or mandibular advancement devices (MAD), maxillomandibular advancement surgery may be considered, even if the patient does not exhibit a retrusive facial profile. However, patients should be informed about the potential morphological changes resulting from surgery (Barrera, 2018; Liu et al., 2017, 2019).

Role of Digital Planning

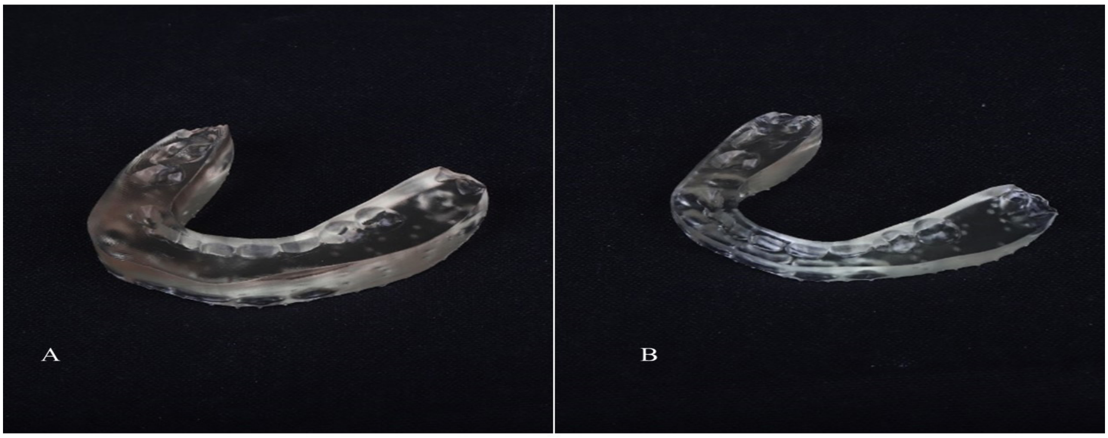
Traditional OS preoperative workflow primarily focused on achieving ideal occlusion, with cephalometric analysis as the primary planning tool. However, cephalometric analysis is limited in detecting asymmetries, as it largely relies on the sagittal plane. This occlusion-centered approach often overlooked crucial aspects of facial symmetry and aesthetics. Consequently, treatment outcomes prioritized functional alignment overachieving balanced facial harmony (Stokbro et al., 2014).

The reliance on sagittal plane analysis in traditional cephalometric techniques limited the ability to evaluate facial symmetry and proportionality fully. This method provided a two-dimensional view, making it nearly impossible to address differences between the left and right sides in the lateral view. As a result, the surgical team often had to choose one side as the basis for planning, leading to potential deviations from the ideal treatment plan. These limitations hindered comprehensive planning and impacted the aesthetic outcomes of orthognathic surgeries (Chen et al., 2021; Stokbro et al., 2014).

As orthognathic planning advances and societal perceptions of aesthetics evolve, there is a noticeable shift towards considering soft tissue in addition to skeletal corrections. In the past, surgical planning was primarily based on the Frankfort horizontal plane, often resulting in inaccurate diagnoses and suboptimal surgical plans. However, with the introduction of approaches like the Arnett analysis (Arnett et al., 1999) is, True Vertical Line (TVL), and Natural Head Position (NHP), a more patient-specific framework for accurate diagnosis and treatment planning has emerged. Advanced 3D analysis and planning software, supported by computer-assisted simulations, now allow for a comprehensive assessment of facial symmetry and skeletal relationships (Arnett et al., 1999; Chen et al., 2021; K. J. C. Lee et al., 2022; Leung et al., 2016).

The virtual OS planning process is comprehensive, beginning with the collection of clinical records, including photographs taken in the Natural Head Position (NHP), assessments of muscle dynamics, temporomandibular joint function, and facial measurements. A CT scan is then captured with the patient in centric occlusion, often stabilized with a wax bite plate, followed by a 3D dental scan using an intraoral scanner. A 3D facial photograph is also taken to capture external facial features. These images—dental scan, CT, and facial scan—are then merged within specialized software, allowing for a virtual simulation of the planned surgery. Based on this digital model, surgical guide splints (Figure 2) are custom-designed, and 3D printed to ensure precise execution during the procedure (Chen et al., 2021). This process ensures that every aspect of the patient's condition is considered, providing a thorough and reassuring approach to orthognathic surgery planning (Alkhayer et al., 2020; Farrell et al., 2014; Hua et al., 2019).

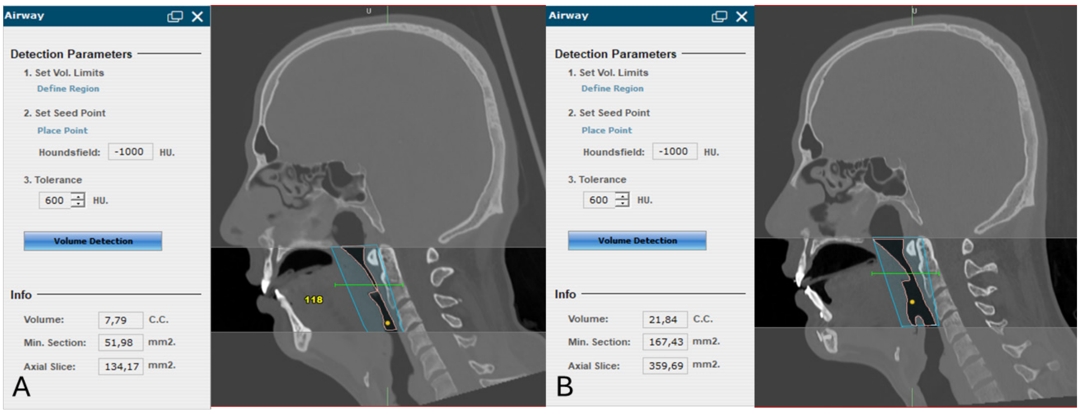
Figure 2
Surgical guide splints



A. Intermediate splint *B. Final splint*

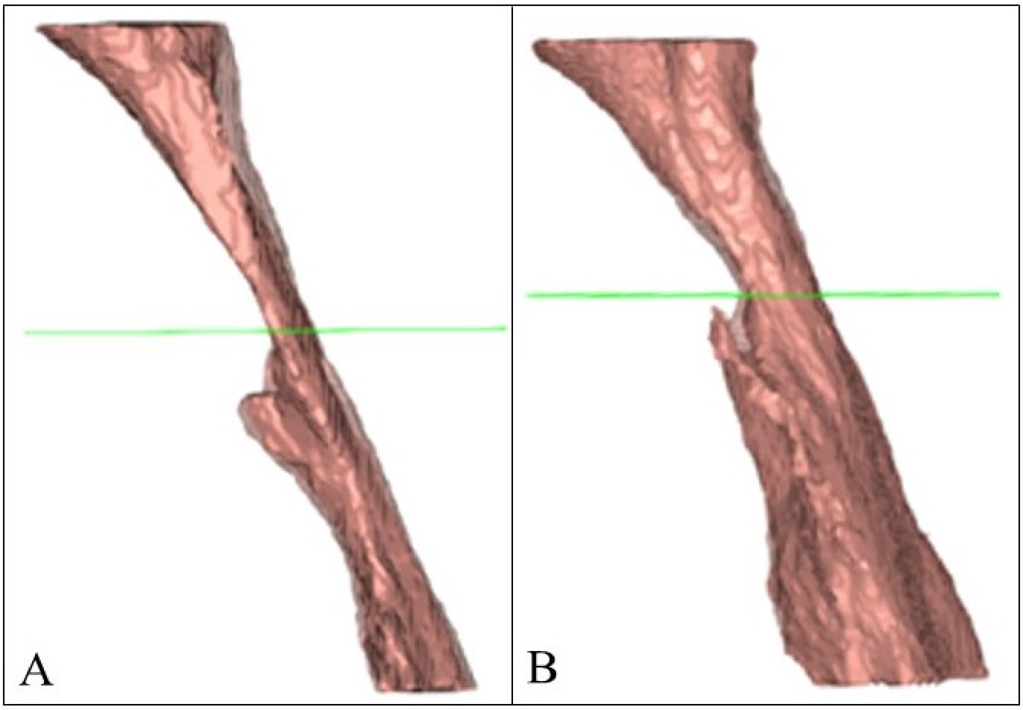
Digital planning software enables clinicians to simulate both preoperative and postoperative conditions, providing a clear visualization of expected surgical outcomes. By virtually adjusting skeletal structures and soft tissues, the surgical team can accurately predict changes in facial aesthetics and function. This simulation capability helps anticipate potential challenges, allowing for adjustments to be made before surgery begins. Ultimately, this leads to greater surgical precision and helps align the procedure with patient expectations (Alkhayer et al., 2020; Gagnier et al., 2024). It also provides better postoperative mandibular condyle position in the articular fossa than traditional orthognathic surgery planning (Alkhayer et al., 2020).

Figure 3
Airway Assessment



A. Preoperative airway assessment of a Class II patient with severe OSAS (Ahi:86.1) B. Postoperative airway assessment of the same patient 6 months after Le Fort I osteotomy and BSSRO with maxillomandibular advancement and counterclockwise rotation of maxillomandibular complex and additional wing genioplasty.

Figure 4
Airway Assessment



A.Preoperative airway, B.ostoperative airway

Integrating 3D airway modelling in digital planning allows for an in-depth assessment of airway structure and patency, which is particularly critical for patients with OSAS and other airway-compromising conditions. This technology enables the surgical team to visualize and measure airway dimensions accurately, ensuring that treatment plans address not only aesthetic and functional goals but also airway health. 3D modelling helps tailor surgical interventions to maintain or improve respiratory function by identifying potential obstructions or narrow regions. This targeted approach not only enhances patient safety and optimizes treatment outcomes for OSAS patients but also provides a proactive benefit for younger orthognathic surgery patients who may not yet have an OSAS diagnosis. With 3D airway visualization, potential airway restrictions can be identified early, allowing the surgical plan to be adjusted to prevent future health issues (Abramson et al., 2010). Modifications such as advancing the maxillomandibular complex further or incorporating more counterclockwise rotation (CCWR) can help safeguard the patient's respiratory health over the long term (Louro et al., 2018; Stokbro et al., 2014).

Digital planning provides patients with a clearer understanding of their treatment by offering 3D visualizations of expected surgical outcomes. Patients gain confidence in the procedure by reviewing virtual models of their facial structures and projected changes and feel more involved in their care. This transparency allows for better communication between the patient and surgical team, as potential adjustments can be discussed and tailored to meet both aesthetic and functional expectations. This collaborative approach helps align patient goals with surgical planning, leading to higher satisfaction and a smoother recovery process (S. J. Lee et al., 2021).

Despite the enhanced predictability offered by digital planning, accurately simulating postoperative soft tissue changes remains challenging. Variations in soft tissue thickness, muscle activation, fat distribution, and tissue elasticity among individuals can lead to differences in how skeletal adjustments translate to soft tissue outcomes. These factors underscore the need for further advancements in soft tissue modelling to achieve even more precise predictions. As technology continues to evolve, the goal is to enhance the accuracy of these simulations, improving both aesthetic and functional results (Alkhayer et al., 2020; Awad et al., 2022; Chantaraaumporn et al., 2023; Knoops et al., 2019).

Figure 5

Three-dimensional changes of the reference points in preoperative digital planning

Models Measurements

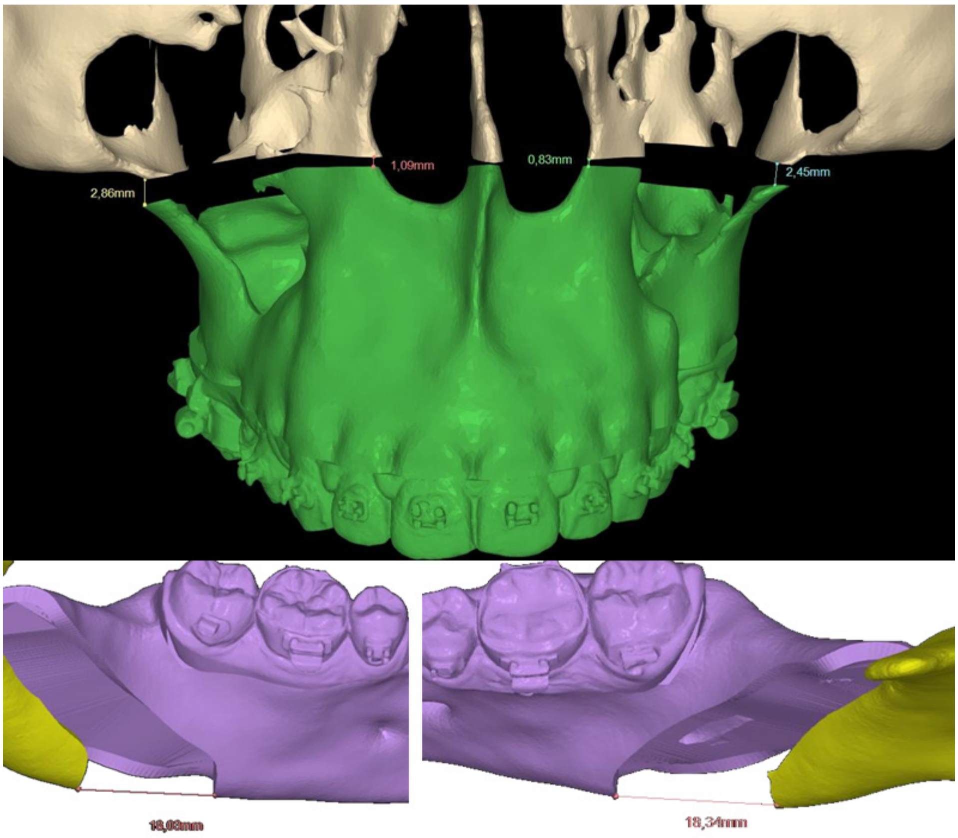
Maxilla		A-P		Vert		Side
ANS	→	3,28	↑	0,74	←	0,43
PNS	→	4,68	↓	4,15	←	0,31
Mx1 tip	→	7,51	↑	1,00	→	0,01
R Canine	→	7,35	↑	0,01	←	0,01
L Canine	→	7,26	↑	0,27	←	0,02
Right Molar MB cusp tip	→	6,94	↓	2,15	←	0,06
Left Molar MB cusp tip	→	6,69	↓	1,75	←	0,09

Mandible		A-P		Vert		Side
Md1 tip	→	12,89	↑	0,23	←	0,02
B Point	→	16,65	↓	0,42	→	0,21
Pogonion	→	18,27	↓	0,55	→	0,30
R Chin	→	18,16	↓	1,74	→	0,29
L Chin	→	18,36	↓	1,56	→	0,31
L Canine	→	12,80	↓	0,49	←	0,03
R Canine	→	12,84	↓	0,64	←	0,03
Left Molar MB cusp tip	→	12,65	↓	1,84	←	0,04
Right Molar MB cusp tip	→	12,75	↓	2,27	←	0,03

Measurement	Ini	Dif	Surg
NASION SCREW	−		
Screw to Mx1 R	96,0	-0,8	95,2
OCCLUSAL PLANES	−		
MxOccPl	106,4°	-5,7°	100,7°
MxOP R	104,5	-6,1	98,4
MxOP L	107,9	-5,4	102,5
MdOccPl	98,1°	-6,6°	91,5°
MdOP R	96,9	-7,0	89,9
MdOP L	99,3	-6,2	93,0
HT PROJECTIONS T...	+		
MIDLINES	−		
Mx Dental Midline	1,4	0,0	1,4
Md Dental Midline	1,3	0,0	1,4
Chin Midline	2,0	-0,3	1,7
CANT +R DOWN -...	−		
Mx33	0,6	0,3	0,9
Md33	0,2	0,2	0,4
Chin Cant	-1,9	0,2	-1,7
Body Cant	-0,8	0,3	-0,4
Gonion Cant	-1,7	-0,4	-2,1
L 2nd Molar Cant	0,6	0,4	1,0

Figure 6

Preoperative osteotomy planning and distances between bony segments

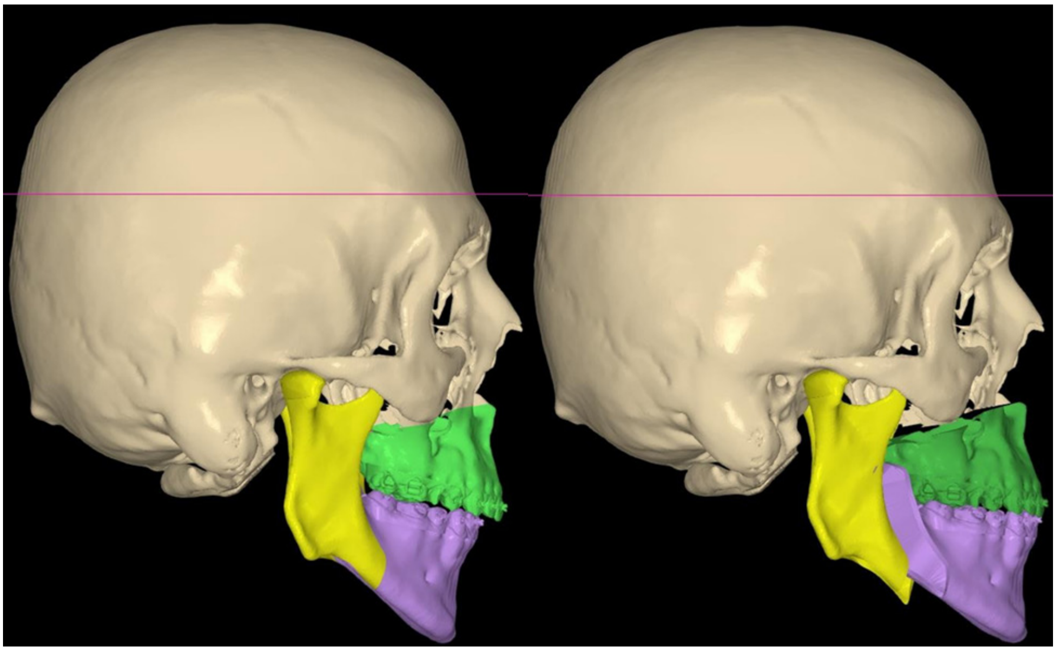


Digital planning has greatly enhanced the precision of identifying airway obstructions in patients with OSAS and other respiratory conditions. By visualizing the specific sites of obstruction, surgeons can tailor their interventions to address these critical areas directly, avoiding unnecessary tissue manipulation. This targeted approach ensures that both functional and aesthetic aspects are addressed, leading to more effective treatment outcomes (Abramson et al., 2010).

It also enables a more refined surgical strategy by clearly identifying obstruction points. Each intervention can be adapted to the patient's unique needs, ensuring that the procedure improves respiratory function and facial aesthetics. Digital tools that support precise mapping of airway structures help maintain or improve airway patency in the long term. This patient-centred approach prioritizes airway health and maximizes the effectiveness of orthognathic surgeries, especially for those at risk of respiratory obstruction (Christino et al., 2021; Vidal-Manyari et al., 2022).

Maxillomandibular advancement and counterclockwise rotation (CCWR) of the maxillomandibular complex significantly enhance airway patency, a crucial benefit for OSAS patients. However, advancing the jaw structures excessively can result in compromised facial aesthetics, especially for those without inherent dentofacial deformities (Brevi et al., 2011; Knudsen et al., 2015; Yu et al., 2017).

Figure 7
Simulation of maxillomandibular counterclockwise rotation



Digital planning and simulation are essential to achieve an optimal balance, allowing the surgical team to predict aesthetic outcomes while addressing functional needs. For OSAS patients with or without dentofacial deformities, these tools ensure that both the airway and facial profile are considered, ultimately reducing complication risks and enhancing overall treatment effectiveness (Farrell et al., 2014; Piombino et al., 2022).

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Developments in the Use of Natural Wound-Healing Drugs in Veterinary Medicine

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Introduction

Plants Used in Wound Healing in Animals

With the advancement of technology, significant progress has been made in the pharmaceutical sector in treating diseases of different types. However, excessive use of medications has also led to issues such as the accumulation of unwanted substances in organs and similar problems. Today, despite all these various medications, the emergence of new diseases that cannot be treated has led scientists to search for more natural and additive-free treatment methods using extracts obtained from different parts of plants. This has resulted in the birth of phytotherapy. Recently, dietary supplements and various supportive products developed through phytotherapy have been commonly used for preventive purposes rather than treating diseases.

Phytotherapy is based on using herbal medicines to treat and prevent diseases in humans and animals. The practices of phytotherapy are quite ancient; the first written document related to phytotherapy can be found in the Ninive tablets belonging to the Sumerian, Akkadian, and Assyrian civilizations established in Mesopotamia around 3000 BC. It is known that these tablets mention the use of plant and animal-derived substances in the treatment of various diseases. During the Islamic civilization period, Ibn Sina and Al Gafini wrote significant works on herbal medicine(Calapai, 2015; Ferreira et al., 2014; Günergun & Etker, 2013).

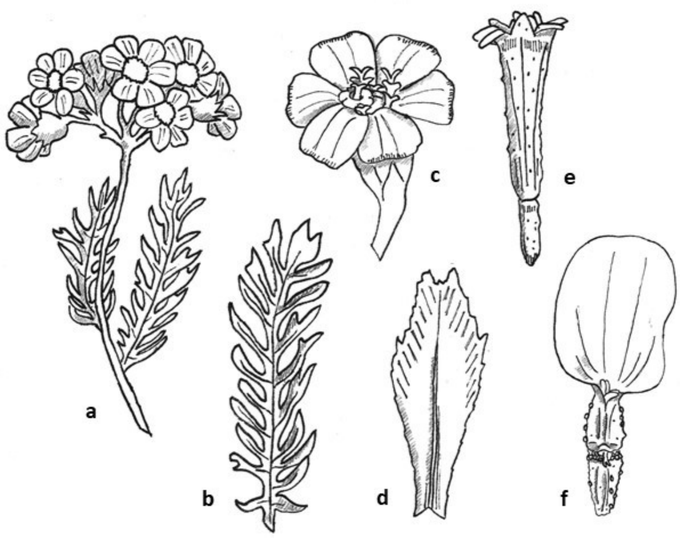
Plant and herbal materials hold an important place within veterinary phytotherapy practices. Some bioactive chemical compounds synthesized by plants have medical effects(Schlittenlacher et al., 2022; Tchetan et al., 2021; YİPEL et al., 2021). The medicinal properties of plants used in phytotherapy stem from the numerous active compounds within the plant kingdom. Often, these active substances extracted from plants are equivalent to synthetic drugs in terms of their therapeutic effects; therefore, they are primarily used in veterinary medicine as antibacterial, antifungal, antiparasitic, disinfectant, and immunostimulant agents (Severino et al., 2008; Yanar, 2022). Additionally, herbal medicines are also utilized to avoid potential side effects that may arise from the long-term use of synthetic drugs and to treat certain chronic diseases. As a result, Severino et al. (2008) state that phytotherapy is a beneficial support for traditional treatments in cases of severe illness(Severino et al., 2008). In veterinary medicine, plants have been used for various purposes throughout history. The plant *Urtica dioica* is used to stimulate egg-laying in chickens, *Scrophularia canina* is utilized for wound antisepsis in cattle, and *Sempervivum tectorum* is employed to accelerate digestion in calves. A study conducted on cows with endometritis reported that plants were more effective than antibiotics (Sharma et al., 2018). A study conducted on dogs with pyoderma, atopic dermatitis, otitis externa, wounds, and dermatophytosis reported the utilization of *Calendula officinalis* L. (Marigold), *Hypericum perforatum* L. (St. John's Wort), Matricaria chamomilla L. (syn. Matricaria recutita L., Chamomile) and *Salvia officinalis* L. yield positive results for their broad-spectrum antibacterial and antifungal effects(Tresch et al., 2019).

Wound healing in veterinary medicine often utilizes various plants, including **gotu kola**, **aloe vera**, **tea tree oil**, and **St. John's wort**. However, more clinical research is needed to establish the safety and efficacy of these herbal treatments (Gölgeli Bedir and Turgut, 2021). In this section, information will be given about the use of various plants in wound healing in animals:

Achillea millefolium (Yarrow)

Achillea millefolium, also known as "Sarısabır" (Yarrow), is a perennial flowering plant with wound-healing properties since ancient times; and has been used for medicinal purposes because of its anti-inflammatory, antimicrobial, and hemostatic effects (Figure 1)

Figure 1
Botanical line drawings of Achillea moschata Wulfen: (a) Plant in toto. (b) Bipinnate leaf. (c) Flower head. (d) Involucral bract (e) disk floret (f) ray floret. Original drawings by L. Colombo.(Bottoni et al., 2022).



Yarrow includes crucial phytochemical compounds like flavonoids (quercetin, luteolin, etc.) that have antioxidant properties and help reduce oxidative stress. These compounds prevent tissue damage by fighting free radicals and promote cell regeneration (Akbar, 2020). Another compound, sesquiterpenes, has antimicrobial and anti-inflammatory properties that reduce the risk of infection and speed up wound healing. Sesquiterpenes also reduce inflammation in the skin, allowing tissues to repair more quickly (Geana et al., 2023). Volatile oils such as 1,8-cineole and α-pinene help prevent wound infections and regenerate tissue. As can be seen, the rich content of yarrow supports its ability to be a powerful wound healer (Tadić et al., 2017).

In the literature, *Achillea millefolium* has been supported by its wound-healing effect. In ancient times, soldiers used the plant to treat wounds and stop bleeding. It has been confirmed that the plant's anti-inflammatory and antimicrobial properties support this effect (Grigore et al., 2020). The control of inflammation is a critical factor in wound healing. Yarrow suppresses increased inflammation and allows tissues to heal faster(Ngo et al., 2020). The environment surrounding the wound is kept clean and sterile to facilitate optimal wound healing. Yarrow also contributes to the acceleration of wound healing by reducing the risk of infection of its antimicrobial properties. Studies have shown that the plant's antibacterial and antifungal properties are particularly effective in preventing infections (Zakeri et al., 2020). While the popularity of herbal treatments is increasing, yarrow is used in alternative medicine for wound treatment in animals (Jarić et al., 2018). The plant, which can be used as a natural support for skin injuries, cuts, and post-operative healing, has properties that prevent wounds from getting infected and reduce inflammation (Frański & Beszterda-Buszczak, 2023; Villalva et al., 2023). Yarrow is usually applied topically to wounds as an infusion or tincture. It has been observed that inflammation and infection are reduced on the wound surface where the plant is practical. It has been observed that wound healing time is reduced and inflammation is controlled in animals (cats and dogs) to which yarrow is applied (Ercil, 2017; Tresch et al., 2019; Uyar, 2017).

Aloe vera (L.) Burm (Syn: *Aloe barbadensis* Miller)

Aloe vera; belongs to the Asphodelaceae (Liliaceae) family and is a shrubby or tree-like, perennial, succulent, and pea-green colored plant (Figure 2) (Surjushe et al., 2008). *A. vera* has been the focus of extensive scientific research regarding its wound-healing properties.

Figure 2
Aerial parts of A. vera (Kumar et al., 2019)

Several studies indicate that it may facilitate the wound-healing process through many different mechanisms. *Aloe vera* has been shown to reduce inflammation; and stimulate fibroblast proliferation, collagen synthesis, wound contraction, re-epithelialization, and angiogenesis. Furthermore, it has been shown to stimulate the production of growth factors, including transforming growth factor-β1 (TGF-β1) and vascular endothelial growth factor (VEGF), at the wound site (Kaewsrisung et al., 2021) Additionally, it has been documented to have antimicrobial properties that facilitate these mechanisms (Jawad, 2014). Furthermore, aloe vera has been shown to accelerate wound healing by increasing collagen synthesis, influencing fibroplasia, and reducing wound size (Razi et al., 2021; Tariq et al., 2021). AL-Dhamary et al. (2024) reported that treatment with *A. vera* gel may result in faster wound healing compared to routine treatments (AL-Dhamary et al., 2024). Findings of studies conducted by Sutrisno (2024), Mara (2022), and Ali (2023) have shown that it has been used in multiple forms including gel, extract, and cream to accelerate the healing process of wounds (B. G. Ali et al., 2023; Dilla Sastri Mara, 2022; Sutrisno et al., 2024). The gel form has been associated with improved outcomes in terms of epithelialization rate and burn wound healing compared to conventional treatments such as silver sulfadiazine cream (Mohamad-Abadi et al., 2023). All studies support that it has the potential to serve as a natural and effective treatment to promote wound healing through its anti-inflammatory, antimicrobial, and collagen-stimulating effects.

Aloe vera has been recognized for its therapeutic activity in veterinary medicine because of its antimicrobial effects, making it an effective topical agent for managing wounds in animals (Jawad, 2014). Moreover, studies have shown that its secondary metabolites can promote wound-healing effects in various animal models, highlighting its potential for use in the veterinary field (Kusmardi et al., 2019). Hydrogel has been shown to increase the number of fibroblasts in socket wounds after tooth extraction in animals, confirming its positive effect on wound healing (Silvi Tiara Dewi & Susanto, 2021). Moreover, studies have shown that fresh and commercial gel can exhibit anti-inflammatory effects by reducing inflammatory mediators such as IL-6, thereby facilitating wound healing in animals (Mohamad-Abadi et al., 2023). The combined application of gel and microcurrent has been suggested as an effective treatment for open wounds in animals, highlighting the potential benefits of this approach in wound healing (Mendonça et al., 2009).

A study conducted by Drudi et al. (2018) evaluated the efficacy of this plant and silver sulfadiazine creams in promoting secondary wound healing in dogs and cats (Drudi et al., 2018). Aloe vera is renowned for its anti-inflammatory and antimicrobial properties, attributed to its bioactive compounds, including polysaccharides and vitamins. The study showed that *A. vera* facilitates the processes of epithelialization, collagen synthesis, and granulation tissue formation, thereby promoting a faster wound healing process. Furthermore, it has been shown to reduce inflammation and maintain a moist wound environment, thereby facilitating the healing process (Drudi et al., 2018). Traditionally used to prevent infections, the antimicrobial effects of silver sulfadiazine were found to be less effective in promoting wound healing, particularly in the epithelialization and scar formation processes, compared to *Aloe ver*a. The trial showed that there was a statistically significant reduction in the size of wounds treated with Aloe vera and that it provided a more effective healing process. This effect is said to be related to the capacity of *A. vera* to increase localized blood flow and stimulate fibroblast and keratinocyte proliferation, which are crucial for tissue repair (Drudi et al., 2018). When Atiba et al. (2014) evaluated the healing efficacy of *Aloe vera* and silver sulfadiazine in the treatment of deep second-degree burns in dogs, they showed that *A. vera* was highly effective in promoting accelerated healing, particularly in terms of epithelialization and reduction of inflammation. Besides, its treatment in dogs was found to result in faster wound closure and superior quality tissue repair compared to silver sulfadiazine treatment (Atiba et al., 2014).

Another study examined the effects of topical *Aloe vera*, honey, and the combination of both on wound healing in goats, resulting in the lowest bacterial counts, followed by *Aloe vera* treatment and combination treatment. Histopathological examination revealed that *A. vera* provided rapid tissue repair, complete wound contraction, and complete epithelialization compared to the other groups. Therefore, it can be concluded that *Aloe vera* L. alone is the most effective in promoting wound healing, followed by the combination of honey and honey alone (Roy et al., 2022).

Research on *A. vera* in veterinary medicine demonstrates its potential for therapeutic applications in promoting wound healing, reducing inflammation, and improving animals' health. Most studies support using *A. vera* as a valuable natural remedy in veterinary practice.

Calendula officinalis L. (Marigold)

Calendula officinalis, a member of the Asteraceae family, is one of the economically important ornamental plants grown worldwide (Figure 3). It blooms in yellow, red, orange, and brown. *C. officinalis* L., commonly known as marigold, has long been recognized for its medicinal properties, particularly in the field of wound healing (Verma et al., 2018). Native to Central and Southern Europe, Western Asia, and the United States, this plant has been a cornerstone of traditional medicine for centuries. Recent scientific studies have further confirmed its therapeutic potential, making it a major topic of interest in contemporary medical research (Ashwlayan et al., 2018).

Figure 3
Calendula officinalis. (Zhang et al., 2024).

In ethnoveterinary medicine, the use of medicinal plants such as *Calendula officinalis* for animal diseases is well documented. (Masika et al., 2000). Moreover, studies on herbal medicines from various regions such as Yemen have revealed the potential of plants such as *C.officinalis* and significantly succeeded in wound healing for animals (Alasbahi & Groot, 2020) ; Preethi & Kuttan, 2009). Flower extracts have strong anti-inflammatory, antimicrobial, and regenerative properties (Baghdadi et al., 2020; Patil et al., 2022), making them an excellent choice for treating wounds and skin conditions in animals (Chroho et al., 2021; Parente et al., 2012). These properties have made calendula-based treatments valuable for veterinary care and offer natural alternatives for healing.

The therapeutic effects of *Calendula officinalis* are due to its rich phytochemical content, including carotenoids, flavonoids, and triterpenoids, which contribute to its medicinal properties (Verma et al., 2018). These compounds are responsible for reducing inflammation and supporting tissue repair, because of their antioxidant effects. Topical applications of *C.officinalis* preparations have been found to enhance wound healing, accelerate re-epithelialization, and granulation tissue formation (Verma et al., 2018).

Flower extracts of the *Calendula officinalis* have stimulated tissue granulation in wounds. This process modulates and facilitates the expression of two important proteins, connective tissue growth factor (CTGF) and α-smooth muscle actin (α-SMA), in the affected area (Shedoeva et al., 2019). In addition, it promotes wound healing by increasing the number of fibroblasts and collagen synthesis (de S Moraes et al., 2019; Dinda et al., 2015; Nowak-Terpiłowska et al., 2023). It has been reported that *C. officinalis* has a positive effect on angiogenesis, the formation of new blood vessels, which is crucial for tissue repair and wound healing (Dinda et al., 2016; Nahar & Choubey, 2024). This targeted treatment has proven effective in veterinary clinics for skin conditions such as surgical wounds, cuts, and ulcers.

Interestingly, using *C. officinalis* in combination with other herbal extracts has been shown to have even greater potential for wound care. Polyherbal formulations containing Calendula have been shown to accelerate the wound healing process by promoting fibroblast and keratinocyte proliferation and increasing angiogenesis at the injury site (Talekar et al., 2017). This synergistic interaction between different herbal extracts offers a natural and powerful approach to wound management, highlighting the effectiveness of such treatments for animals. Da Silva Ferreira et al. (2022) analyzed the phytotherapy compound's clinical and histological effects on surgical wounds in female dogs. This compound, containing *Calendula officinalis*, *Aloe vera*, *Symphytum officinale*, *Vitis vinifera*, D-Panthenol, and Denatonium Benzoate®, has shown promising results in veterinary postsurgical care. Reduced inflammation, rapid wound healing, and improved appearance of wounds were noted in treated dogs (da Silva Ferreira et al., 2022).

In another study, it has been found that a 2% non-ionic *Calendula officinalis* cream was used to treat a significant laceration wound in a young Quarter Horse, facilitating the healing process (Boscarato et al., 2020). This result is consistent with the broader scientific literature suggesting that Calendula extracts have anti-inflammatory and wound-healing properties that may be useful in treating equine wounds. It has been used to treat hoof-related wounds and infections in animals (cattle, goats, sheep, and pigs) (Walkenhorst et al., 2019). It has been reported that calendula-based creams and ointments are frequently used to treat external wounds, especially on animal hooves. This effect is due to the plant's active secondary metabolites, including triterpenoids and flavonoids, which facilitate tissue regeneration and reduce inflammation. The presence of antimicrobial properties of *C. officinalis* L. during wound healing also helps reduce the risk of infection and dependence on synthetic antibiotics, which is crucial in combating antimicrobial resistance (Walkenhorst et al., 2019).

As a result, this plant has been identified as a valuable natural medicine in veterinary wound care, characterized by its capacity to stimulate fibroblast proliferation, promote angiogenesis, reduce inflammation, and accelerate healing. Calendula's long history in traditional medicine, supported by modern scientific evidence, positions it as a promising herbal alternative for treating animals.

Centella asiatica (Gotu Kola)

Centella asiatica (Gotu kola), is a thin-stemmed, green-colored, leafy plant that grows in many temperate and tropical swamps in the world (Figure 4). It is a medicinal plant known in traditional medicine for its wound-healing, anti-inflammatory, and antioxidant properties. This plant, which is widely used in Southeast Asia, is also frequently used in wound treatment, skin regeneration, and anti-inflammatory treatments in modern medicine(Orhan, 2012).

Figure 4
Centella asiatica (L.) Urban (Apiaceae) (Orhan, 2012).

The wound-healing properties of *Centella asiatica* are due to its triterpenoids (asiatic acid, madecassic acid and asiaticoside). These components increase collagen production by promoting fibroblast proliferation and accelerate tissue repair. It has been stated that *Centella asiatica* accelerates the wound-healing process with its asiaticoside content and exhibits healing effects at the cellular level. Animal studies have reported that *Centella Asiatica* extract significantly increases wound closure and epithelialization processes(Shukla et al., 1999).

C. asiatica has an anti-inflammatory effect during the wound healing process. Triterpenoid components suppress inflammatory response by regulating macrophage and fibroblast activity. It has been observed that the triterpene components of the plant play an important role in suppressing inflammation and accelerating wound-healing (James & Dubery, 2009). Additionally, this mechanism reduces discomfort and inflammation, facilitating the healing of damaged tissue.

In addition, *Centella asiatica* contains powerful antioxidants that reduce oxidative stress. Components such as asiatic acid and madecassic acid neutralize free radicals and prevent cellular damage during the wound-healing. It has been stated that antioxidant compounds increase collagen synthesis, renew skin tissue, and help scars become less visible (Bonté et al., 1995). The synthesis of collagen represents a crucial stage in the wound healing process. The plant *Centella asiatica* has been demonstrated to facilitate the strengthening of injured tissue by accelerating this process. Studies have shown that *Centella asiatica* increases collagen production on fibroblasts and helps wound tissue repair more rapidly. This effect is thought to be especially important in reducing scar tissue (Maquart et al., 1990).

Veterinarians use this valuable plant for skin conditions such as burns, psoriasis, and eczema besides wound-healing treatment in clinics for dogs and cats. Triterpenoid components play an important role in their mechanisms. The use of the plant is increasing especially in reducing scars after surgery (Brinkhaus et al., 2000).

Controlling inflammation after injuries and surgical operations in animals is crucial for accelerating healing. *C. asiatica* is used especially in clinical applications in cats and dogs, especially after surgical interventions or traumatic injuries. For example, it is applied in the form of herbal ointment or topical cream for faster healing of stitches after surgical intervention, minimizing scars, and reducing inflammation and swelling around the wound (Ro et al., 2021). *C. asiatica* has been shown to regulate inflammatory responses, thereby relieving localized edema and pain in the wound area. James and Dubery (2009) emphasized the effects of *Centella asiatica* in reducing inflammation and stated that triterpenoid compounds accelerate cellular repair by suppressing inflammation (James & Dubery, 2009).

Controlling inflammation after injuries and surgical interventions in commercially valuable horses is becoming a critical part of the healing process, because of *Centella asiatica's* triterpenoids. Wounds can become infected and the healing process can be slowed down and prolonged due to horse mobility. Topical use of *Centella asiatica* on wounds can reduce these risks and accelerate the wound closure process (Girma et al., 2024).

C. asiatica has gained an important place in both traditional and modern veterinary medicine with its wound-healing potential. Scientific research strongly supports its contributions to wound-healing processes in animals. Also, its use in burns, scars, and tissue regeneration is becoming increasingly widespread in clinical applications.

Hypericum perforatum L**.**

It is a perennial herbaceous plant with a 30-80 cm height blooms bright yellow flowers between May and September (Figure 5).

H. perforatum (St. John's wort), is known for its wound-healing properties attributed to its various bioactive components such as naphthodianthrones, flavonoids, and phloroglucinols. These compounds have been shown to exhibit several pharmacological activities that contribute to the wound healing process, including anti-inflammatory, antimicrobial, and antioxidant effects (M. Ali et al., 2018; Seyhan, 2020; Yadollah-Damavandi et al., 2015). Several key areas are categorized to promote wound healing, such as improving cellular processes, modulating inflammation, and antimicrobial action for mechanisms belonging to *Hypericum perforatum*.

Figure 5
Hypericum perforatum (St. John's wort) (Suryawanshi et al., 2024)

Hypericum perforatum extracts have been shown to significantly facilitate fibroblast migration, a critical process for wound closure (Hostanska et al., 2012; Süntar et al., 2010). For example, Süntar et al. (2010) showed that the oily extract of *Hypericum* *perforatum*, rich in hyperforin, promoted fibroblast migration without significantly affecting proliferation rates(Süntar et al., 2010). Additionally, Ali et al. (2018) reported that a niosomal topical drug delivery system containing *Hypericum perforatum* showed the potential to improve collagen synthesis in wound healing models(M. Ali et al., 2018).

H. perforatum is a plant used in traditional medicine for centuries to facilitate wound healing and treat injuries in animals. The anti-inflammatory and tissue repair properties have shown high efficacy in treating wounds and injuries. It has been one of the medicinal plants used as an alternative to allopathic drugs in organic agriculture, especially within certified organic programs. *Hypericum perforatum* is frequently used together with other plant species such as *Symphytum officinale* and *Calendula officinalis* for the treatment of various conditions, including abscesses and skin injuries (Lans et al., 2007).

In the study conducted by Ali et al. (2018), *Hypericum perforatum* extract, standardized for compounds such as hyperforin and hypericins, was applied with niosomal gel in treating of wounds in dogs. This gel; prepared using 80% ethanol extract and niosome technology, showed significant wound healing effects in an in vivo test in dogs. The reduced inflammation targeted for healing, accelerated proliferative rate, and complete wound' re-epithelialization within 21 days were achieved. In addition, these results were more effective than the results observed in the control and panthenol cream groups, indicating that *H. perforatum* has the potential to be used in transdermal wound treatments(M. Ali et al., 2018). Carnevali et al. (2019) evaluated the efficacy of a plant-based formulation containing neem oil and *Hypericum perforatum* extract in healing wound myiasis in domestic animals. Wounds caused by *Wohlfahrtia magnifica* larvae healed within 10 to 32 days without further infestation or bacterial complications and without using any antibiotics or disinfectants. The natural formulation was effective in treating wounds and promoting healing without toxic side effects and was presented as a safer alternative to creolin and insecticides (Carnevali et al., 2019).

The study conducted by Markovic et al. (2021) investigated the ethnopharmacological applications of medicinal plants in Pirot County, Eastern Serbia. In interviews with 631 local residents, a total of 192 plant species were frequently used, 46 of which were used in veterinary medicine. The most commonly used plants include *Cichorium intybus*, *Hypericum perforatum*, and *Rumex patientia*, primarily used to treat diarrhea, wounds, skin conditions, and fever in farm animals. The most commonly used plant families are *Asteraceae*, *Hypericaceae,* and *Polygonaceae*. The findings provide valuable insights for potential phytopharmacological studies in veterinary care(Marković et al., 2021).

Melaleuca alternifolia (Maiden & Betche) Cheel (Tea Tree)

Melaleuca alternifolia oil (Tea Tree; Çay ağacı), is an essential oil known for its antimicrobial, antifungal, and anti-inflammatory properties. This oil has recently been applied clinically by veterinarians for various skin problems and wound treatments in cats and dogs. However, it should be used with caution due to toxicity.

Tea tree oil is an essential oil derived from the *M. alternifolia*, which is native to Australia and can grow up to 5-7 meters tall and is in the form of a shrub (Figure 6). Due to its strong antiseptic effect and wide range of use, it is exported. Fresh leaves and branch tips collected from plants during the flowering period are used to obtain essential oil (Sürme et al., 2020).

Figure 6
Tee tree (*Melaleuca leucadendra*) (Köhler, n.d.)

Tea tree oil has been used in traditional medicine for centuries in various forms, especially for antiseptic purposes (Gölgeli Bedir and Turgut, 2021). Tea Tree Oil has a broad-spectrum antimicrobial effect, especially in this way the terpinen-4-ol and α-terpineol components it contains. Studies have shown that Tea Tree Oil is effective against bacteria such as *Staphylococc*i and *Streptococci* and is used in skin infections in dogs (Fitzi et al., 2002). The positive effects of tea tree oil have been shown in frequently seen skin diseases such as pyoderma. It significantly reduces symptoms of pruritus, erythema, pustules, abscesses, crusting, irritation, alopecia, and skin thickening (Szewczuk et al., 2023). In an open, multicenter study of 53 dogs with chronic dermatitis and pruritus, when 10% tea tree oil cream was applied twice daily for 4 weeks, veterinarians observed a good or very good response in 82% of the dogs, a moderate response in 7.8%, and an inadequate response in 9.8%. At the end of the study, a strong and significant reduction in symptoms was observed (Fitzi et al., 2002). When a 10% tea tree cream was applied twice daily to a dog with localized pruritic dermatitis, 71% of the animals treated with tea tree oil cream had relief from pruritus and alopecia after 10 days (Reichling et al., 2004). The antifungal effect of this oil provides relief from redness and itching that occur on the skin in fungal infections. Veterinarians use it topically, especially in cases of dermatitis caused by fungi such as **Malassezia pachydermati*s* and *Microsporum canis* (Tong et al., 1992). Another study reported that tea tree oil is also effective against fungal infections and has been used successfully against *Malassezia* and *Dermatophytes* species, especially those common in cats and dogs (Weseler et al., 2002). The anti-inflammatory properties of tea tree oil facilitate the alleviation of inflammatory reactions on the skin. The topical application of tea tree oil in the treatment of wounds has been demonstrated to reduce inflammation and contribute to the acceleration of skin tissue renewal (Koh et al., 2002). Tea Tree Oil, applied topically by veterinarians during the healing process after surgical procedures in cats and dogs, can help prevent wound infections and support rapid healing tissue (Fitzi et al., 2002).

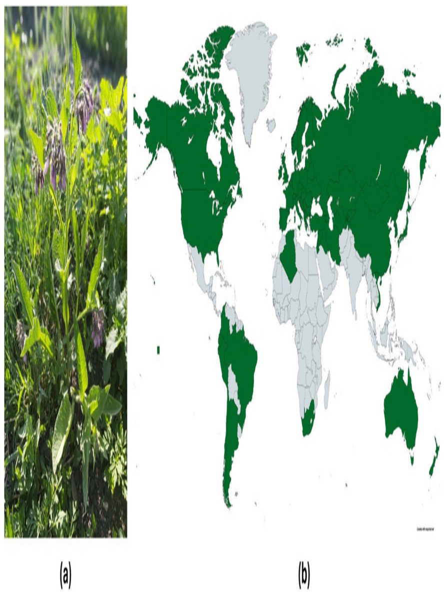
Although Tea Tree Oil has strong antimicrobial and anti-inflammatory properties, it should be used carefully, especially in cats. This plant can cause toxicity in case of excessive exposure or incorrect use during use in animals (Khan et al., 2013). Using this oil in high doses or undiluted in cats can cause neurological toxicity, ataxia, drooling, depression and, even coma. A study has shown that cats are sensitive to tea tree oil and that toxic effects can occur even at low doses (Bischoff & Guale, 1998; Elliott & Seawright, 1993). In another study conducted on cats, a topical application of 100% tea tree oil was performed on Ankara cats and the cats experienced hypothermia, decreased coordination, and tremors. The study determined that the cats' liver enzymes were elevated. The accumulated urine from the cats was positive for terpinen-4-ol, a component of tea tree oil. One cat was reported to have died in this study (Bischoff & Guale, 1998). In dogs, this oil is generally considered safe when used in a controlled manner. However, veterinarians recommend that the oil be diluted correctly and used only at certain concentrations. Typically, 1-2% diluted solutions are considered safe for topical applications (Helton & Werner, 2018). In a study, it was determined that the undesirable symptoms in dogs applied with pure tea tree oil were depression, lethargy, apathy, paresis, weakness, ataxia, tremors or muscle twitching, and rarely vomiting, coma, lying in a horizontal position, dermatitis, pruritus or rash, and elevated liver enzymes (Khan et al., 2013). Death occurred when 0.3-0.4 ml of tea tree oil was accidentally administered intravenously to an English shepherd dog. In another study conducted on dogs, 28.5 ml of pure tea tree oil was applied through the skin, and after the 3rd dose, the dog became ataxic and died (Khan et al., 2013). When 7 to 8 drops of tea tree oil were applied undiluted as a flea repellent, partial paralysis of the hind legs, ataxia, and depressive behavior were observed in dogs (Poppenga, 2007).

Tea tree oil is an effective natural treatment agent for dermatological problems, skin infections, and wound healing in cats and dogs. However, it should be used with caution in cats due to the risk of toxicity. Diluted forms are considered safe by veterinarians for topical application. Overdosage should be avoided and caution should be given to cat and dog relatives about the careful use of the oil.

***Symphytum officinale* L. (Comfrey)**

Symphytum officinale is a perennial flowering plant from the Boraginaceae family (Figure 7). It can bloom in blue, purple, pink or white. (Trifan et al., 2024) Comfrey (*S. officinale*) is traditionally recognized for its wound-healing properties, which are attributed to its anti-inflammatory, and analgesic effects and its capacity to stimulate tissue regeneration and promote wound healing (Le et al., 2021).

Figure 7
Symphytum officinale (Photo by Adriana Trifan) (Trifan et al., 2024)



The plant has a long history of therapeutic use, with records dating back to the 16th century, particularly for improving wound healing (Gomes et al., 2010). Comfrey is renowned for its efficacy in treating various types of wounds, bone fractures, and bruises in traditional medicine (Bagheri et al., 2021). The root extract of the plant has been found to exhibit anti-inflammatory effects by influencing NF-κB signaling, which can help reduce inflammation in wounds, and is widely used for the management of musculoskeletal disorders, wound healing, and inflammatory conditions (Seigner et al., 2019). The wound-healing properties of comfrey (*Symphytum officinale*) have been recognized in the veterinary field. Several studies have shown that comfrey root preparations, known for their analgesic and anti-inflammatory properties, can facilitate wound healing in animals (Yang et al., 2011). The anti-inflammatory and analgesic effects of the plant, together with its ability to stimulate tissue regeneration, make it a valuable natural remedy for wound management in veterinary practice (Inkeniene Asta Marija & Vaiciuleviciene, 2023). Bioactive compounds found in comfrey, including allantoin, choline, and rosmarinic acid, are responsible for the anti-inflammatory and wound-healing effects observed in this plant (D'urso et al., 2020; Kučera et al., 2004). These compounds contribute to the plant's capacity to reduce inflammation and facilitate tissue repair (Kučera et al., 2004). Topical application of the plant's roots has been shown to reduce inflammation (Dähnhardt et al., 2020). In addition, comfrey has been used in folk medicine as an externally applied poultice to facilitate wound healing (Melnyk et al., 2022). Its effectiveness in this regard is attributed to its capacity to accelerate superficial wound healing. The therapeutic properties of comfrey include anti-inflammatory, analgesic, granulation-promoting, and anti-exudative effects. Comfrey-based treatments such as herbal creams can offer a natural and effective approach to managing wounds and promoting healing in veterinary medicine.

Other Herbs

Mathan Thailam is formulated using a blend of *Acalypha indica*, *Datura metel*, and Coconut oil besides copper sulfate, known for its wound-healing properties. The inclusion of copper sulphate in certain formulations is noteworthy because copper is a vital component in angiogenesis, collagen synthesis, and stabilization of extracellular matrix proteins. These processes are essential for effective wound healing (K et al., 2019). The anti-inflammatory properties of Mathan Thailam contribute to the reduction of swelling and pain observed at the wound site. This is especially advantageous for chronic wounds where inflammation can hinder healing. Moreover, the herbal components of Mathan Thailam have been shown to exhibit antimicrobial activity, which helps prevent infection, a common complication in wound healing (Selvaraju et al., 2022).

In a recent study, Selvaraju et al. (2022) demonstrated that Mathan Thailam was effective in addressing post-cesarean wound dehiscence in a Kangayam cow with uterine torsion (Selvaraju et al., 2022). After the surgical procedure, the cow exhibited a significant postoperative complication of reopening of the surgical wound and subsequent infection. Conventional methods used to re-seam the wound were unsuccessful due to the wideness of the opening. Mathan Thailam was applied topically for five days after regular wound cleaning. The wound was found to show significant healing with granulation tissue formation and after one month, the cow's wound was completely healed. Researchers have mentioned the potential of Mathan Thailam as an alternative treatment in veterinary care, especially for chronic or post-operative wounds, and have also highlighted its rejuvenating properties ((Selvaraju et al., 2022).

Although papain, an enzyme derived from papaya, is well documented in human medicine for its wound-healing properties, its applications in veterinary medicine have not yet been widely explored.

It has been investigated the effectiveness of natural remedies, including papain gel and sunflower oil, in treating severely necrotic wounds in dogs (Porsani et al., 2016). The study included three cases in which dogs with extensive necrotic wounds were treated with papain-gel accelerated healing by promoting tissue granulation, debridement of necrotic tissue, and overall faster healing. In one case, sunflower oil, known for its anti-inflammatory and antimicrobial effects, was also used to support healing. In addition to being effective, these treatments are low-cost and accessible alternatives for wound management in animals (Porsani et al., 2016). Orlandini et al. (2017) described the use of papain cream and lyophilized parsley root extract (*Petroselinum crispum*) in the treatment of an abscess caused by a multiresistant *Escherichia coli* strain in a horse (Orlandini et al., 2017). Papain, a proteolytic enzyme, is renowned for its wound healing and anti-inflammatory properties, while parsley root extract is known for its antimicrobial activity. The combination of these two natural drugs was effective against the resistant bacterial strain when applied to the infected area of the horse. The treatment resulted in a significant reduction in infection and inflammation, thus demonstrating the potential of these alternative therapies in the management of difficult bacterial infections in veterinary medicine (Orlandini et al., 2017).

In conclusion, the resurgence of interest in phytotherapy serves to highlight the potential of plant-based treatments in veterinary medicine. As evidenced throughout history and corroborated by recent research, plants and their bioactive compounds represent a natural and effective alternative to synthetic drugs for managing various conditions, including wound healing. The utilization of plants such as *Calendula officinalis*, *Hypericum perforatum*, and *Aloe vera* highlights their potential as antibacterial, antifungal, and anti-inflammatory agents with minimal adverse effects. While traditional knowledge provides a robust foundation, modern scientific validation is imperative to optimize the utilization of phytotherapy in veterinary medicine. This includes conducting rigorous clinical trials to establish efficacy, standardize dosages, and ensure safety. Enlargement of our understanding of plant-based treatments will not only enhance their integration into veterinary practice but also provide sustainable and additive-free solutions to the growing challenges posed by drug resistance and synthetic medication side effects. There is a need to screen for new plants, many of which have especially antimicrobial, anti-inflammatory, analgesic, and antioxidant effects for wound treatment in the future. Consequently, the continued exploration of veterinary phytotherapy promises significant benefits for animal health and the broader ecological balance.

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The Role of Polgün in the Historical Development of Water Slides

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Introduction

Purpose and Problem of the Research

This research aims to examine the historical development, status, and potential future innovations of water slides and amusement park equipment. Evaluating the role and contributions of Polgün, one of the leading companies in the sector, is also part of this purpose. The main problem of the research is how to more effectively manage factors such as safety, durability, user satisfaction, and environmental impacts in the design and production of water slides and amusement park equipment, how to apply innovative solutions and technologies in the sector, and how to overcome the challenges faced by companies in this field. The research also aims to provide guiding suggestions to the stakeholders in the sector by presenting successful examples in the sector and the strategies of leading companies such as Polgün for these problems.

Research Model

This research will use a descriptive research model that examines the historical development, current situation, and future innovations in the water slides and amusement park equipment industry. The research model will analyze the practices and strategies of the leading companies in the sector, especially Polgün, by using qualitative and quantitative data collection methods together.

Research Questions

General Introduction of Water Slides

Water parks are unique entertainment venues designed with the needs of people of all age groups in mind, where the community spends time together having fun with various water activities (Yerli & Aykut, 2021). These types of parks combine the refreshing and fun atmosphere that the water has to offer, allowing families and groups of friends to make unforgettable memories. Among the most popular and indispensable attractions of water parks are water slides. Each slide has been carefully designed to offer visitors a unique adventure. In the design of the slides, many factors are taken into consideration, such as slope, water flow, the need for safety barriers, cornering conditions, and the necessity of skiing without or with boots (Water slide, 2024). These factors are meticulously calculated and applied to ensure that the slides provide a safe and enjoyable experience.

Water slides are designed and manufactured by international and local safety standards. Each slide is designed to be fully compliant with the requirements and safety protocols set by the countries. In this way, the safety of visitors is kept at the highest level, and possible accidents are prevented. Well-designed and safe slides make it one of the most exciting and popular parts of water parks, contributing to making memories that visitors will want to return to again and again.

Water parks are places where people of all ages can enjoy their time and enjoy the fun of water with the various water activities and fun areas they offer. These parks both encourage physical activity and help holidaymakers relieve stress with the calming effect of water. This multifaceted attraction of water parks makes them among the indispensable holiday destinations of the summer months.

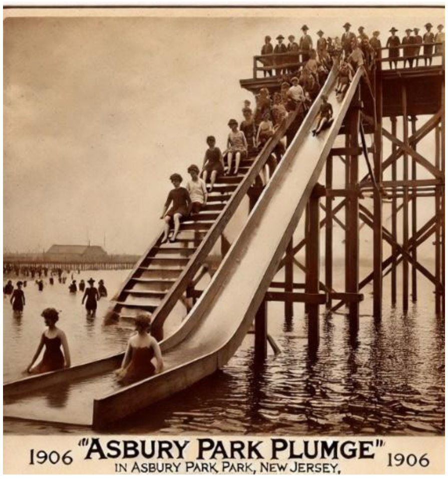
Examples of the First Water Parks in History

Asbury Park, New Jersey, ABD (1906)

The origin of water slides dates to the early 20th century. The first water slide was installed in Asbury Park, New Jersey, United States in1906. This slide became one of the popular entertainment venues of the period and laid the foundation for water slides. The image of the History of the Asbury Park Boardwalk course is shown in Figure 1.

Figure 1

History of the Asbury Park Boardwalk

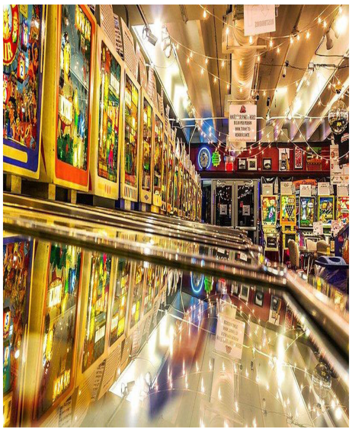


Founded in 1871 by James Bradley, Asbury Park began as a world-class facility (Asbury Park Boardwalk, 2024). Despite the various problems of the period, the decline in tourism did not prevent the city from maintaining its unique entertainment culture

(Asbury Park Boardwalk, 2024). Today, the transformation continues, and the coastal road now retains the original glory of its past with modern design and innovative amenities. Asbury Park represents a major milestone in the history of water parks, with the water slide installed in 1906, and has played a major role in the evolution of water-based entertainment. The image of the *2024 event poster* of the Asbury Park Boardwalk course is shown in Figure 2. The image of the Asbury Park Boardwalk course is shown in Figure 3.

Figure 2
Asbury Park, 2024 event poster

Figure 3
Asbury Park



Wicksteed Park, İngiltere (1926)

Wicksteed Park is a historic amusement park in Kettering, England, founded in 1926 (Historic England, 2024). It was designed and built by Charles Wicksteed in 1926 (Historic England, 2024). One of the most important features that distinguishes this park from others in the world is that it is the oldest surviving example in England and has survived to the present day in the world (Historic England, 2024). The image of the color photograph of a colorful water slide watched by many visitors is shown in Figure 4.

Figure 4
Color photograph of a colorful water slide watched by many visitors (1980)

Today, Wicksteed Park continues to exist as a major attraction, preserving its historic heritage and continuing to offer modern leisure facilities and proving its quality with its membership in BALPPA (British Association of Amusement Parks, Piers, and Leisure Centres) (Wicksteed Charitable Trust, 2024). The image of Wicksteed Park's old original slide is shown in Figure 5.

Figure 5
Evening Telegraph article showing Wicksteed Park's old original slide

Retro
Looking back at how the county used to live
Including Remember When on pages 22&35
It's the slide show!

The image of a 1926 water slide designed and built by Charles Wicksteed is shown in Figure 6.

Figure 6
A 1926 water slide designed and built by Charles Wicksteed

Wet'n Wild, Orlando, Florida (1977)

Wet'n Wild Orlando was the flagship water park of Wet'n Wild, located on International Drive in Orlando, Florida, and owned by NBC Universal (Wikipedia contributors, 2024). The park closed in January 2017 after welcoming many visitors for 39 years. The image of Wicksteed Park 2024 event poster is shown in Figure 7.

Figure 7
Wicksteed Park, 2024 event poster

The image of the black and white image of Wet'n Wild's artist rendering is shown in Figure 8.

Figure 8
Black and white image of Wet'n Wild's artist rendering

The image of black and white image of Wet'n Wild's artist rendering is shown in Figure 9.

Figure 9
From Florida State Archives

Wet'n Wild water parks around the world have continued to add state-of-the-art rides and push boundaries throughout their time in operation (Broadaway, 2021). In

2006, Wet'n Wild became the first water park in the country to offer waterproof electronic wristbands that allow guests to pay for everything in the park by simply scanning their bracelets (Broadaway, 2021). This innovation has allowed visitors to move around the park more comfortably and practically, and has significantly improved the user experience (Broadaway, 2021). The image of Wet'n Wild Orlando is shown in Figure 10.

Figure 10
Wet'n Wild Orlando

In 1994, he was inducted into the International Association of Amusement Parks and Attractions Hall of Fame (Broadaway, 2021). Wet'n Wild Orlando has been named the world's original water park (Broadaway, 2021).

River Country, Walt Disney World, Florida (1976)

River Country is the first water park located at the Walt Disney World Resort, opened in 1976 (Disney Parks Wiki, 2024). This park is known as one of the first water parks in the world with a theme (Disney Parks Wiki, 2024). River Country welcomed approximately 4,000 visitors a day for 25 years and never reopened after its seasonal closure in 2001 (Disney Parks Wiki, 2024).

The nostalgic value of River Country is considered an important part of Disney World's history. The park was Disney's first contribution to the water park concept and formed the basis for today's water parks such as Blizzard Beach and Typhoon Lagoon.

The image of River Country is shown in Figure 11.

Figure 11
River Country

The image of Disney's Blizzard Beach Water Park is shown in Figure 12.

Figure 12
Disney's Blizzard Beach Water Park

The image of Disney's Blizzard Beach Water Park is shown in Figure 13.

Figure 13
Disney's Blizzard Beach Water Park

DEVELOPMENT AND POPULARIZATION OF WATER SLIDES

Technological Advances and Design Changes

Water slides have gained immense popularity over time, becoming an indispensable element of amusement and water parks. While the first water slides used heavy materials such as wood and metal, today light and durable materials such as fiberglass and plastic are preferred. These improvements have increased the safety and durability of slides. In addition, the integration of day-to-day scientific and engineering principles into slide design has resulted in smoother and faster sliding experiences. Computer-aided design (CAD) and hydrodynamic modeling have optimized the performance of water slides.

Thematic and Innovative Designs

Water slides have become the most attractive and thematic elements of amusement and water parks. Equipped with creative themes, water slides not only offer visitors a gliding experience but also immerse them in fantastic stories. These themes provide park visitors with unique experiences that challenge the imagination and make every moment memorable. Each slide is enriched with thematic details, decorated with decorations, and designed according to the atmosphere of the respective themes.

Among the indispensable attractions of modern water parks, high-adrenaline slides such as free fall slides, tube slides, and funnel slides offer visitors truly breathtaking moments. Freefall slides captivate visitors with the sense of freedom and excitement they experience as they quickly fall from a high point. Tube slides take visitors on a fascinating journey through the play of light and dynamic movements of water as they glide quickly through a closed pipe. Funnel slides, on the other hand, provide unique experiences by feeling the centrifugal force while rotating rapidly in a wide and rotating funnel.

These exciting slides are not only for adrenaline junkies but also for visitors of all ages, encouraging them to try again and again. Full of high speed, excitement, and surprises, these attractions are located at the heart of modern water parks and attract millions of visitors every year. This dynamic and impressive world of water parks offers every visitor the opportunity to collect unforgettable memories.

Entertainment and Safety Standards

Water slides have a highly specific and wide market. It is impossible to limit the designs of slides. For this reason, products can be produced by the standards with a safety specification that includes all issues such as dimensions and designs on a country basis. With safety requirements and design guidance rules, the European Standard is used for everyone related to water slides, especially designers, manufacturers, operators, and users (CEN, 2017).

Water parks are subject to high safety standards and regulations. Organizations such as the European Committee for Standardization (CEN) set standards to ensure the safe use of water slides. EN 1069 is a regulation that includes the safety standards set for water slides in Europe. This standard covers the requirements for the design, construction, and maintenance of slides. EN 1069 considers the slope of slides, water flow, safety barriers, and other important factors to ensure user safety.

In the United States, the F2376 standard, set by the American Society for Testing and Materials (ASTM), was created to ensure the safe use of water slides. This standard applies to the classification, design, manufacture, construction, inspection, large-scale modification and operation of water slide systems (ASTM, 2024). ASTM F2376 aims to keep user safety at the highest level and is an important reference point for water parks.

In China, the China Special Equipment Inspection and Research Institute (CSEI) is an agency that oversees the safety of water slides and other amusement park equipment. CSEI standards set requirements for the design, construction, and maintenance of water slides. These standards are important to ensure user safety and prevent potential accidents (CSEI, 2024). In addition, the International Organization for Standardization (ISO) also sets general safety standards for water parks and water slides (ISO, 2024). These standards are accepted worldwide. In this way, a harmonious and safe structure is provided for water parks and slides in different countries. Standards ensure credibility by setting consistent benchmarks for both businesses and consumers.

POLGÜN'S PLACE IN THE SECTOR

History & Establishment

Polgün started its activities in 2002 in Muğla-Menteşe. Since then, Polgün has become one of the rare companies in the field of steel construction and fiberglass manufacturing in its sector. In its modern factory of 70,000 m², it not only imports water slides and playgrounds in the sector but also has made a name for itself in the sector by producing its own brand Splash Tower, Animations, Splash Adventure, Splash Zone, Mountain Coaster products and projects such as water parks, hotels, camping areas, and pools.

Our company, which made its first export in 2015, has implemented water park projects since that date and has signed more than 2000 projects around the world. Polgün has always pioneered innovations in the sector.

Polgün gained the title of being the first and only R&D center in Muğla in 2021. In this center, studies are carried out on sustainable solutions by following the latest technological developments. It is constantly on the lookout for innovative solutions to deliver unique, safe, and fun experiences. In addition, in 2024, the foundations of a new business line were laid in Muğla with the CNC model manufacturing branch, which includes 5-axis machining machines. This step aims to increase Polgün's capacity to produce its models for giant water slides and to reduce foreign dependency. In addition, this new factory will not only be limited to the production of water slides but also has the goal of producing air and land vehicles and the defense industry.

In the R&D center, projects are carried out on water slides that shape the sector in terms of engineering and materials. Polgün has signature slides such as Babochka, Monarch Butterfly, and Hydra, which show its presence in the industry. These unique slides are developed every year, equipped with new features and improved.

Polgün's Place in the Water Slide Industry

As a company operating in the field of water slide and entertainment products manufacturing, Polgün provides services in water slide and entertainment products projects for aquaparks, hotels, campsites, and pools. Polgün, which carries out all processes such as design, project design, manufacturing, sales, and after-sales services within its structure, also carries out P&D and R&D studies in the R&D center within the company. Steel and composite productions are carried out in modern production facilities of 70,000 square meters, and it offers complete solutions to its customers by realizing turnkey water slide and children's playground projects.

Polgün offers comprehensive services from concept design to detailed engineering solutions for water parks and amusement parks. With its project management services, it ensures that projects are completed on time and within budget. Providing professional installation and assembly services for all the products it produces, Polgün increases customer satisfaction with post-installation support and maintenance services. The R&D center leads the industry by constantly developing innovative solutions and technologies for water slides and amusement park equipment while working on sustainable and environmentally friendly products. With its customer-oriented approach and quality service approach, it maintains its leading position in the sector and responds to the needs of the market with its innovative projects.

Polgün is a leader in the water park sector that distinguishes itself from its competitors with its strong position and innovative approach. Its adventure, which started in Muğla-Menteşe in 2002, has turned into a success story that has signed more than 2000 projects around the world today. Known for its high-quality steel construction and fiberglass manufacturing, Polgün has become a standard-setter in the sector with the projects it has carried out in its modern production facilities. While the company combines both entertainment and safety with its brands such as Splash Tower, Splash Adventure, and Splash Zone, it has been the pioneer of innovations in the sector with its unique designs and innovative solutions. Polgün's R&D center leads the industry in developing sustainable and environmentally friendly products in water park equipment. With its customer-oriented approach, superior quality understanding, and continuous innovation, Polgün stands out as an indispensable partner and a reliable brand in the water park sector.

EXAMPLES OF POLGÜN WATER PARKS AROUND THE WORLD

Mövenpick Waterpark Resort & Spa Soma Bay/ Egypt

The Splash Tower and the pirate theme are used in perfect harmony in the Mövenpick Waterpark Resort & Spa Soma Bay project. Located in the Soma Bay region of Egypt, this luxury resort is designed to provide vacationers with an unforgettable experience (Tripadvisor, 2024). The resort's water park, "Splash Mania" has become a favorite among vacationers, with numerous slides and water attractions for all ages (Tripadvisor, 2024).

Splash Tower, a water park favorite, is equipped with a variety of water slides, water guns, interactive water games, and giant pouring buckets. It offers visitors an exciting and fun aquatic adventure. Large buckets tip over as they fill, pouring a huge wave of water over the guests underneath, which is one of the park's most popular moments. The pirate theme, on the other hand, adds a fun and adventurous atmosphere to the water park. Pirate ship-shaped playgrounds are decorated with water cannons and pirate flags. This theme sparks children's imaginations and provides a nostalgic and enjoyable experience for adults.

Splash Mania is equipped with a large number of slides with different heights and speeds. There are slides suitable for both children and adults, ensuring that all family members have a pleasant time. High-speed slides, wave pools, and special water playgrounds for children provide holidaymakers with a unique experience with the various activities offered by the park. This facility has become one of the indispensable addresses of holidaymakers with its facilities that appeal to visitors of all ages. The image of the Movenpick Waterpark adult slide group is shown in Figure 14.

Figure 14
Movenpick Waterpark adult slide group

The image of the Pirate Theme & Splash Tower is shown in Figure 15.

Figure 15
Pirate Theme & Splash Tower

Cube Concept /Greece

Cube Concept water park projects include various slide groups and water attractions. Each slide group has special designs that prioritize the safety and fun of users. The children's slide group attracts the attention of children with its colorful and attractive design, while it is built by high safety standards.

Extensive R&D studies have been carried out for colorful and attractive designs, and special patterns suitable for the theme have been integrated into the slides. As a result of these R&D studies, unique slides have emerged that attract attention and offer a visual feast in every corner of the park. Cube Concept redefines the imagination and sense of fun of visitors of all ages by providing users with a unique water park experience. The image of the Cube Concept slide group is shown in Figure 16.

Figure 16.
Cube Concept slide group

Kosino / Ukraine

Kosina is a mega attraction located in Ukraine. It offers visitors an unforgettable and entertaining experience with water slides and playgroups for adults and children. In this water park, there is the Babochka slide, which emerged as a result of our R&D studies and which we describe as our signature slide today. The Babochka slide is specially designed for this attraction, with a height of 12 meters and a length of 55 meters (Kosino Aquapark, 2024).

The Babochka slide stands out as the most eye-catching and popular attraction of the park. With its unique design and adrenaline-filled structure, it gives its visitors exciting moments. In addition, there are 10 different types of slides and children's playgrounds in the park. Each slide is equipped according to the latest safety standards, ensuring that visitors of all age groups can enjoy themselves safely and enjoyably.

These diverse and impressive attractions offered by the park spark the imaginations of both children and adults while allowing families to collect unforgettable memories that can be spent together. The water park has become one of the most popular entertainment centers in the region with its innovative designs and high-security measures. The image of the Kosina slide group is shown in Figure 17.

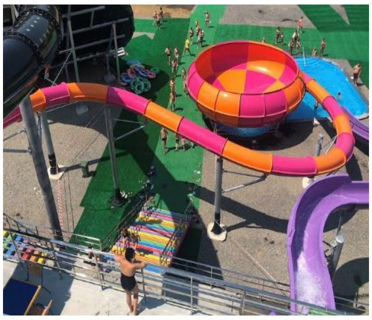
Figure 17
Kosina slide group

The image of the Babochka slide is shown in Figure 18.

Figure 18
Babochka slide

The image of the Space Bowl slide is shown in Figure 19.

Figure 19
Space Bowl slide



Nirvana Cosmopolitan / Türkiye

Nirvana Cosmopolitan is a large water park located in Lara, Antalya that offers a variety of water slides and water attractions (Nirvana Hotels, 2024). The hotel's water park offers a variety of water slides and attractions for children and adults. The water park features high-speed slides, wave pools, and special water playgrounds for children. With our R&D studies, the world's largest children's playground with an underwater theme has been designed. In this project, a system has been established in which mechanical, dynamic, and static systems work together, reaching heights that interactive and conventional parks cannot reach. In addition, it is aimed to improve the motor skills and reflexes of the users with interactive games with mechanical and hydraulic infrastructure in this park. The images of the Nirvana Cosmopolitan slide group are shown in Figure 19.

Figure 19
Nirvana Cosmopolitan slide group

Polgün's Goals and Vision

Polgün is taking firm steps towards becoming a globally recognized brand in the water slides and entertainment products sector. The company's long-term goals and vision are based on a strategy focused on sustainability, innovation, and global growth, and it aims to consolidate its leadership in the industry.

Strategic Objectives

Polgün aims to increase its exports with the offices it has opened in Europe and America to have an effective presence in the international market. Developing environmentally friendly production processes and water-saving projects are among Polgün's priorities. It closely follows the latest technological developments and integrates these technologies into its products. The R&D center in Muğla allows Polgün to develop projects that shape the sector in terms of engineering and materials. Earning the title of being the first and only R&D center, the company is constantly on the lookout for innovative solutions to deliver unique, safe, and enjoyable experiences.

Vision

Polgün's vision is to become a world leader in the water slides and entertainment products industry.

- Customer Satisfaction: To provide the highest quality service to customers and to develop products that exceed their expectations.
- Innovation and Quality: To lead innovations in the sector by constantly developing new products and technologies.
- Environment and Community Sensitivity: To develop projects that are sensitive to the environment and beneficial to society, to take an active role in social responsibility projects by adhering to the principle of sustainability.
- Training and Development: To have the most competent and knowledgeable staff in the sector, giving importance to the continuous training and development of employees.

In line with these goals and vision, Polgün aims to strengthen its presence in the sector and reach a wider customer base by reinforcing its leadership in the global market. The company's growth strategy is based on the principles of innovation and sustainability and is constantly evolving in this direction.

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Conceptual Design of Recyclable Waste Recovery Automation

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Introduction

Recycling has become a necessity as a result of rapidly depleting natural resources. Many civilizations in history have reused scrap metals by melting helmets, swords and various metal parts they used in furnaces and pouring them into molds, making metal money, etc. needed items. These studies have been the foundations of recycling.

As the most important goal of waste materials recovery targets, these materials can be used in addition to our natural resources used in the production sector. In recent years, when industrialization has increased, the need for natural resources has increased rapidly, and recycling processes have become a necessity with the rapid depletion of existing natural resources. On the other hand, instead of procuring and processİng these resources in raw form, wastes obtained with less cost provide large-scale benefits to economies. In the 1800s, a deposit system was introduced for the sale of bottles contaİnİng liquids and the sold bottles were started to be collected again. In 1813, Benjamin Law made pure cotton from idle textile products. During World War 2, the raw material problem increased significantly and the importance of recyclable materials was realized. Various announcements and campaigns were made in Europe to raise public awareness about recycling. In this way, they were asked to support their countries. Waste materials collected in recycling are classified as plastic, glass, paper, etc. by passing through a sortİng center. The machine we will design in this study will be a machine for the collection of waste materials by separating them at the source. The system will be designed by conceptual design method. Conceptual design steps will be discussed and the ideal design selection will be aimed by usİng the method.

In their work, which presents a systematic approach to engineering design, they explained systematic design in four main steps: clarification of purpose, conceptual design, shaping design and detailed design. They explained the steps of conceptual design and gave detailed information about its use (Beitz et al., 1996). He conducted his studies on web-based conceptual design and implemented the design system on the web. As a result of this work, the margİn of error was minimized and the design was easier to use. It has created a solution space that can be continuously improved and enabled comprehensive thinking in new designs (Mayda, 2007: 119). In his study, he used conceptual design to develop a stair lift for the elderly and disabled people and achieved successful results. In his study, he determİned the basic function by abstracting and divided it İnto sub-functions. He developed solution proposals for the sub-functions he created. As a result of the conceptual design process, he determined the most appropriate design among the solution alternatives and designed an innovative system (Bozbuğa, 2018: 120). In their study, they used conceptual design to design a new lawn mower. They concluded their work with a design with high innovative value (Börklü & Erdemir, 2019). In his study, he discussed the conceptual design approach together with other design approaches on different examples and showed practically that a good conceptual design solution can be obtaİned when these approaches are used together (Şanlier, 2019: 119).

Material And Method

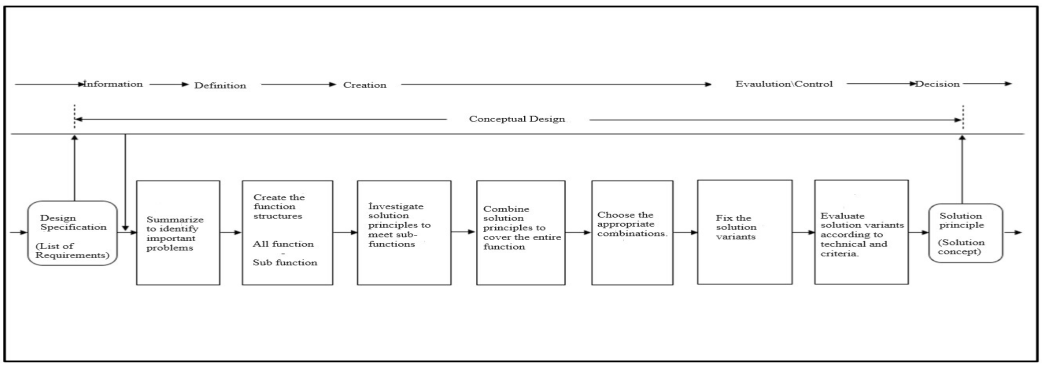
Conceptual design is an important part of the systematic design approach in which the basic solution path is presented through elaboration. The German scientists (Beitz et al., 1996) introduced the systematic engineering design, which consists of four main stages;

- Clarifying the purpose
- Conceptual design
- Forming design
- Detailed design

In the conceptual design phase, design alternatives are eliminated through systematic evaluations and the most ideal design is selected. Creative solutions are realized at this stage. Conceptual design consists of nine steps. The conceptual design stages given in Figure 1 start with the creation of the design specification. Problems are clearly defined and summarized. Then, function structures are created and sub-functions appropriate to these structures are determined. Solution methods that can respond to these sub-functions are investigated. The solution methods found are combİned to correspond to the whole function. Appropriate combinations are made. Solution variants are fixed. These variants are evaluated accordİng to technical and economic criteria and the solution concept is expressed.

Figure 1

Conceptual Design Steps



In this study, we will design a recycling vending machine for the collection of paper and plastic wastes at the source using the steps shown in Figure 1.

Design Specification Preparation

In this step, the design is considered from a broad perspective and a list of wants and desires for the system is created. Here, wants are denoted by “I” and are system features that must be met absolutely. Desires are denoted by “A” and are features that can be met withİn the possibilities. It is possible to update this list durİng the design process (Şekercioğlu,2019).

Table 1
Checklist for Design Specification Preparation

Maİn title	Examples
Geometry	Size, height, width, diameter, number
Kinematics	Direction of movement, speed, acceleration
Force	Force direction, magnitude, frequency, deformation
Energy	Pressure, temperature, heating, cooling, capacity
Material	Physical and chemical properties, auxiliary materials
Signal	İnput, output, control instruments and devices
Safety	Direct safety, environmental safety
Ergonomics	Height adjustment, lighting, shape
Manufacturİng	Maximum part size, suitable production method, tolerance
Quality control	Test and measurement facilities, conformity to standards
Assembly	Installİng, positionİng, foundation preparation
Transport	Area, mode of transport, environment and natural conditions
Operation	Sound level, wear, operatİng environment (acidic, basic)
Recyclİng	Reuse, storage
Cost	Acceptable manufacturİng cost, investment and depreciation
Business plan	End date, planning and control, delivery date
Maintenance	Service İntervals, inspection, replacement, repair

We can facilitate our assessment by using the checklist given in Table 1 to prepare the list of needs.

Figure 2
Waste Collection Vending Machine Design Specification

I/A	Needs
I	Paper And Plastic Shall Be Defined As Waste Material
A	Additional İtem Defİnitions Can Be Made As Functional Design.
I	The Maximum Weight Of Waste Materials Should Be As Follows, $G_{MAX\ WASTE} = 5$ kg
I	The Maximum Waste Size That Can Be Collected Should Be As Follows. $W_{MAX} = 25$ cm $L_{MAX} = 35$ cm $H_{MAX} = 10$ cm
I	Waste Inlet Openİng Should Be Maximally As Follows $W_{MAX} = 27$ cm $H_{MAX} = 12$ cm
I	Vending Machine Dimensions Should Be Designed İn Such A Way That Each İndividual Can Use It Comfortably
I	Payment Will Be Made İn Return For Waste (Coins, Chips, Stamps, Etc.).
I	Safety And Security Measures Must Be Taken
I	System Sensitivity Must Be High
I	Should Be Manufactured From Easy-To-Produce Parts.

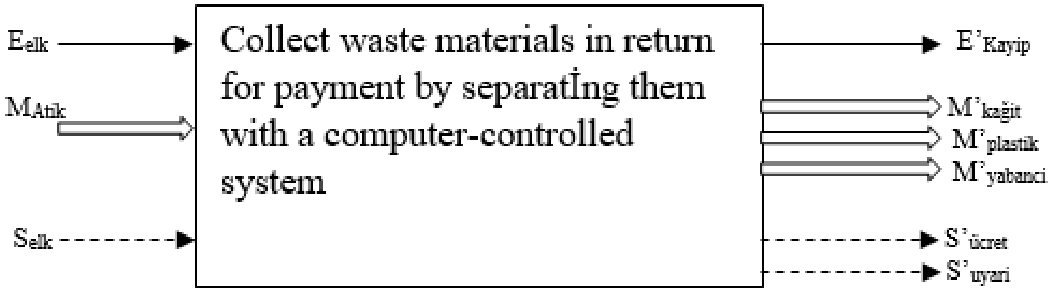
Figure 2 shows the specification for the design of the waste collection vending machine. Here the wishes and desires are clearly stated and the design is guided accordİngly.

Creating Function Structures

Function structures are handled in two groups. First, the whole function is determined. Then it is decomposed into sub-functions to be detailed.

Figure 3

Full Function of Waste Vending Machine Design



First of all, the entire function diagram of the designed system is revealed to express its main purpose. In the system, inputs and outputs are expressed as energy "E", material "M" and signal "S". Inputs to the system are expressed as "E-M-S" and outputs as "E'-M'-S'". Figure 3 shows the energy, material and signal inputs and outputs of the waste vending machine design. The most general expression of the system is "sort waste materials with a computer-controlled system and collect them in return for payment".

Sub-functionalisation

By dividing the whole function structure, sub-function structures are created as in figure 4. The whole function structure is more complex than the sub-function structure. Dividing in this way finds the most suitable startİng point for solving the problem. A better understanding of the system is achieved. The design can be modified by addİng or removing function structures.

Figure 4

Dividing the Entire Function Scheme Into Sub-Functions (Beitz et al., 1996)

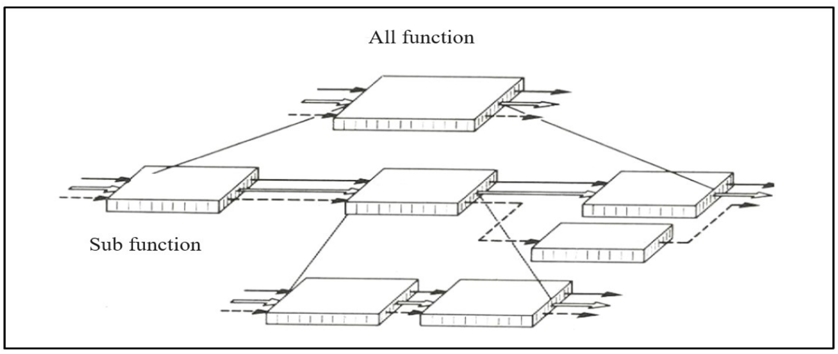
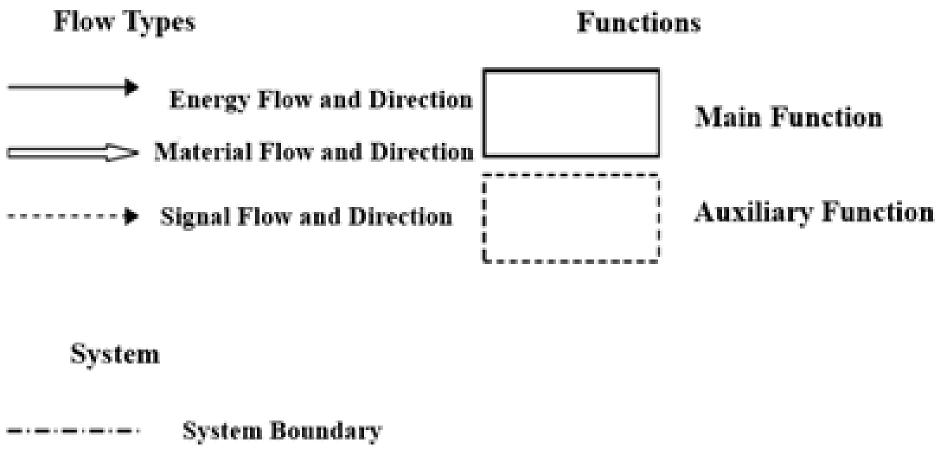


Figure 5 shows the symbols used to represent functions. Considerations in developing function structures;

- It should be in an evolving order.

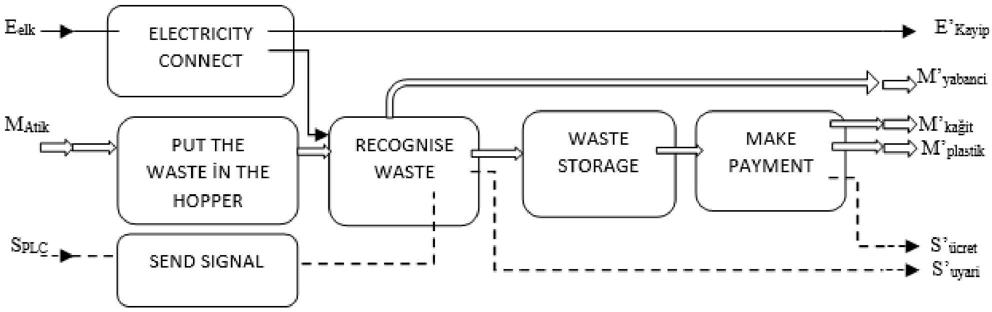
- It should be simple and straightforward.
- They should be represented by standard symbols.
- Different solution concepts should be generated.
- Generally valid function blocks should be used.
- Energy, material and signal data must be defined.

Figure 5
Symbols Representing Functions (Mayda, 2007: 119)



The diagram of the sub-functions of the waste vendİng machine design is shown in Figure 6. In this figure, the workİng system is divided into sub-functions.

Figure 6
Waste Vending Machine Sub Function Diagram



Establishing Solution Principles

Solution options are created for the design with all functions and sub-functions defined. These solution options are shown in a table called morphological card (Table 2). A sufficient number of solution options are created by combining the solution variants in the morphological table.

Table 2
Morphological Card for Waste Vending Machine

Solution Path / Sub Function	C1	C2	C3	C4
Power	Electric Energy	Solar Energy	Electricity And Solar Energy	Battery
Control	Manual Control	Remote Control	Computer	
Product Identification	Object Recognition	Camera		
Waste Diversion	Pneumatic	Electric	Hydraulic	
Warning/Effect	Lighted	Sound	Illuminated And Audible	
Material	Stainless Stainless Sheet	Plastic	St 37 Sheet	

Combining Solution Principles

Table 3
Waste Vending Machİne Conceptual Design Options

SOLUTION PATH / SUB FUNCTION		C1	C2	C3	C4
1	POWER	ELECTRIC ENERGY	SOLAR ENERGY	ELECTRICITY AND SOLAR ENERGY	BATTERY
2	CONTROL	MANUAL CONTROL	REMOTE CONTROL	COMPUTER	
3	PRODUCT IDENTİFİCATİON	OBJECT RECOGNITION	CAMERA		
4	WASTE DIVERSİON	PNEUMATİC	ELECTRIC	HYDRAULIC	
5	WARNING/EFFECT	LIGHTED	SOUND	ILLUMINATED AND AUDİBLE	
6	MATERIAL	STAINLESS STAINLESS SHEET	PLASTIC	ST 37 SHEET	

Solution alternatives for waste vending machİne design are created by making selections from the morphological card created in Table 3.

Tablo 4
Design Alternatives Table

Black CV-1	1-C1,2-C3,3-C1,4-C1,5-C1,6-C3	Green CV-4	1-C2,2-C1,3-C1,4-C1,5-C2,6-C1
Yellow CV-2	1-C1,2-C3,3-C1,4-C2,5-C2,6-C3	Gray CV-5	1-C3,2-C3,3-C1,4-C2,5-C2,6-C3
Orange CV-3	1-C1,2-C2,3-C2,4-C3,5-C2,6-C3	Blue CV-6	1-C4,2-C3,3-C2,4-C3,5-C3,6-C2

Selection of Suitable Joints

When the part of creating design alternatives is completed, the designs that may be suitable among these alternatives are selected. For this process, a selection card table is created as shown in Figure 7. In this table, the elimİnation process is carried out accordİng to the followİng selection criteria and efforts are continued to collect missing information. These selection criteria are;

- Compatible with all functions
- Meeting the list of needs
- Being doable
- Being within cost limits
- Ensuring safety measures
- Preferred by the designer

Figure 7

Waste Vending Machine Conceptual Design Selection Card

Election Card

Election Criteria
(+) Yes
(-) No
(?)Lackof Information
(!)Check Condition

Decision

Decision Criteria
(+) Sustain Solution
(-) Take Out The Solution
(?) Collect İnformation
(!)Check The List Of Requirements For Changes

Solution Variants	A (Compatible With All Functions)	B (Meets Specification Requirements)	C (İn Prİnciple İt Can Happen)	D (Allowable Cost)	E (Meets Safety Requirements Directly)	F (Beİng A Designer Preference)	G (Sufficient İnformation)	Opİnions (Reasons)	Decision
Cv-1	+	+	+	-	+	-	+		+
Cv-2	+	+	+	+	+	+	+		+
Cv-3	-	+	+	-	-	+	?	Not Enough İnformation	-
Cv-4	-	+	+	-	-	-	+	High Cost	-
Cv-5	+	+	+	+	+	-	+		+
Cv-6	+	+	+	-	+	-	?	Not Enough İnformation	-

Fixing Solution Variants

In this step, we will focus on the design alternatives that we have selected in the selection card as maintaining the solution. We will consider the rough scale drawings for these designs and evaluate the designs. Rough calculations can be made if necessary. Definitions can be expressed by creatİng kİnematic models. Technological market research is conducted. Solutions can be better evaluated in the light of this data. System properties of alternative concepts are expressed.

Figure 8
Waste Vending Machine Conceptual Design Solution Variant-1

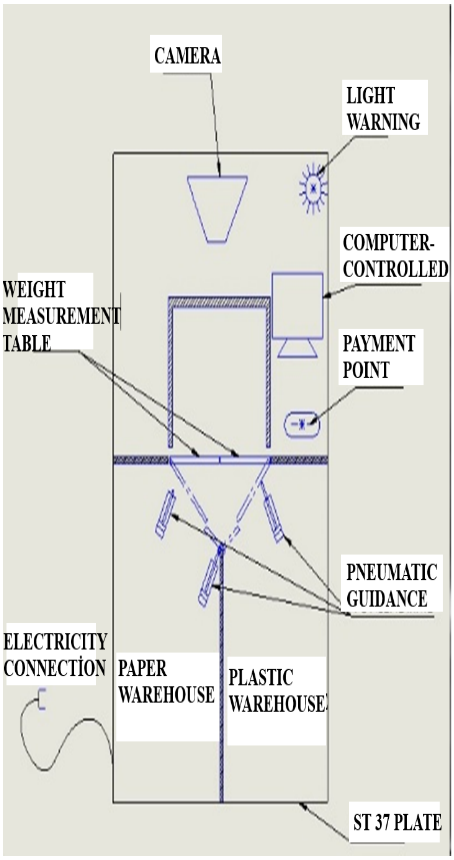
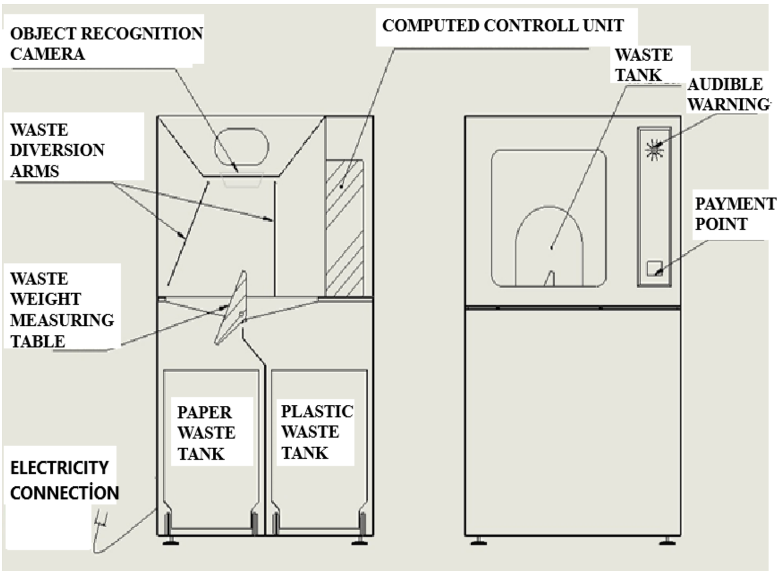


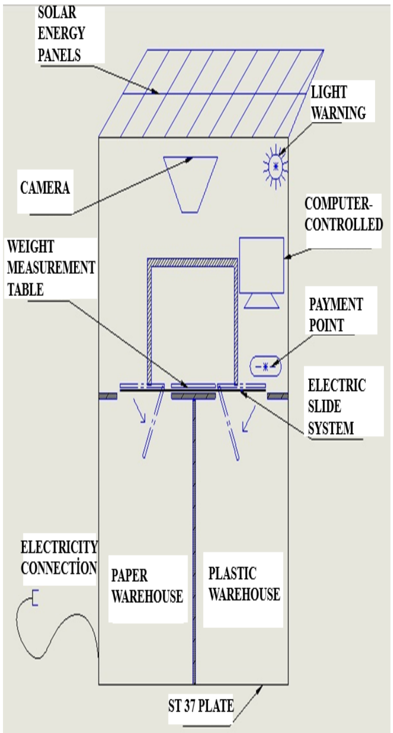
Figure 8 shows our design alternative which is electrically operated, computer controlled, includes object recognition technology, the steering mechanism works with pneumatics, has illumİnated warnİngs and can be produced from ST-37 sheet metal. Storage is fixed inside the machİne.

Figure 9
Waste Vending Machine Conceptual Design Solution Variant-2



In Figure 9, there is a design alternative that is electrically operated, computer controlled, has object recognition technology, the steering mechanism works with electric pistons, can make audible warning and can be manufactured from ST-37 sheet metal. There is an easily changeable storage system.

Figure 10
Waste Vending Machine Conceptual Design Solution Variant-5

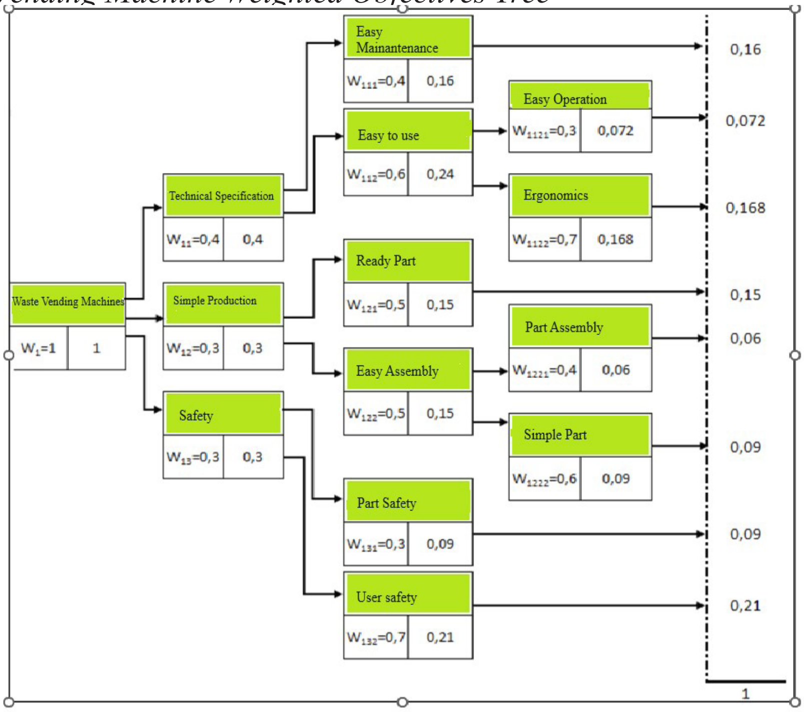


The design alternative shown in Figure 10 is a conceptual design of a vending machine powered by electricity and solar energy, computer controlled, with object recognition technology, waste routing with electric slides, with an audible warning system and designed from ST-37 sheet metal.

Evaluating Solution Variants According to Technical and Economic Criteria

Among the conceptual design alternatives evaluated in the selection card, the designs that are positive are re-evaluated and the most appropriate solution method is selected. At this stage, firstly, the objectives tree is created. Here, evaluation is made accordİng to the criteria. Percentage values are assigned accordİng to their importance. In the last part, the sum of values should be '1'.

Figure 11
Waste Vending Machine Weighted Objectives Tree



An evaluation chart is prepared according to the criteria and values determined in Figure 11.

Table 5
Waste Vending Machine Evaluation Table

Evaluation table				Solution-1			Solution -2			Solution -5		
Criteria		W	Parameters	Ratio	Value	Weight Value	Ratio	Value	Weight Value	Ratio	Value	Weight Value
1	Easy maintenance	0.16	Easy maintenance	Middle	8	1,28	More	9	1,44	Middle	7	1,12
2	Easy operation	0.072	Easy to use	Middle	6	0,432	More	8	0,576	Middle	5	0,36
3	Ergonomic	0.168	Ergonomics	Middle	6	1,008	More	7	1,176	Less	4	0,672
4	Ready made part	0.15	Standard part	Middle	5	0,75	Middle	6	0,9	Middle	6	0,9
5	Part assembly	0.06	Open assembly process	Middle	5	0,3	Less	6	0,36	Middle	5	0,3
6	Simple part	0.09	Simplicity	Middle	5	0,45	Middle	6	0,54	Middle	5	0,45
7	Part safety	0.09	Reliability	More	8	0,72	More	8	0,72	Middle	7	0,63
8	User safety	0.21	Safety	More	8	1,68	More	9	1,89	More	8	1,68
∑Wt=1 d: value sum Ad: Weight value sum				∑d1=51 ∑Ad1=6,62			∑d2=59 ∑Ad2=7,602			∑d5=47 ∑Ad5=6,112		

In Table 5, the solutions were evaluated by assigning value grades separately. In this evaluation, the value analysis table n Table 2 was used to quantify the criteria. Being able to rate the weight values well will provide great convenience in finding the most ideal solution. While there are evaluation criteria between 0-10 in the value analysis, according to the VDİ 2225 guide, a more rough evaluation is made between 0-4.

Table 6

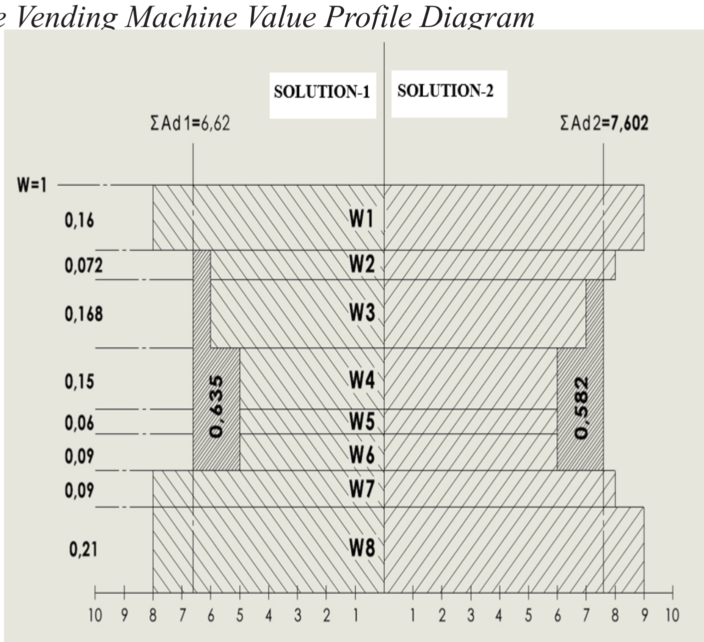
Value Analysis Schedule and VDİ 2225 Guide (Mayda, 2007: 119)

Value Calculation			
Value Analysis Chart		**Vdi 2225 Guide**	
Weight	Meaning	Weight	Meaning
0	Impractical Solution	0	Inadequate (Well Below Average)
1	Unsuitable Solution		
2	Weak Solution	1	Middle (Below Average)
3	Intermediate Solution		
4	Suitable Solution	2	Appropriate (Average)
5	Enough Solution		
6	A Good Solution With A Few Shortcomings	3	Good (Above Average)
7	Good Solution		
8	Very Good Solution	4	Very Good (Well Above Average)
9	Solution in Excess Of Need		
10	Ideal Solution		

According to Table 5, the design with the lowest weight value in the evaluation chart is eliminated and a value profile diagram (Figure 12) is drawn for the remaining two conceptual designs shown İn green.

Figure 12

Waste Vending Machine Value Profile Diagram



In the value profile diagram, we have transferred the parameters for the last two conceptual designs as shown in Figure 12. In this diagram, the vertical lengths are given according to the weight values of the measurement criteria. Horizontal lengths represent the values we have given in the solution option for that criterion. Finally, we have shown the sum of the weight values calculated in Table 5 for the solutions with vertical lines. With these vertical lines, we have shown the remaining gap areas in the criteria with less criterion value on that axis with dark coloured hatchng regions. The size of these dark coloured hatching areas expresses the size of the gap for that solution criterion. (Börklü & Erdemir, 2019; Bozdemir & Toktaş, 2001; Doğan,2021,p:67; Mayda & Börklü, 2008; Mayda & Riza Börklü, 2014;Parlar vd.,2017; Şanlier & Börklü,2017; Şekercioğlu, 2019; Yaldiz,2019,p:71) Since the size of the missing areas for Solution-1 is larger than Solution-2, 'Solution-2' conceptual design of waste vending machine was determined as the most ideal conceptual design option as a result of the method.

Results And Discussion

As a result of the research, the conceptual design method we applied showed the solution-2 option for the most ideal design. Accordng to this design, the power unit will be operated by electrical connection. The control unit is computerised. As object recognition technology, the material type will be defined accordng to the density of the material by optimisng weight and volume measurement. Then, the guidance mechanism to be operated with the electrical system will be activated and the material will be transmitted to the warehouse section. The user will be paid as a result of the calculation to be made according to object recognition technology. This process will be notified to the user with the sound effect method. In the production of the machİne, ST 37 sheet metal or carbon fibre composite material will be used mainly in the body and hoppers. Composite materials, especially carbon composites, are extremely resistant to vandalism and impacts outside the cabin. (Kayrıcı & Taser, 2024, ss. 12885-12898) The result will be as shown in Figure 13.

Figure 13
Recovery Vending Machine

Conclusions And Suggestions

As a result, the conceptual design method has evaluated and presented the most ideal solution option for the waste vendİng machine in a systematic way by giving fast results. With this method, our list of requirements is specified n detail. The basic problem is expressed abstractly as a whole function and divided into sub-functions. Solution alternatives have been developed for each function. With the help of the morphological card, solution variants were created by combinng these solution methods appropriately. These design alternatives were eliminated with the help of a selection card and the remaining solutions were evaluated and the last two solution variants were obtaned. These solution variants were discussed in a diagram called value profile diagram and the most ideal design was selected. The most successful design has been reached in all functions by selectİng the solution method in the problem sub-functions that we have handled systematically.

This method provides great convenience to designers as a solution. Selection processes sometimes create big problems for designers and prolong decision-making processes. These processes sometimes extend to the production stages and design changes can be made during production and material and time losses may occur. It will be of great benefit to the designer to be able to handle these processes in detail before starting the design and to solve them in a timely manner. The success of the solution will also benefit the producer organisations by creating positive results in increasing the market share by increasing the customer's orientation to the product in the offer size works. Conceptual design makes a great contribution to designers in this respect. It is a design method that designers should use with importance.

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Breast Cancer Detection with Machine Learning Algorithms

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Introduction

Cancer is a life-threatening disease caused by the uncontrolled division and growth of cells in a specific organ or tissue in the body. Currently, over 100 types of cancer are recognized, classified based on their behavior and response to treatment. A critical aspect of cancer pathology is determining whether tumor cells are benign or malignant, which is essential for accurate diagnosis and effective treatment planning (Cooper, 2000).

Cancer ranks as the second leading cause of death globally, claiming an estimated 9.6 million lives in 2018 alone (MHDF, 2021).

Tumors are masses formed by the uncontrolled growth of cells. While benign tumors remain localized and do not spread, malignant tumors can invade surrounding tissues and spread to other parts of the body. Cancer begins when abnormal cells multiply uncontrollably. In this context, a benign tumor is confined to its original location and does not harm surrounding tissues. In contrast, a malignant tumor invades nearby tissues and attempts to spread beyond its site of origin, often reaching other organs through the lymphatic system and bloodstream. Therefore, early detection plays a crucial role in the effective treatment of cancer (Patel, 2020).

Breast cancer is the most prevalent health issue worldwide. It is a life-threatening disease for women and ranks among the leading causes of death in the female population (Akram et al., 2017).

Cancer is the most commonly diagnosed disease in the majority of countries and is the leading cause of cancer-related deaths in over 100 nations (Bray et al., 2018).

The risk of developing breast cancer in men is just 1% of the risk faced by women. In countries with a low or medium Human Development Index (HDI), the breast cancer mortality rate is 48%, which is four times higher than in countries with a high or very high HDI (Wild et al., 2020).

According to World Health Organization statistics for 2020, 2.26 million people worldwide were diagnosed with breast cancer, and approximately 685,000 women lost their lives to the disease that year (Ariffin, 2022).

Early diagnosis is crucial to increase survival rates in breast cancer, which is a life-threatening disease. Subtypes of breast cancer are directly linked to the treatment process (Uddin & Wang, 2022).

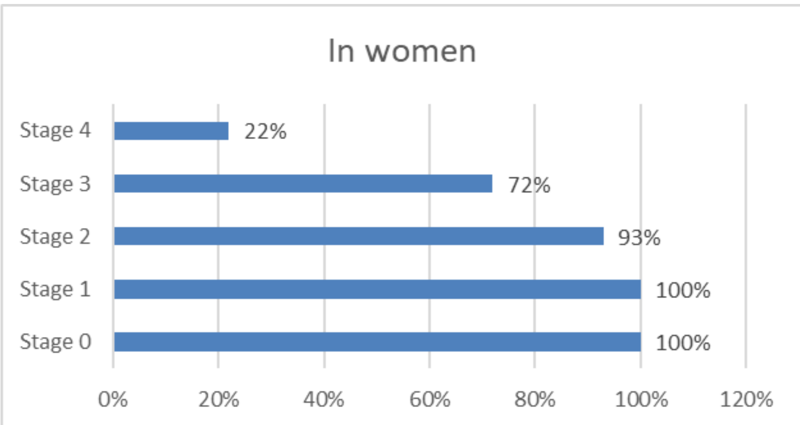
Breast cancer is especially common among women aged 40 to 49 and is the leading cause of cancer-related deaths in women worldwide (Jemal et al., 2010).

Among the 18.1 million cancer cases recorded worldwide in 2018, lung cancer ranked second with 11.6 percent (Bray et al.,2018).

As with all other types of cancer, early detection of breast cancer is crucial in reducing mortality (Tapak et al.,2018).

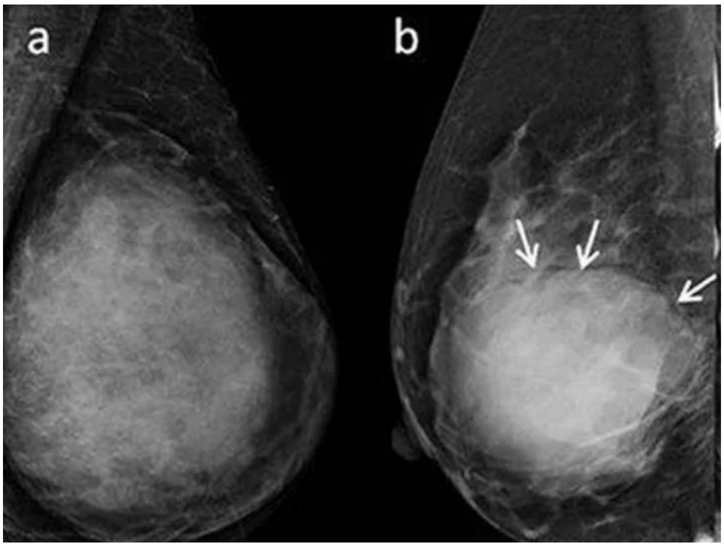
Breast cancer incidence rates have been rising over the past decade in many transitioning countries, with regions in South America, Africa, and Asia experiencing the fastest increases. This may be attributed to demographic factors associated with social and economic development, including high fertility rates, increased obesity and physical inactivity, and limited improvements in breast cancer screening and awareness (Figure 1).

Figure 1
Survival Rates by Breast Cancer Stage



Research indicates that early detection of breast cancer can significantly reduce mortality rates. In breast cancer diagnosis, mammography images examined by radiologists can provide valuable information about the progression of the disease. Figure 2 displays mammograms of benign and malignant breast tissues (Özgür & Keser, 2021).

Figure 2
a) *Mammography Image of a Normal Breast*
b) *A Mammographic Image of a Phylloid Tumor (Özdoğan, 2022).*



Early detection of breast cancer increases the chances of successful treatment and survival. In 61.4% of women, the cancer is diagnosed at stage one, with a five-year survival rate of 98.8% to 100%. For women diagnosed at stage two, the survival rate drops to 93%, for women diagnosed at stage three it drops to 72% and for women diagnosed at stage four it drops to 22%.

It is known that breast cancer occurs in one in every 8 women worldwide and in one in every 9-10 women inTürkiye. As often emphasized, the prognosis for breast cancer is promising when detected early. Table 1 clearly shows the importance of early detection. This situation reveals that new methods are needed to detect even very small malignant tissues (Fear et al., 2002).

Table 1
Relative Chances of Survival According to the Stages of Breast Cancer (Hagness et al., 1998).

Phase	5 Years Relative Survival Chance
0	100%
I	100%
IIA	92%
I B	81%
IIIA	67%
III	54%
IV	27%

Advances in artificial intelligence technologies have led to significant progress in disease diagnosis. Recently, there has been a major breakthrough in the field, particularly with the introduction of deep learning methods and convolutional neural networks. These techniques can even outperform human experts by achieving high performance in classification without the need for predefined feature spaces. Breast cancer diagnosis requires the interpretation of test results, and expert knowledge is essential. With the development of machine learning techniques, successful applications are now being implemented in breast cancer diagnosis (Duggento et al., 2019).

In this context, AI systems can be used as a tool to assist clinicians and radiologists or operate independently. As a result, AI solutions aim to enhance the efficiency of the healthcare system and improve patient outcomes. Recent advances in computer processing power and increased data accessibility have been crucial in the development of computer-aided detection (CADe) and diagnosis (CADx) systems (Hickman, 2021).

The deep learning model developed by Wang et al. (2016) achieved a discrimination accuracy of 87.3% when characterizing microcalcification (calcium deposits in breast tissue) alone.

Liu et al. (2021) developed a deep learning model that combines mammography and clinical variables to predict malignant breast microcalcification in the BI-RADS 4 subgroups evaluated by radiologists. When comparing the performance of radiologists with the combined model in predicting whether breast microcalcification were malignant, they found that the diagnostic capability of the combined model was nearly equivalent to that of a senior radiologist and significantly better than that of a junior radiologist.

By using the least squares support vector machine (LS-SVM) classification algorithm, a 98% success rate has been achieved in breast cancer data (Polat & Güneş, 2007).

Khan et al. (2008) classified breast cancer data using fuzzy decision trees and achieved better results than with independent classifiers.

Delen et al. (2005) developed prediction models using two popular data mining algorithms, artificial neural networks and decision trees, on a large breast cancer dataset. In this study, they achieved an accuracy rate of 93.6% with decision trees and 91.2% with the artificial neural network model.

Akyol (2018) carried out the feature determination process in the breast cancer dataset using the Recursive Feature Selection method and achieved a 98% success rate by applying the random forest algorithm for classification purposes.

Papageorgiou et al. (2015) analyzed the data of 40 patients through a health assistant developed with the fuzzy cognitive map (FCM) method and achieved an accuracy of 95%.

Kolay and Erdoğmuş (2016) classified a breast cancer dataset without any preprocessing using Matlab and Weka software through the K-means method and obtained success rates ranging from 45% to 79% with various parameter changes.

Various results have been obtained based on algorithms, hyperparameters and methods. Using various methods such as decision support machines, decision trees, logistic regression, random forest, K-nearest neighbor, naive bayes and artificial neural networks, accuracy performance between 79.8% and 99% has been achieved (Amrane et al., 2018; Ganggayah et al., 2019; Agarap et al.,2018; Vaka et al., 2021; Akyol, 2017; Sevli, 2019; Mohammed et al., 2020). Despite high success rates, AI-based efforts to optimize breast cancer diagnosis are still ongoing.

The study aims to develop an artificial intelligence model capable of making fast and accurate predictions for the diagnosis of breast cancer, a prevalent disease today. This approach seeks to minimize time and effort in diagnosis while ensuring accurate detection of the disease. Another objective is to train the AI model using diverse and extensive datasets to continually improve diagnostic accuracy. The subsequent sections of the study cover the materials and methods, findings, and conclusions.

Material and Methods

This section explains the proposed model and the steps outlined in the study. First, the algorithm techniques used in the study are described, followed by the process of obtaining and preparing the dataset. Finally, the model-building stages are detailed. To achieve this, the study employed support vector machine (SVM), K-nearest neighbor (KNN), artificial neural network (ANN), random forest, and logistic regression algorithms.

Data Set

The data for this study was obtained from a public platform accessible via the website (URL1). The dataset comprises 2,633 samples, including breast ultrasound images of women aged 25 to 75, collected in 2018. It represents 600 female patients and contains 2,633 images, each averaging 500x500 pixels in PNG format. Both the original and actual images are provided in the dataset, categorized into three classes: normal, benign, and malignant.

The data used in this study consist of benign, malignant, and normal breast ultrasound images. The dataset includes a total of 2,633 breast ultrasound images. A table summarizing the data is provided below.

Table 2

Number and Percentages of Data Used in the Study

Area of Use	Number of Data	Percent (%)
Training	2100	%75
Test	533	%25
Total	2633	%100

Support Vector Machine

SVM is a powerful machine learning algorithm for data classification. It aims to determine a boundary (hyperplane) that maximizes the distance between two classes. To identify this boundary, SVM utilizes data points located on the edge of the classes, known as support vectors. For data that is not linearly separated, it facilitates classification by moving the data to higher dimensions with kernel functions. SVM gives good results, especially for high-dimensional datasets and various classification problems; however, the computational cost can be high for large datasets (Cortes & Vapnik, 1995).

K-Nearest Neighbor Algorithm

In the KNN) algorithm, when adding a new data point, the distance of this point from other points in the existing data set is calculated and its k nearest neighbors are looked at. This technique compares the new data to the existing data, calculates the distance and classifies it. The KNN algorithm is regarded as one of the simplest machine learning algorithms. When a new sample is added to the dataset, its \(k\) nearest neighbors are identified, and the class of the new sample is determined based on these neighbors (Kılınç et al., 2016).

Artificial Neural Network Algorithm

ANNs consist of interconnected elements, like neurons in the human brain. These elements have memories capable of processing information. Artificial Neural Networks (ANNs) are designed to emulate the structure and function of the biological nervous system. They are self-learning algorithmic models capable of learning, memorizing, interpreting, and comparing data (Elmas, 2016).

Random Forest Algorithm

Random Forest, a method introduced by Leo Breiman in 2001, is a model that combines multiple decision trees. When data is processed through N decision trees, the predictions are averaged to make a more accurate overall prediction. Random Forest addresses the issue of overfitting, which is common in traditional decision trees, by splitting the dataset and its attributes into multiple subsets and processing them across different trees (Breiman, 2001).

Logistic Regression Algorithm

Logistic regression is a supervised machine learning algorithm commonly used in classification problems, particularly those involving two classes. Unlike linear regression, it uses the logistic (sigmoid) function to constrain the predicted values between 0 and 1. This ensures that the model's outputs represent probabilities, which can be used in classification tasks. Logistic regression is the preferred method for probabilistic classification and binary decision problems, and it is applied in areas such as disease prediction, customer behavior analysis, and spam detection (Cox, 1958).

Performance Evaluation

Out of the total 2,633 samples, 75% of the dataset was used for training and 25% for testing, with the division being randomized. After training was completed, the classification accuracy was evaluated using the test data. By comparing the classes predicted by the system with the test classes, the proportion of correctly predicted examples determined the overall classification accuracy. In this study, the learning performance was calculated using the confusion matrix, as shown in Table 3. Using the obtained parameters, accuracy, F1 score, precision, and sensitivity values were calculated using the following equations.

Table 3
Confusion matrix

Estimated Values	Actual Values	
	Positive	Negative
Positive	True Positive (TP)	False Positive (FP)
Negative	False Negative (FN)	True Negative (TN)

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \quad (1)$$

$$\mathrm{Re}call = \frac{TP}{TP + FN} \quad (2)$$

$$\mathrm{Pr}ecision = \frac{TP}{TP + FP} \quad (3)$$

$$F1 = \frac{2\ x\ precesion + recall}{precesion + recall} \quad (4)$$

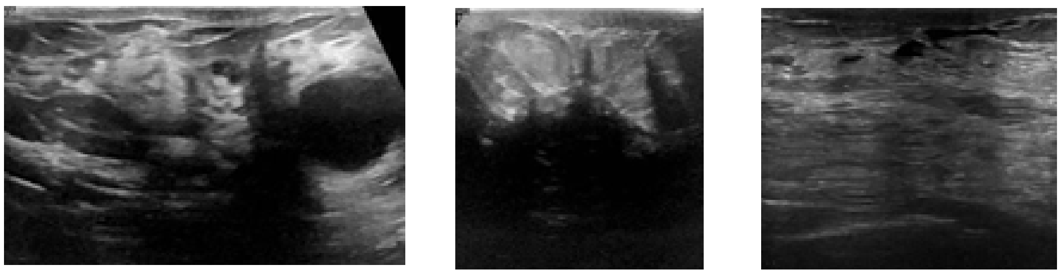
Findings

The model was trained using normal and benign ultrasound images along with images of breast cancer. Therefore, the values of the model’s inputs are defined. The input values include normal, benign and malignant ultrasound images. Figure 3 shows examples of the ultrasound images used in the study.

Figure 3

Benign, Malignant and Normal Breast Ultrasounds

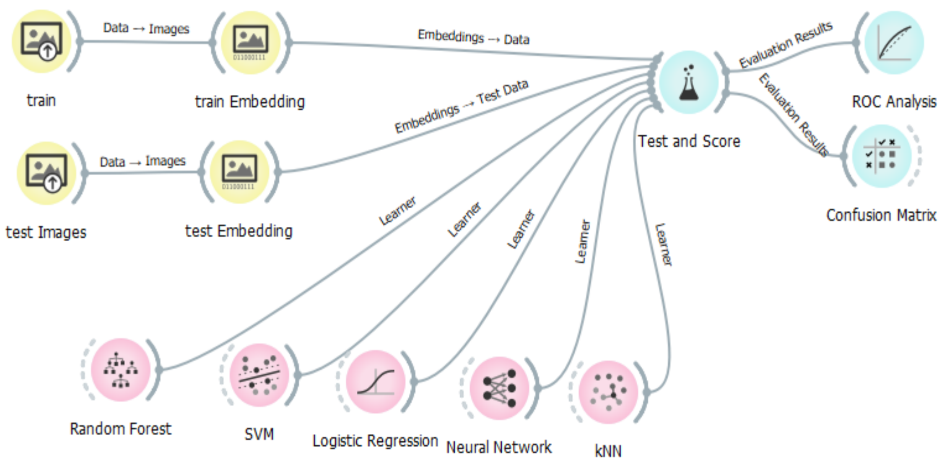
Benign *Malignant* *Normal*



The breast cancer detection model used in this study is shown in Figure 4. In the data analysis program, the image data is divided into two groups: training and test data. The input data is processed, and models are then created using three different algorithms. In the “Test and Score” section, the results and performance metrics of these models are presented in tables. Following the Test and Score section, visualizations of the test data are displayed according to the algorithms. These visualizations include the accuracy values of each algorithm as percentages, accuracy and loss graphs for the output layer, and other relevant data.

Figure 4

Breast Cancer Detection Model



The dataset containing breast cancer findings was classified separately using SVMs, KNN, ANN, fandom forest and logistic regression models with 533 samples, which constitute 25% of the total 2633 samples. For each model, a confusion matrix was created, accuracy, classification success, sensitivity, predictive accuracy and precision values were calculated and given in Table 4.

Table 4

Classification Achievements of Models

Model Name	AUC	CA	F1	Precision	Recal
SVM	0.958	0.871	0.870	0.872	0.871
KNN	0.966	0.897	0.894	0.895	0.897
ANN	0.979	0.893	0.892	0.893	0.893
Random Forest	0.959	0.831	0.816	0.849	0.831
Logistic Regression	0.975	0.886	0.884	0.895	0.886

Table 5 shows the confusion matrix values for the algorithms used in the study based on the type of tumor. In these algorithms, it is seen that KNN gives the best percentage results in classification success according to benign, malignant and normal categories. In the KNN technique, 89.9 % benign, 90.2 % malignant and 81.0 % normal were obtained.

Table 5
Confusion Matrix Results of the Algorithm Models Used in the Study

SVM

Actual \ Predicted	benign	malignant	normal	Σ
benign	85.5 %	9.7 %	8.3 %	250
malignant	12.2 %	88.3 %	0.0 %	250
normal	2.3 %	2.0 %	91.7 %	33
Σ	262	247	24	533

KNN

Actual \ Predicted	benign	malignant	normal	Σ
benign	89.9 %	6.7 %	9.5 %	250
malignant	7.0 %	90.2 %	9.5 %	250
normal	3.1 %	3.1 %	81.0 %	33
Σ	257	255	21	533

Random Forest

Actual \ Predicted	benign	malignant	normal	Σ
benign	77.6 %	6.7 %	0.0 %	250
malignant	15.5 %	90.2 %	0.0 %	250
normal	6.9 %	3.1 %	100.0 %	33
Σ	303	225	5	533

Logistic Regression

Actual \ Predicted	benign	malignant	normal	Σ
benign	82.8 %	3.2 %	9.1 %	250
malignant	13.4 %	95.9 %	0.0 %	250
normal	3.8 %	0.9 %	90.9 %	33
Σ	291	220	22	533

ANN

Actual \ Predicted	benign	malignant	normal	Σ
benign	89.9 %	6.7 %	9.5 %	250
malignant	7.0 %	90.2 %	9.5 %	250
normal	3.1 %	3.1 %	81.0 %	33
Σ	257	255	21	533

To classify the data using artificial intelligence, the dataset was split into 75% training data and 25% test data. Machine learning algorithms were applied to the dataset, and their performance was evaluated using the test data.

Figure 5
Accuracy Performance of Algorithms in Breast Cancer Diagnosis

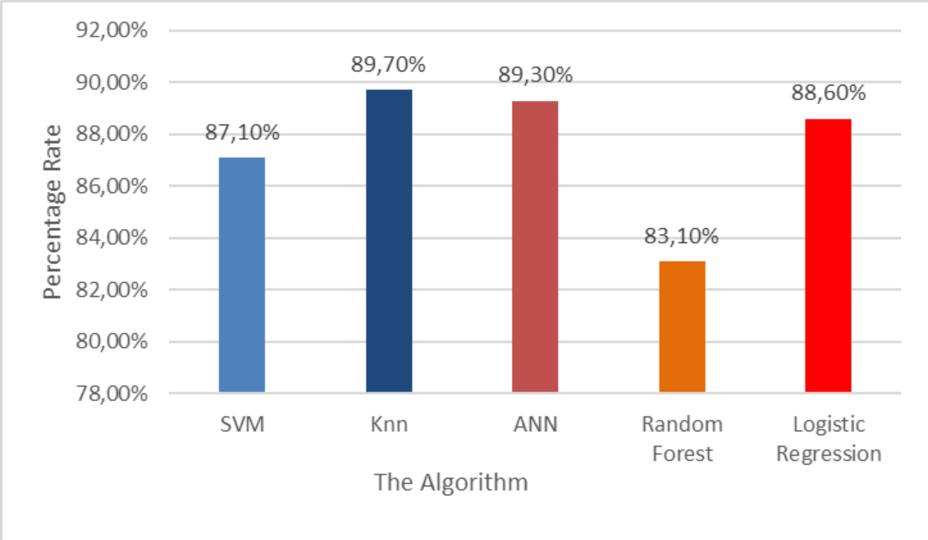


Figure 6 shows the ROC analysis plot of TP and FP plot according to benign breast tomography in diagnosing patients.

Figure 6
ROC Analysis Graph of Benign TP and FP

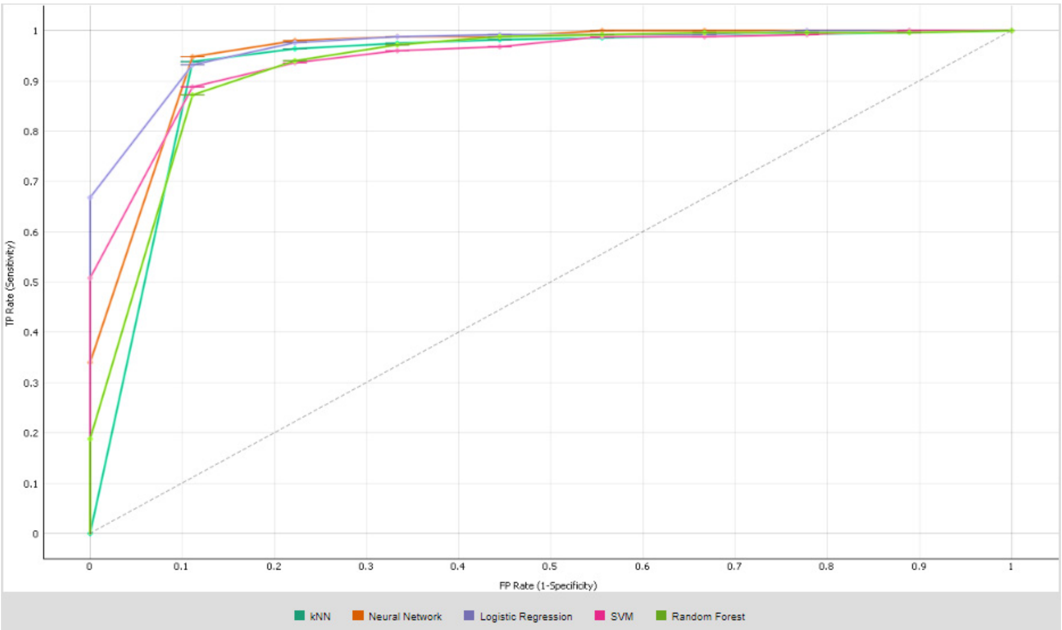


Figure 7 shows the ROC analysis plot of TP and FP plot according to malignant breast tomography in diagnosing patients.

Figure 7
Malignant TP and FP ROC Analysis Graph

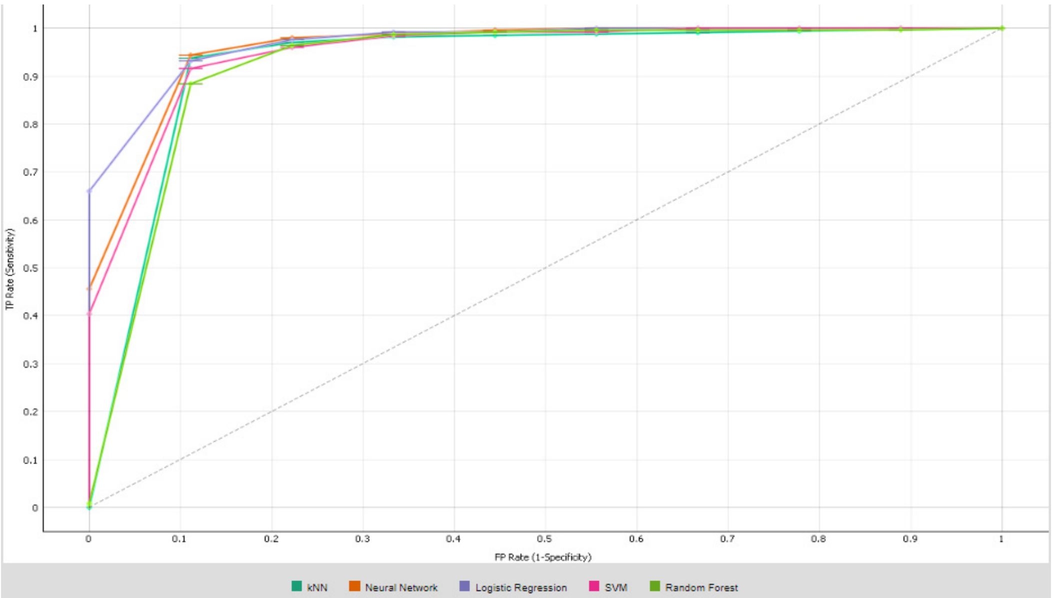
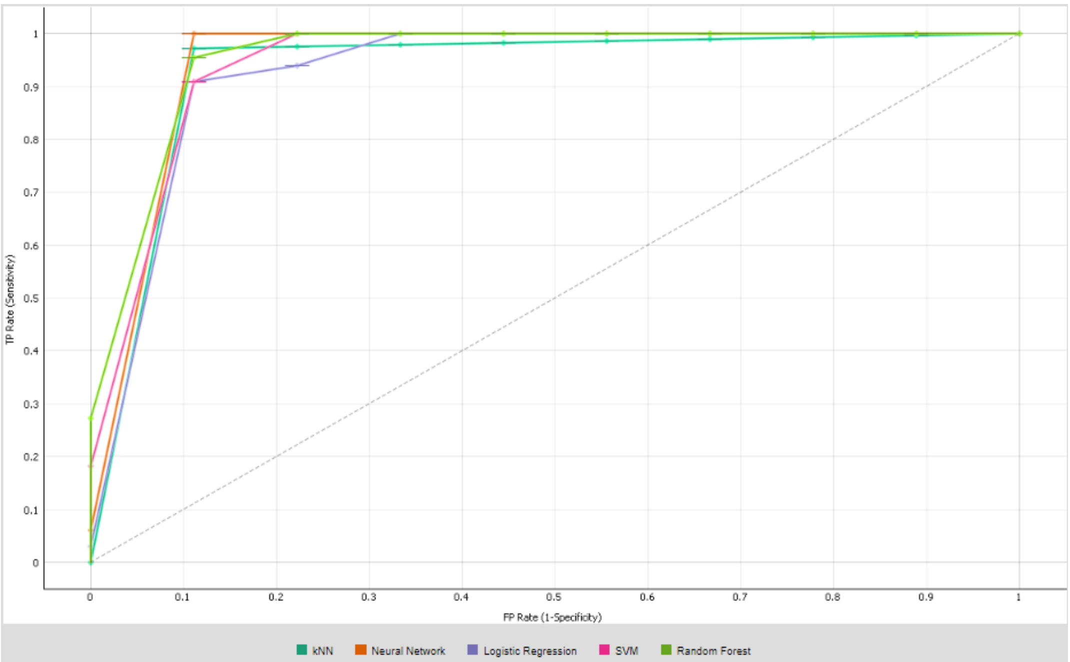


Figure 8 shows the ROC analysis plot of TP and FP graphs compared to normal breast tomography in the diagnosis of patients.

Figure 8
Malignant TP and FP ROC Analysis Graph



When the ROC curve approaches the upper left corner, it indicates a high true positive rate and a large area under the curve. This helps us to understand whether positives are successfully separated from negatives. Analysis of Table 4 reveals that the ANN model outperforms the other models, achieving an AUC value of 0.979.

Results

Tumors that cause cancer disease are divided into multiple classifications as benign, malignant and normal. In this study, benign, malignant and normal tumors that can cause breast cancer were classified. Early diagnosis plays a crucial role in improving the survival rate of breast cancer. In this study, an ANN algorithm is proposed for the early detection of the disease. The proposed model achieved 97.9% AUC, 89.3% CA, 89.2% F1 score, 89.3% precision, and 89.3% recall. Detecting malignant tumors is especially significant in breast cancer diagnosis. An evaluation of the results indicates that the proposed ANN accurately predicts both benign and malignant tumors. These results show that breast cancer can be detected quite successfully based on artificial intelligence. In this direction, it is thought that in future studies, expanding the dataset and learning on larger datasets will provide more successful results.

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Artificial Intelligence and Robotics: Integrated Systems and Applications

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Introduction

Since the beginning of the 21st century, technology and innovation have advanced rapidly, transforming every aspect of our lives. Among the pioneers of this transformation are artificial intelligence and robotics technologies. Artificial intelligence (AI) is a collection of algorithms and techniques that enable machines to exhibit human-like intelligence, while robotics deals with autonomous or semi-autonomous machines that perform physical tasks. The combination of these two disciplines has gone beyond the future seen only in science fiction works and turned into today's realities(Flasiński, 2016).

Integrating artificial intelligence and robotics technologies has enabled various applications, from industrial automation to medical devices, and the agriculture service sector. This integration increases the environmental perception and decision-making capabilities of machines, allowing for the development of more flexible, efficient, and intelligent systems (Brunette et al., 2009). For example, AI-powered robotic arms can perform precise surgical interventions and provide quality control on production lines. At the same time, applications such as autonomous vehicles and drones are concrete examples of how artificial intelligence and robotics technologies are transforming our lives (Jackson, 2019).

This book chapter addresses the integration of artificial intelligence and robotic systems, aiming to examine the key components, application areas, and challenges of these technologies. First, the historical development and basic principles of the concepts of artificial intelligence and robotics will be discussed, then how these two fields come together and how integrated systems are created will be examined. This section will also discuss the opportunities presented by integrated systems and the technical and ethical challenges faced. Developing artificial intelligence and robotics technologies not only transforms the industrial and service sectors but also deeply affects the general structure of society and the daily lives of individuals. Understanding the dimensions of this transformation and its possible future impacts is of great importance for those working in academia and industry. In this regard, this book chapter aims to provide readers with a comprehensive understanding of the integration of artificial intelligence and robotics.

Integration of Artificial Intelligence and Robotic Systems

Technological Components

Sensors

Sensors are devices that enable robotic systems to collect information from their surroundings. Different types of sensors are available, and each one detects different data. Image sensors cameras and devices such as LiDAR (Light Detection and Ranging) collect visual information about the environment (Voges & Wagner, 2021). Touch and pressure sensors enable robots to sense touch and pressure. Among the motion sensors, accelerometers and gyroscopes are used to track the movement and position of a robot. Proximity sensors help robots detect objects around them and avoid collisions (Tu et al., 2019).

Actuators

Actuators are components that allow robots to perform physical movements. They provide mechanical movement using electric, hydraulic, or pneumatic power. Electric motors are generally used for smaller, precise movements. Hydraulic actuators are used in applications that require more force, such as lifting heavy loads. Pneumatic actuators are preferred in situations requiring fast and powerful movements (Conrad et al., 2024).

Processors

Processors serve as the "brains" of robotic systems. By running artificial intelligence algorithms, it processes the data from the sensors and sends the appropriate commands to the actuators. Processors used in robotic systems generally must have high processing capacity and low energy consumption. For this purpose, general-purpose microprocessors (CPUs), graphics processing units (GPUs), and chips specialized for artificial intelligence (TPU and NPU) are used (Putra et al., 2024).

Software

Software is one of the most critical components that determine the functionality of robotic systems. This software processes sensor data, executes decision-making processes, and controls the robot's movements. Real-time operating systems (RTOS) enable robots to operate reliably and quickly (Putra et al., 2024). Artificial intelligence algorithms such as image processing, object recognition, path planning, and decision-making enable robots to exhibit intelligent behaviors. Control systems are software modules that precisely control the movements of robots.

These components play a critical role in the integration of artificial intelligence and robotic systems. While the sensors collect environmental data; processors process this data, software analyzes it, and actuators perform the necessary physical movements because of these analyses. In this way, robotic systems can perform complex tasks autonomously.

Algorithms and Learning Methods

Machine Learning

Machine learning aims to develop models that can make decisions by learning from data and discovering patterns. In robotic systems, machine learning is used to develop autonomous behaviors. For example, it is possible with machine learning algorithms for a robot to recognize objects in its environment, plan its motion paths, or optimize tasks. Basic machine learning methods include supervised learning, unsupervised learning, and reinforcement learning (Zhou, 2021).

Deep Learning

Deep learning creates multi-layered learning models using artificial neural networks. These models can extract meaningful information from large and complex data sets.

Deep learning in robotic systems is widely used, especially in tasks such as image processing and object recognition. For example, deep learning makes it possible for an autonomous vehicle to recognize pedestrians or other vehicles on the road. It is also used for learning robotic dexterity and manipulation tasks (Janiesch et al., 2021).

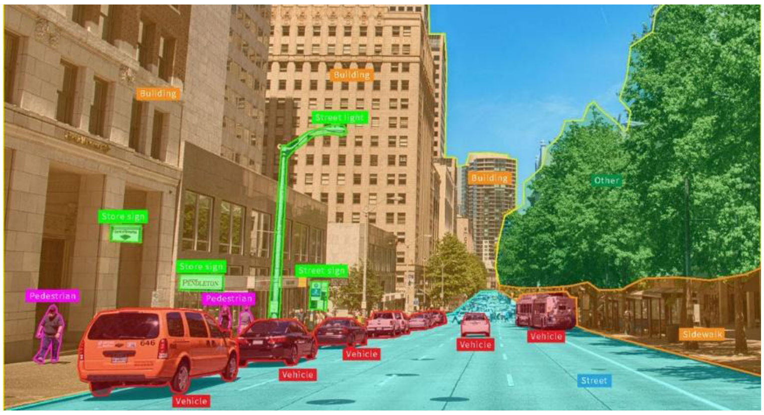
Natural Language Processing

Natural language processing (NLP) is a sub-branch of artificial intelligence used by robots to understand and generate human language. NLP involves text and speech analysis, giving robots the ability to interact with users naturally. For example, a robotic assistant in a home can use NLP techniques to understand and execute the user's voice commands. In addition, NLP algorithms can also be used for robots to answer questions and share information with humans (Galassi et al., 2020).

Computer Vision

Computer vision is the process of extracting meaningful information from image and video data. This technology allows robots to see and interpret the world around them. Computer vision techniques are used in tasks such as facial recognition, object detection, motion tracking, and 3D modeling. For example, an industrial robot can use computer vision techniques to detect defects on the production line. Computer vision is also critical for autonomous navigation and mapping (Xu et al., 2021). An example of a computer vision image is shown in Figure 1.

Figure 1.
Computer vision (Computer Vision, 2023)



These algorithms and learning methods allow robotic systems to understand, learn, and make decisions based on environmental data. Machine learning and deep learning enable robots to make data-driven decisions and optimize tasks, while methods such as natural language processing and computer vision help robots interact with humans and increase their environmental awareness. In this way, robotic systems become more flexible, intelligent, and autonomous.

Data Management and Analysis

Data Collection

For robotic systems to function successfully, they must constantly collect data from their environment and operations. Data collection is carried out through various sensors. For example, devices such as cameras, radars, LiDAR sensors, accelerometers, and microphones collect visual, spatial, motion, and audio data. This data helps robots understand their surroundings and gain situational awareness. In the data collection process, the accuracy and consistency of the data are of paramount importance because this data influences the robot's decisions (Mazhar et al., 2021).

Data Processing

The raw data collected is often not directly available in its raw form; This data needs to be processed to be converted into meaningful information. The data processing process includes filtering, noise reduction, feature extraction, and data transformation. For example, an image processing system can recognize objects by analyzing camera data, or a voice recognition system can convert spoken words into text. Data processing is a critical step for robots to make sense of the information they perceive and to make logical decisions using this information (Pansara, 2022).

Decision-Making Processes

After data collection and processing, robotic systems decide to act using this information. The decision-making process is driven by artificial intelligence algorithms and machine learning models. In this process, robotic systems choose the most appropriate action to achieve specific goals. For example, an autonomous vehicle can identify traffic signs and other vehicles and decide to proceed at the appropriate speed, or a manufacturing robot can decide which products need to be re-inspected for quality control. Techniques such as optimization, path planning, task assignment, and control strategies are often used in decision-making processes (Langfeldt, 2022).

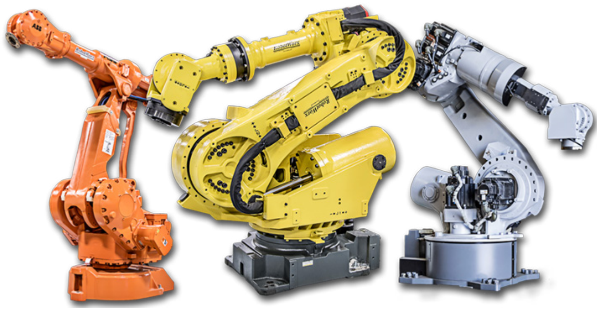
Data management and analysis ensure that robotic systems operate accurately, reliably, and effectively. Effective data management improves system performance, reduces errors, and ensures security. Furthermore, continuous data analysis allows systems to learn and improve over time, which contributes to robotic systems becoming more intelligent and autonomous.

Application Areas

Artificial intelligence and robotic technologies are used very effectively, especially in the field of industry. Robots are used to perform repetitive and precise jobs such as assembly, welding, and painting on production lines. Industrial robots operate at high speed and accuracy, optimizing production processes and reducing costs. Automation systems make production processes efficient by minimizing human intervention. Robots can automatically perform tasks such as material handling, packaging, and palletizing. In quality control processes, robots equipped with image processing and sensor technologies detect errors by checking the quality of the products and ensuring that quality standards are maintained (Arents & Greitans, 2022). An example of an industrial robot image is shown in Figure 2.

Figure 2

Industrial robot (Industrial robot, n.d.)



Recently, artificial intelligence and robotic systems have been used effectively in the field of medicine and health. Robotic surgical systems allow surgeons to perform precise and minimally invasive operations. Robotic surgery systems, such as da Vinci's, enable complex surgeries to be performed with small incisions. AI-powered medical imaging systems accelerate diagnostic processes and improve accuracy by analyzing

MRI, CT scans, and X-ray images. Rehabilitation robots help patients with the physical therapy process. These robots help paralyzed or injured patients regain their mobility (Han et al., 2022).

The agricultural sector has also been affected by these rapid technological advances. Agricultural robots increase efficiency by automating fruit and vegetable picking processes. These robots use sensors to determine plant maturity and optimize the harvesting process. Agricultural drones are used to monitor the condition of crops, perform spraying, and optimize irrigation plans. High-resolution images and data improve agriculture management. Agricultural robots and sensors analyze the chemical and physical properties of the soil. This data helps optimize fertilization and irrigation strategies (Cheng et al., 2023).

Another sector that attracts attention is the service sector. Robotic assistants used in homes and hotels help people by providing cleaning, food preparation, and other services. Customer service robots are used in banks, stores, and other service points. These robots perform tasks such as providing information to customers, giving directions, and performing simple actions (Graf & Eckstein, 2023).

Artificial intelligence technologies, which have become an indispensable part of the field of security and defense, are developing day by day and achieving very important successes in this field. Unmanned aerial vehicles are used in reconnaissance, tracking, and unmanned missions. They are widely used in military operations to collect information and ensure security in risky areas. Autonomous ground vehicles are used in operations such as reconnaissance, material handling, and operating in hazardous areas. These vehicles increase the safety of security forces and military personnel. Security robots are used to provide security in public spaces and private properties. Thanks to cameras, sensors, and artificial intelligence algorithms, it detects and reports suspicious behavior (Araya & King, 2022).

These application areas show how artificial intelligence and robotics technologies are integrated into different areas of our lives and the potential benefits these technologies offer. Each area plays a critical role in achieving goals such as increasing efficiency, reducing costs, and ensuring human safety.

Technical and Ethical Challenges

The safe operation of robotic systems is critical for the protection of both users and the environment. In terms of physical safety, robots need to be designed and operated in a way that does not harm humans. For example, industrial robots need to be equipped with safety systems to prevent collisions with humans in their work areas. Robotic systems can exchange data over internet connections and networks. This creates a potential target for cyberattacks and malware. Cybersecurity threats make it imperative that systems are protected against unauthorized access, data leaks, and operational disruptions (Amoo et al., 2024). Vulnerabilities in critical systems such as autonomous vehicles and medical robots can have serious consequences. The proliferation of artificial intelligence and robotics technologies brings with it the automation of many manual and routine tasks. This can lead to unemployment in some lines of work and requires employees to renew their skills. It can cause economic and social imbalances in society.

Robotic systems collect and process large amounts of data. This data may include users' personal information, habits, and behaviors. Data privacy is important to ensure that this information is not misused and that users' privacy is protected. Robots and devices used in healthcare work with sensitive personal data, so strict regulations are required in this regard. Situations may arise where artificial intelligence systems may make unethical decisions. For example, an autonomous vehicle may need to decide who to hurt in the event of an accident. Such situations require reflection on how to apply ethical principles during the programming of robots (Umoga et al., 2024).

The development of artificial intelligence and robotics technologies can create gaps in existing legal systems. Legal regulations are necessary to regulate the use of these technologies and to prevent possible misuse. For example, the introduction of autonomous vehicles to traffic should be controlled by legal regulations such as liability and insurance issues. International standards have been set to ensure the safe, effective, and ethical development and use of artificial intelligence and robotic systems. These standards cover various stages from the design to the use of the systems and harmonize the applications in different countries. The standards also ensure device interoperability and user safety.

These technical and ethical challenges are important issues to consider ensuring that AI and robotics technologies are developed and used responsibly and safely. Solving these challenges requires a great emphasis on ethical principles, user safety, and international cooperation in the technology development process.

Future Perspectives

Rapid advances in artificial intelligence and robotic technologies continue. More sophisticated artificial intelligence algorithms will enable robots to learn and perform more complex tasks. Significant advances are expected in the areas of deep learning, reinforcement learning, and natural language processing. Robots will become more autonomous, and better adapting to their environment and changing conditions. This is especially critical in systems such as autonomous vehicles and unmanned aerial vehicles. Nanorobots and biomimetic designs could revolutionize fields such as medicine and environmental sciences. These technologies can be used in applications such as cellular-level therapy and environmental cleanup (Wang et al., 2022).

The development of hybrid systems, where humans and machines work together, will bring major changes in business and everyday life. Co-operative robots (Cobots) are designed to work safely and efficiently side by side with humans. These robots increase productivity by assisting human workers in factories, laboratories, and healthcare facilities. Augmented Reality (AR) and wearable technologies facilitate human-machine interaction, enabling operators to control and interact with robots. For example, maintenance personnel can monitor the condition of robots and give them instructions through AR glasses. Biomechanical implants and prostheses integrated into the human body can increase physical abilities. Such technologies can improve the quality of life of people with disabilities and support people's physical workforce (Weiss et al., 2021). An example of a cobot image is shown in Figure 3.

Figure 3

Cobot (Cobot, n.d.)

The proliferation of artificial intelligence and robotic technologies can lead to significant changes in the social structure and labor market. While automation and artificial intelligence will cause some jobs to disappear, they will also lead to the emergence of new business areas and professions. Routine and repetitive tasks will be handled by automation, while jobs that require creative and strategic thinking will continue to be done by humans. The integration of robots and artificial intelligence into everyday life could change the way society interacts with. For example, robotic assistants and smart home systems can provide seniors and people with disabilities with greater independence. At the same time, there are risks such as reduced social interactions between people. In the future, individuals will need to have skills that are compatible with technology. Education systems can be restructured to focus more on areas such as digital literacy, artificial intelligence, data science, and robotics (Tapalova & Zhiyenbayeva, 2022).

These perspectives are important for understanding the future implications and potential of AI and robotics technologies. Technological advances, human-machine collaboration, and societal impacts present both opportunities and challenges. Therefore, during the development and implementation of these technologies, it is necessary to pay attention to ethics, security, and social responsibility issues.

Conclusions and Suggestions

The integration of artificial intelligence and robotic systems has led to radical transformations in various industries in the modern world. The efficiency, accuracy and speed provided by these technologies in areas such as industry, medicine, agriculture, service sector and security have created new opportunities while improving business processes. However, significant challenges have also emerged, such as changes in the labor market, ethical issues, safety risks, and the necessity of regulatory frameworks. Future developments need to be carefully considered from an ethical and societal point of view, as well as technological innovations.

It is critical to increase R&D investments to move artificial intelligence and robotic technologies to advanced levels. Innovative solutions should be developed and implemented, especially in areas such as advanced algorithms, autonomous systems and unmanned vehicles. Training programs must be restructured to prepare the workforce of the future for these technologies. Training programs should be created in areas such as artificial intelligence, data science, robotics engineering, and cyber security, and continuing training opportunities should be offered for existing employees. In addition, digital literacy and critical thinking skills should be encouraged.

A comprehensive ethical framework should be established to ensure the ethical use of artificial intelligence and robotic systems. There should be clear and consistent regulations on data privacy, algorithmic transparency, and responsible use of AI. In addition, legal regulations should be developed at national and international levels to ensure the safe and fair use of these technologies. It is important to ensure a broad dialogue on the societal impact of artificial intelligence and robotic technologies. Raising public awareness about these technologies and listening to their concerns will facilitate social acceptance and adaptation. In addition, cooperation and dialogue between policymakers, academics, industry leaders, and non-governmental organizations should be encouraged. The safety standards of artificial intelligence and robotic systems should be strengthened. Strong defense mechanisms should be developed to protect against cybersecurity threats. In terms of physical safety, regulations should be made, and strict inspections should be carried out to ensure safe working conditions for robots.

More advanced algorithms should be developed in areas such as deep learning, explainable artificial intelligence, reinforcement learning, and hybrid AI models. This will enable artificial intelligence to be used effectively in more complex and dynamic tasks. Studies on hybrid systems that optimize human and machine collaboration should be increased. Cobots and augmented reality technologies can offer more efficient and safe solutions for human-machine interaction. Research in areas such as biomechanical implants, prosthetics, and nanorobots could offer important innovations in terms of medical treatments and augmenting human capabilities. Developments in this area can lead to major advances in the medical and healthcare industry.

Studies should be carried out on the development and implementation of artificial intelligence and robotic systems by the principles of sustainability and justice. This aims to ensure that technologies fairly benefit all segments of society and minimize their environmental impact. International cooperation in the field of artificial intelligence and robotics should be encouraged and universal standards should be set. This will ensure that technologies are used safely, ethically, and effectively on a global scale.

In conclusion, advances in artificial intelligence and robotics technologies have the potential to lead to major changes in all areas of society. To ensure that these changes are positive, great importance should be given to the principles of ethics, safety, and social responsibility in technology development processes.

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Forest Fire Risk Analysis with Visual Data

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Introduction

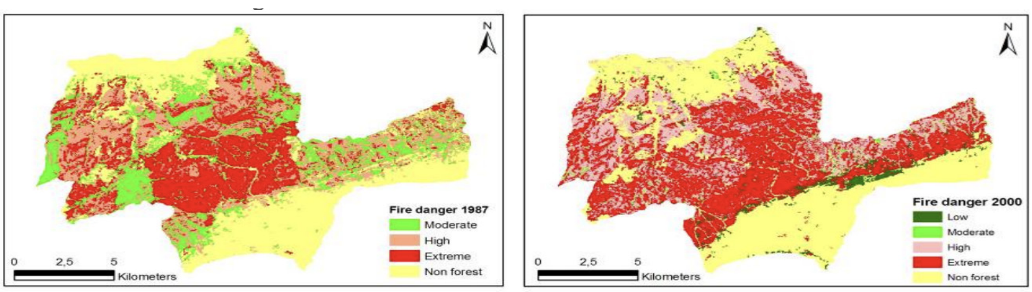
Forest fires are large-scale disasters that have serious impacts on both natural ecosystems and human societies worldwide. Millions of hectares of land are destroyed by forest fires each year, disrupting the environmental balance and threatening biodiversity. Developing effective risk assessment methods to manage and prevent the effects of fire is critical to environmental protection and disaster management.

Visual data plays an important role in forest fire risk analysis. In recent years, technological advances have enabled the use of visual data collection tools such as satellite and drone technology. Such data allows you to monitor large areas quickly and effectively. Remote sensing technologies, in particular, enable the collection of large-scale data, allowing detailed analysis for fire risk assessment. Satellite images are used to analyze forest cover, vegetation density, and topographic changes (Lechner & Martin, 2020).

However, collecting visual data is not enough. This data needs to be processed and analyzed intelligently. This is where machine learning and deep learning algorithms come into play. These algorithms can be used to predict fire risk and identify potential risk areas by processing information from visual data. Deep learning techniques provide significant benefits in fire risk assessment, especially because they can detect complex patterns and anomalies in large data sets (Smith & White, 2021).

Figure 1

Spatial Fire Danger Maps for Korudag Forest District Derived from the 1987- 2000 Landsat Images (Saglam, Bilgili, Dincdurmaz, Kadiogullari, & Kucuk, 2008)



Visual data analysis is an important tool in wildfire suppression as it helps determine the likelihood of fire spread, affected areas, and possible response strategies. For example, factors such as temperature changes, vegetation changes, and humidity provide evidence that fire risk may be increasing. This data plays a key role in determining both short-term and long-term fire prevention strategies.

This chapter provides a comprehensive overview of the role of visual data in wildfire risk analysis. The chapter examines the role of remote sensing technology and machine learning algorithms in this process and provides detailed information on how this data is collected and analyzed. It also discusses the effectiveness and application areas of these technologies in fire protection and evaluates the strengths and weaknesses of existing methods.

Theoretical Background

Forest fire risk analysis is a comprehensive field of research aimed at understanding the causes of fires, the dynamics of fire spread, and the control of these processes. The process combines both traditional methods and modern technologies and is based on a variety of multidisciplinary approaches. This section describes the theoretical basis of the forest fire risk assessment method and the visual data analysis techniques used in this process.

Forest Fire Risk Assessment Methods

Wildfire risk assessments have traditionally relied on estimates based on fire history, weather data, and vegetation conditions. Traditional methods typically consider static factors such as fire history and fuel type to determine fire risk.

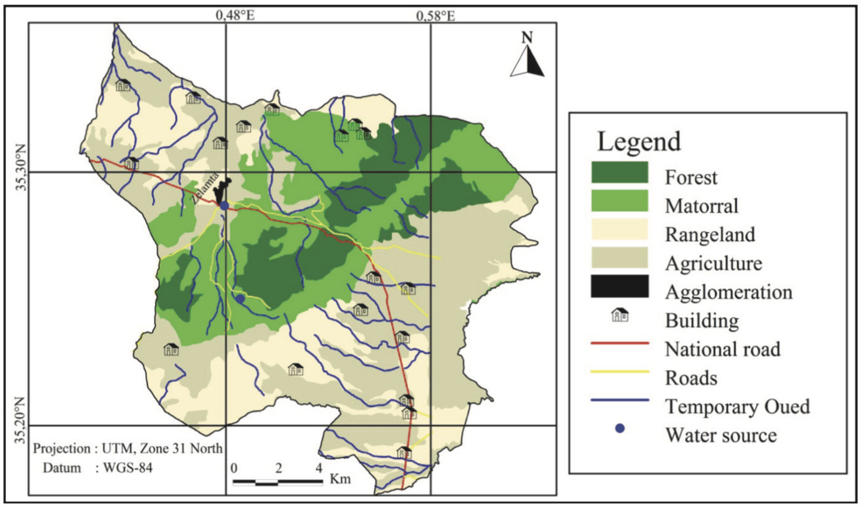
However, these methods may not adequately reflect the dynamic nature of fire risk and constant changes in environmental variables. This can lead to poor fire management strategies and cause fires to spread faster than expected (Lechner & Martin, 2020).

Modern technology is now integrated into the wildfire risk assessment process. Remote sensing technology plays an important role here. Satellite images allow you to observe large areas and analyze them for fire risk. In particular, indices such as the "Normalized Difference Vegetation Index (NDVI)" are used to determine fire risk by determining the health and density of vegetation. It is also possible to analyze topography and land use using satellite data (Smith & White, 2021).

Areas of Use of Visual Data

Figure 2

Occupation and Land Use Mapping of the Study Area (Ahmed, Baig, & Shahid, 2022)



Visual data is one of the most effective tools for wildfire risk analysis. This data provides a comprehensive perspective to assess the effects of fire before, during, and after the fire. Although remote sensing techniques are used specifically to determine wildfire risk, they also play an important role in assessing the resulting damage. Satellite imagery is used to identify areas affected by fire and develop strategies for repairing these areas. Drone technology is also an effective tool for collecting detailed data in smaller and less accessible areas (Zhang, Zhang, & Lu, 2020).

Another advantage of these technologies is the ability to analyze large data sets to determine fire risk. Big data analytics and artificial intelligence play an important role here. Deep learning algorithms, in particular, can detect complex patterns and indicators of fire risk by processing large amounts of visual data. These algorithms can be used to predict possible fire-starting and spreading paths.

Deep Learning and Machine Learning Methods

In recent years, deep learning and machine learning techniques have played an important role in visual data analysis. These techniques are used to solve complex problems such as forest fire risk analysis and provide greater accuracy than traditional methods. Deep learning has made great progress, especially in the fields of image classification and object recognition. Deep learning models such as "Convolutional Neural Network (CNN)" can be used to detect fire-prone areas by extracting meaningful information from visual data (Yang & Xu, 2021). These methods work effectively on large datasets and improve our ability to predict fire risk. This plays an important role in developing fire management strategies and optimizing emergency response processes. Deep learning algorithms, especially those used to understand the spread dynamics of fire and model these dynamics, are important for firefighting efforts.

Data Fusion and Integration of Multi-Source Data

In addition to visual data, wildfire risk analysis uses a variety of data sources, including meteorological data, topographic data, and land use information. Combining these data (data fusion) allows for more comprehensive and accurate risk analysis. By combining data from different sources, data fusion techniques can be used to more accurately assess fire risk. Machine learning algorithms are important tools for combining different types of data to obtain meaningful results (Smith & White, 2021). Data fusion plays an important role, especially when analyzing large amounts of data and integrating information from different data sources. These technologies increase the accuracy of wildfire risk analysis, allowing for more accurate predictions of fire causes and assessments of the likelihood of fire spread.

Methods

This section details how data used for forest fire risk analysis are collected, processed, and analyzed. This study covers the process used to obtain visual data, the techniques used to process these data, and the evaluation of the results.

Data Collection

The most basic data source for forest fire risk analysis is visual data. Visual data will be collected in the study using satellite images, drone images, and other remote sensing techniques. High-resolution satellite images in particular can monitor forest areas from a broad perspective and provide important information such as vegetation, topography, and land use required for risk analysis. Satellite platforms used in the data collection process may include satellites that provide broadband data: Sentinel-2, Landsat, and MODIS. These satellites provide data over different periods, creating a comprehensive data set for forest fire risk analysis. The collected data is prepared for processing in the GIS (Geographic Information System) environment.

Data Processing

Processing of collected visual data is one of the most important stages of the wildfire risk analysis process. At this stage, the quality of the data is increased which makes it more suitable for analysis. Data processing may include the following steps:

- **Pre-Processing:** Radiometric and geometric corrections are performed on satellite images. Radial correction optimizes the brightness and contrast settings of the image, while geometric correction provides the geographical location of the image. This stage is important to ensure that the data meets the accuracy of the analysis.
- **Visual Data Analysis:** The processed data is analyzed using specific indicators and features for forest fire risk analysis. Indexes that provide information about vegetation and moisture status, such as "Normalized Difference Vegetation Index (NDVI)" and "Normalized Difference Moisture Index (NDMI)", are calculated. These indicators are important in determining forest fire risk. indexes provide important indicators in determining forest fire risk.
- **Topographic Analysis:** To assess wildfire risk, topographic features such as terrain slope, elevation, and orientation are analyzed. These analyses help determine how a fire will spread and what potential hazard areas exist.

Machine Learning and Deep Learning Models

After the data processing phase, a more detailed risk analysis is performed using machine learning and deep learning algorithms. This study aims to automatically classify visual data and identify fire-prone areas using deep learning techniques such as Convolutional Neural Networks (CNNs). This process includes the following steps:

- **Model Training:** Visual data is used with labeled fire risk data to train deep learning models. By recognizing specific visual patterns, the model learns how those patterns relate to fire risk.
- **Model Validation:** The trained model is tested on a validation dataset and its performance is evaluated. The validation process is important for determining the accuracy and generalization ability of a model.
- **Prediction and Classification:** Based on new visual data, the trained model makes predictions and classifies areas prone to wildfires. This process is used to map risky areas and develop fire management strategies.

Data Fusion and Multi-Source Data Analysis

Combining data from different sources (data fusion) plays an important role in increasing the accuracy of wildfire risk analysis. In addition to visual data, meteorological data, topographic data, and land use information are also included in the analysis process. Data fusion enables more comprehensive and accurate risk analysis by integrating information from different data sources.

- **Meteorological Data Integration:** Meteorological data such as temperature, humidity, wind speed, and direction play an important role in the analysis of forest fire risk. These data are evaluated together with visual data to determine the fire risk.
- **Topographic Data Integration:** Topographic features such as terrain slope, elevation and orientation are important factors affecting the probability of fire spread. These data are analyzed in parallel with visual data to increase the accuracy of fire risk estimates.

Data fusion is used with machine learning algorithms to increase the accuracy and reliability of results obtained during the wildfire risk analysis process.

Applications and Examples

In this section, the application areas and practical examples of the methods used in forest fire risk analysis are discussed. These applications reveal the validity and reliability of the method by presenting the results obtained in different geographical regions and different environmental conditions.

United States: California Fires

Large-scale wildfires have been occurring frequently in California, especially in recent years. Analysis of visual data plays an important role in the management and prevention of these fires. Fires in California generally occur in hot, dry climates and in areas where fires can spread rapidly with wind. Satellite images and remote sensing techniques are widely used in these areas to determine fire risks and ensure rapid intervention.

Lechner and Martin (2020) state that remote sensing technology used in California fires can determine fire risk with high accuracy and help make effective fire management decisions. Thanks to these technologies, sensitive areas can be identified in advance and preventive measures can be better planned before fires break out. Deep learning models, especially those developed to predict wildfire occurrence, play a critical role in California's fire management process.

Australia: Major Fires of 2019-2020

The massive bushfires that occurred in Australia from 2019 to 2020 had a major impact worldwide. Risk analysis for these fires using visual data and machine learning algorithms provided critical information to understand the spread and suppression dynamics of the fire. Smith and White (2021) state that the data fusion techniques used in these fires integrated data from different sources, resulting in more accurate and comprehensive results in fire risk analysis.

The example of the bushfires in Australia demonstrates the importance of data fusion. Weather data, satellite imagery, and terrain information were combined to identify high-risk areas in advance and develop emergency response strategies for these areas. Satellite imagery was also used effectively to assess post-fire damage and plan recovery efforts.

China: Applications of Artificial Intelligence in Forest Fire Management

China is one of the countries with high fire risk due to its large forest area. In recent years, AI-based solutions have been developed for forest fire prevention and management. Zhang, Zhang, and Lu (2020) emphasize that deep learning algorithms used in forest fire risk analysis in China provide high accuracy, especially when processing visual data, and can detect complex fire risk patterns. hese applications use deep learning models such as Convolutional Neural Networks (CNNs) to process data obtained from satellite images of large forest areas and classify fire-prone areas. These AI-based approaches have played an important role in the development of fire management strategies and effective prevention of the spread of fire. These applications in China have influenced the development of similar fire protection systems in other countries.

Türkiye: Early Warning Systems Against Forest Fires

Turkey is one of the countries that attaches the most importance to remote sensing technology and early warning systems in combating forest fires. Especially in the Mediterranean region, the risk of fire increases significantly with the increase in summer temperatures. Yang, Xu et al. (2021) state that an early warning system developed in Turkey allows early detection of fire-prone areas using meteorological data and satellite images.

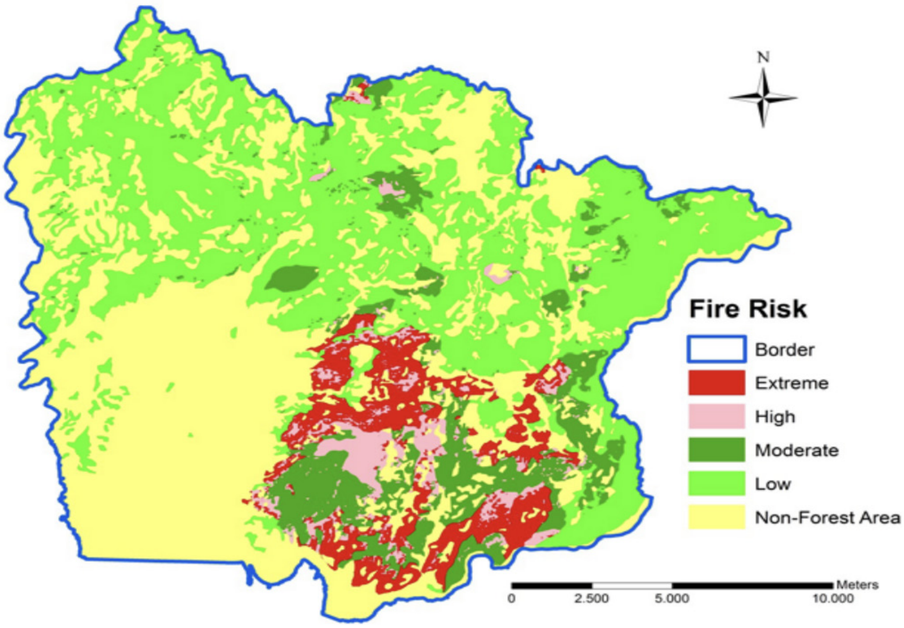
These applications in Turkey show how effective the use of modern technology is in extinguishing forest fires. Early warning systems allow rapid intervention in cases where the risk of fire is high and play an important role in extinguishing fires. The effectiveness of these systems contributes to the development of fire prevention strategies at local and national levels.

Results and Discussion

This research focuses on the use of visual data in forest fire risk analysis and the processing of these data using machine learning techniques. The results show that visual data plays an important role in determining forest fire risk and modern analytical methods can estimate fire risk more accurately and effectively.

Figure 3

Fire Risk Maps (Sivrikaya, Saglam, Akay, & Bozali, 2014)



Effectiveness of Visual Data

Research results show that satellite images and other remote sensing data can determine forest fire risk with high accuracy. In particular, the use of indices such as "Normalized Difference Vegetation Index (NDVI)" and "Normalized Difference Moisture Index (NDMI)" provides important information about vegetation health and moisture content, which can be used to identify areas with high fire risk. A study by Lechner and Martin (2020) emphasizes that fire risk analysis using satellite images in California plays an important role in planning pre-fire preparedness measures. Similarly, the use of satellite images in applications in Australia and China has made significant contributions to the determination of fire risk and the development of intervention strategies.

The Role of Machine Learning and Deep Learning Methods

Machine learning and deep learning techniques offer significant benefits for forest fire risk analysis. Deep learning algorithms such as convolutional neural networks (CNNs) discussed in this study achieve high accuracy in the automatic processing and classification of visual data. A study by Zhang, Zhang, and Lu (2020) shows that deep learning models in forest fire management in China are successful in identifying fire-prone areas. These results demonstrate how machine learning techniques can be effectively used in fire risk analysis and how these techniques can be integrated into fire management decision-making processes. The accuracy of deep learning algorithms is critical for predicting fire risks and taking preventive measures.

Importance of Data Fusion

Another important finding discussed in this study is that data fusion increases the accuracy of bushfire risk analysis by combining different data sources. Smith and White (2021) state that data fusion, which combines meteorological data, terrain information, and satellite imagery for fire risk analysis in large fires in Australia, provides more comprehensive and reliable results in fire management. Data fusion allows for more accurate detection of high-fire risk areas by integrating information from different sources. This integration plays an important role in the development of fire management strategies and contributes to the planning of measures to prevent the spread of fire.

Limitations of the Study and Future Studies

Although this study provides important information on wildfire risk analysis, some limitations should be considered. First, data quality and availability play an important role in fire risk analysis. The resolution and update frequency of satellite images can affect the accuracy of the analysis. In addition, the performance of machine learning algorithms is directly related to the diversity and quality of the datasets used. Future studies can increase the generalizability and accuracy of this method by using more datasets in different geographical regions. In addition, the development and optimization of machine learning algorithms can provide better fire risk analysis results. Further development of data fusion techniques has the potential to increase the effectiveness of fire prevention strategies and expand the scope of research in this area.

Future Studies and Directions

This study has addressed the current approaches to forest fire risk analysis with visual data and highlighted the effectiveness of these methods. However, future studies need to be enriched with new technologies and methods to achieve more successful results in combating forest fires. In this section, future research and possible directions in this field will be discussed.

Advanced Data Integration and Fusion

Future research is expected to further address the integration and fusion of diverse data sources. In addition to data already in use, such as satellite imagery, weather data, and terrain information, data from drones and other ground-based sensors can be incorporated into this fusion process to increase the accuracy of fire risk analysis. As Smith and White (2021) point out, integrating more data sources allows for more comprehensive and reliable analysis.

Real-Time Data Processing and Forecasting Systems

Rapid response is essential in combating forest fires. Therefore, future research should focus on real-time data processing and forecasting systems. Real-time data processing allows for more dynamic and instantaneous fire risk analysis. Such systems can continuously monitor fire hazards and provide immediate warnings in fire-prone areas. This will help develop a rapid response strategy to prevent the spread of fire.

Development of Artificial Intelligence and Machine Learning Algorithms

The use of machine learning and artificial intelligence (AI) technologies in fire risk analysis has enabled significant progress in this field. However, these technologies need further development and optimization. In particular, deep learning can increase the ability of algorithms to process more complex data. Although research by Zhang, Zhang, and Lu (2020) has demonstrated the success of such algorithms, developing algorithms customized for different climatic conditions and forest structures can increase the accuracy of fire risk analysis.

Human-AI Collaboration and Decision Support Systems

Another direction for future research could be the development of decision-support systems that enhance collaboration between humans and AI. The human factor still plays a significant role in fire management, and AI-based systems must be designed to support expert decision-making. Such systems could help emergency crews make faster and more accurate decisions by making fire risk analysis results easier to understand.

Sustainable Fire Management Strategies

Sustainability is an important element in combating forest fires. Future research should focus not only on fire risk reduction but also on post-fire ecosystem recovery and the development of long-term fire management strategies. This requires developing long-term plans to minimize post-fire damage and protect forest ecosystems. In this context, the development and implementation of sustainable forest management policies will play an important role in reducing future fire risks.

Global Collaboration and Data Sharing

Finally, global cooperation and data sharing in the field of forest fire risk analysis and management is an important issue for future research. Sharing data from different fire risk geographic areas and creating a global database can increase the accuracy of fire risk analyses and contribute to the development of international fire management strategies. Such cooperation will enable the development of more effective and coordinated approaches to combating forest fires.

Conclusion

This study has discussed in detail the use of visual data in forest fire risk analysis and the importance of processing these data using machine learning and deep learning techniques. It has been shown that visual data plays an important role in forest fire prevention and management, and especially satellite images and indicators derived from these images can contribute greatly to the identification of areas at high fire risk. Integrating visual data into fire management strategies plays an active role in determining actions to be taken before a fire and offers significant risk reduction opportunities.

This study highlights the benefits of machine learning and deep learning techniques in forest fire risk analysis. Deep learning algorithms such as convolutional neural networks (CNNs) have been shown to detect fire-prone areas more accurately and quickly because they can process large data sets. These technologies offer a more scalable and dynamic fire management solution compared to traditional methods and play a critical role in early fire detection and response. An important finding of this study is that data fusion increases the accuracy of forest fire risk analysis. By combining and analyzing various data sources, especially meteorological data, topographic information, and satellite images, high-fire risk areas can now be identified more accurately.

The results highlight the potential of data fusion in disaster management and the importance of further research in this area. It has also been shown that data fusion can play an important role not only in fire risk analysis but also in post-fire damage assessment and ecosystem restoration. The results of this study demonstrate the effectiveness of existing methods in forest fire risk analysis and also point to many areas for future research. In particular, the development of real-time data processing systems, the optimization of machine learning and deep learning algorithms, and the creation of decision support systems that enhance human-AI collaboration can bring significant advances to the fire prevention process. Developing sustainable fire prevention strategies and improving global cooperation and data sharing are essential for long-term success in combating forest fires.

In conclusion, this research demonstrates that visual data and modern analytical techniques can be used effectively in forest fire risk analysis and make a significant contribution to the literature in this field. The results demonstrate the importance of visual data in determining fire risk and highlight the importance of integrating these methods into fire management processes. Future research in this area is expected to further improve the accuracy and effectiveness of wildfire risk assessments, thereby enabling significant advances in protecting human life and ecosystems.

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Green Metric Approaches in Gas Chromatography

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Introduction

Since introducing the first principles of green chemistry 25 years ago, ideas about sustainability and chemistry have progressed with solid and permanent steps, with companies adding sustainability officers and universities adding curriculum and chemistry-related processes. In this chapter, we will investigate the influence of green chemistry, which is not much talked about, on gas chromatography (GC). What is green chemistry by defining it? What is not? We will seek answers to your questions. Then is gas chromatography green? How can it be greener? We will put forward the latest developments in the literature by bringing these questions to the agenda.

The 12 Principles of Green Chemistry were explained in the late 1990s, and awareness was raised on this issue like many others. It was difficult and painful for humanity to enter the age of enlightenment after the dark age. However, scientific innovations and developments and the technology they bring are quite rapid. Especially the change after the Industrial Revolution is dizzying. Although these conveniences and changes make people happy, they have created another problem: environmental pollution. Although awareness of this situation and searches for a solution were expressed in the 1950s, the real attention-grabbing implementation was in the 1990s. In this regard, analytical chemistry and analysis methods have also played their part and interacted. In our age, analysis is everything; measuring, determining the existing amount, or seeking answers to what exists is a constant need in every field such as food, cosmetics, industry, medicine, etc. Therefore, it is important and necessary not to underestimate the effectiveness of analysis methods, to look for greener, easier methods, and to be ready for changes (Malissa & Roth, 1987; Pimentel & Coonrod, 1985).

More recently, the United Nations has established the 17 Sustainable Development Goals (UN SDGs) that guide policymaking across government and institutional platforms, including the 12 Principles of Green Chemistry and the UN Sustainable Development Goals, which focus on viable methods in chemical sciences and analytical chemistry research and development guides. This environmental movement is one of the most important points of development and sustainability. The understanding of quality also requires this. Because quality means sustainability, applicability, and convenience. Green chemistry touches upon sustainable points such as ease of application, less reagent use, analysis time, and analyzer health, and measures them with various metrics. These metrics appeal to visual perception as well as on a numerical scale. While it offers a general perspective on the developed or applied method, it also has detailed applications, examining each step. But no matter what view they present, their underlying measurement purpose is to protect human health, reduce environmental pollution, and consume less energy (Anastas, 1999; Keith et al., 2007).

Green analytical chemistry

Green analytical chemistry supports the reduction of toxic chemicals and waste and saves energy in the processes besides using minimum waste. In achieving these goals, the 12 principles of green chemistry serve as an important guide (Sajid & Płotka-Wasylka, 2022).

These principles of green analytical chemistry;

1. Waste management

2. Atomic economy

3. Less hazardous chemical synthesis

4. Scheming safer chemicals

5. More reliable solvents and excipients

6. Plan for energy capability

7. Greener syntheses with renewable raw materials

8. Reduction of by-products (derivatives)

9. Catalysis

10. Device of twist

11. Elimination of pollution for all time

12. More credible chemistry to prevent accidents (Sajid & Płotka-Wasylka, 2022; Sogut & Çelebi, 2020)

Over time, various measurements have been improved to evaluate the greenness of analytical procedures. These are specific or general and feasible for analytical methods. (Płotka et al., 2013; Sajid & Płotka-Wasylka, 2022).

Green analytical chemistry methods

Recent research indicates that to make analytical methodologies more environmentally friendly there needs to be a combination of small changes to current methods and big innovations that completely change how analysis is done. Some strategies include substituting reagents and solvents using automation and advanced flow techniques to reduce chemical usage miniaturization and measuring analytes directly in the field rather than through sampling (Płotka et al., 2013).

Analytical Method Volume Intensity (AMVI)

The analytical method of volume density is applied to evaluate liquid chromatographic methods. Determining the solvent used in this application and the total volume of waste resulting from the experiment with a specific procedure allows this method to be carried out (Imam & Abdelrahman, 2023).

Chemical hazard assessment for management strategies (CHEMS-1)

It is a strategic evaluation method that aims to put chemical release data into a systematic mechanism to evaluate the toxic effects of the chemicals used within the procedure in the experiment and the toxicity effects that may occur in case of exposure to these chemicals (Swanson et al., 1997).

Chromatography environmental assessment tools

This approach offers an extremely effective yet simple application method used to profile gas chromatography (GC) methods in terms of their suitability for green chemistry. Its goal is to reduce the damage caused by organic reagents to the environment and the public health used in GC methods. The environmental assessment tool (EAT) carefully examines the health, environmental, and safety topics for all chemicals included in the chromatographic methods. Also, it calculates a total score by rating the suitability of the different methods used with an understanding of green chemistry. It allows the comparison of calculation methods about their suitability for green chemistry (Gaber et al., 2011; Shi et al., 2023).

Life cycle assessment (LCA)

This method is applied to products to measure environmental impact factors (Jacquemin et al., 2012).

PROMETHEE: Preference ranking organization method for enrichment evaluations

The purpose of PROMETHEE, which is used as a multi-metric priority-setting method, is to be used as a decision support tool in problems such as selection and clustering. Here, the advantages and disadvantages of the options available for decision are compared, and the aim is to reach the most appropriate solution (Karasakal et al., 2019).

Modified eco-scale with green certificate

Aiming at the quantitative method of green parameters, the modified eco scale with green certification evaluates the process of hazards, reagents, energy, and waste. The application can be applied to sample preparation and analytical measurement procedures, while values are analyzed semi-quantitatively. The result of this analysis interprets the inherent toxicity and risks related to the use of reagents and assists in correct classifications. The disadvantages are that only numerical data is presented and no evaluation is made for sampling (Shi et al., 2023).

- ***HEXAGON***

This method, which aims to evaluate the optimum conditions or tests for analytical methods, can be applied to sample preparation and analytical measurement procedures and allows qualitative and quantitative evaluation to be carried out (Shi et al., 2023).

TOPSIS: Order of preference technique based on similarity to the ideal solution

Multi-criteria decision analysis is a group of tools used to score and rank alternatives according to the evaluation criteria studied, and TOPSIS is one of the multi-criteria decision analysis tools applied in the preference of the best alternative among others (Al-Hazmi et al., 2016; Nowak et al., 2020).

- ***RGB***

In the RGB metric, a global evaluation of analytical methods or procedures is achieved by utilizing the main colors red, green, and blue. The red (R) color represents the achievement of these methods, typically evaluated through classical validation techniques. The green (G) color means reliable and eco-friendly, such as hazards related to reagents or waste, energy consumption, and vocational dangers. The blue (B) color represents productivity and practical effectiveness. Each attribute is assigned a color score (CS) ranging from 0% to 100%, providing a comprehensive and transparent measurement, qualitatively or quantitatively. This approach enables the equation of different analytical procedures and predicts all possible applications for newly developed methods. However, the evaluation procedure can be tiring and difficult, and there is no clear method to detect the weights of the different criteria used in the evaluation (Shi et al., 2023).

NEMI: National Environmental Method Index

It is one of the oldest methods used to measure the greenness of analytical procedures, and this method creates a circle divided into four areas. Each area explains an alternative requirement of this method and is colored red or green depending on the requirements (Sajid & Płotka-Wasylka, 2022).

The requirement for green labeling of the initial field is that the chemicals used in the process must be toxic, bio-accumulative, and have no lasting effects. The second area requires no chemicals to be the harmful waste D, F, P, or U lists. If the pH range of the sample is between 2 and 12, the third area is marked green. Finally, the fourth area is marked green when the amount of waste generated in the process is 50 grams. NEMI pictogram is given for example in Figure 1(Sajid & Płotka-Wasylka, 2022).

Figure 1
An Example of NEMI Pictogram

In addition to the advantage of being easily understandable, NEMI has two important disadvantages: it takes a long time to collect information, and it is very general.

Analytical eco-scale

Analytical eco-scale, one of the most common green analytical chemistry methods, is measured by subtracting some penalty points from 100 points. Here, 100 points are defined as the ideal green analysis. After subtracting penalty points from this value, the closer the remaining value is to 100, the greener the analysis is. Penalty points vary depending on the quantity and quality of the chemicals to be used, the energy consumption in the process, occupational hazards in the conditions, the amount of waste to be generated, and the methods of processing the waste (Sajid & Płotka-Wasylka, 2022).

Penalty scoring begins with assigning penalty points to the solvent and reagent. Here, the pictograms of the chemical are considered. Each hazard pictogram on chemical bottles constitutes a penalty point; if the pictogram is classified as dangerous, this number is multiplied by two, and if the pictogram is classified as a warning, the number is multiplied by one. The resulting hazard score is multiplied by one if the chemical amount is less than 10 mL or 10 g, by two if it is between 10 and 100 mL (or grams), and by three if it is greater than 100 mL (or grams) (Sajid & Płotka-Wasylka, 2022; Soyseven et al., 2023).

When assigning penalty points to energy consumption, energy consumption per sample is considered (Sajid & Płotka-Wasylka, 2022).

- Energy consumption per sample ≤0.1 kWh = 0.
- Energy consumption per sample: ≤1.5 kWh = 1
- Energy consumption per sample: ≤1.5 kWh = 2

While assigning occupational hazard penalty points, three points are assigned for any gas or vapor released into the air. If the process is in seclusion, no points are assigned. Penalty points are given depending on the amount of waste and the treatment status of the waste (Sajid & Płotka-Wasylka, 2022; Tobiszewski et al., 2015).

Table 1
Scoring According To The Amount Of Waste And The Treatment Status Of The Waste

Amount of waste	**Penalty points**
<1 mL or 1 g	1
1–10 mL or 1–10 g	3
>10 mL or 10 g	5
Waste Treatment Method	**Penalty points**
Recycle	0
degradation	1
Passivation	2
No Purification	3

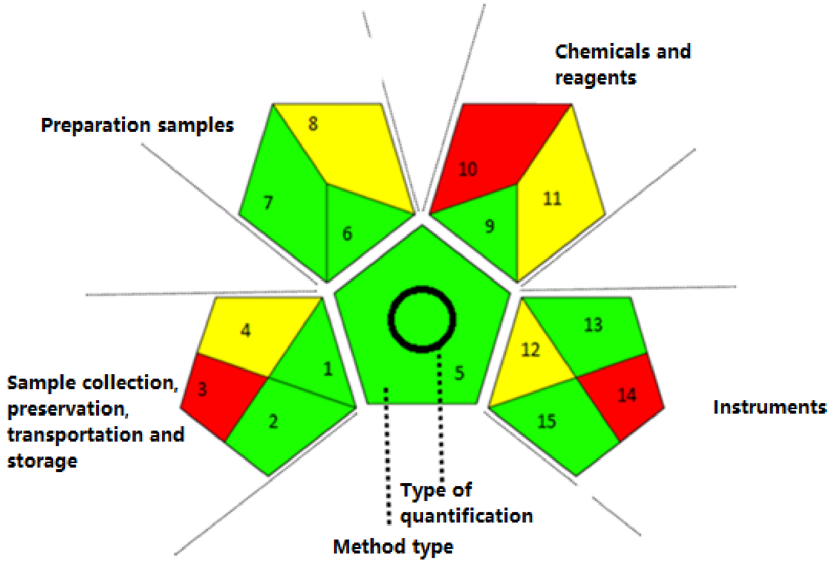
The final score is obtained by adding all the points and subtracting them from 100. A process with 75 or above is defined as optimum green analysis. A process with a scoring range of 50–75 is considered acceptable green analysis, while a process below 50 points is defined as insufficient green analysis (Sajid & Płotka-Wasylka, 2022).

Analytical eco scale gains an advantage by providing quantitative evaluation, as it is carried out with numerical evaluation out of 100. However, disadvantages arise due to the danger of pictograms and the effects of waste and chemicals on the environment not being fully taken into account (Sajid & Płotka-Wasylka, 2022; Tobiszewski et al., 2015).

- ***GAPI: Green analytical procedure index***

GAPI is a pictogram consisting of five pentagrams, as shown in Figure 1, and each pentagram here describes the environmental impacts of the analytical method.

Figure 2
GAPI Pentagram (Sajid & Płotka-Wasylka, 2022)



The first pentagram is divided into four parts. The first of these parts is related to the collecting sample method. If the sample is collected online, it is marked green; if it is collected online or offline, it is marked yellow; and if it is collected offline, it is marked red. The second field provides information about the preservation method of the sample. The third area concerns the transportation of samples. When special conditions are required for storage, the fourth field is marked in red (Sajid & Płotka-Wasylka, 2022).

The second pentagram gives information about the type of method, and this field is indicated by the number 5. If the method does not require sample preparation, the field is green-marked. If simple methods are used such as filtering during the sample preparation, the area is labeled yellow, and if complex methods such as extraction are required, the area is labeled red. The circle within this area indicates whether the method is used for quality or quantity. This method is used only for quality reasons, a circle is not included (Sajid & Płotka-Wasylka, 2022).

The third pentagram consists of three areas numbered 6, 7, and 8, which contain the various measures of this preparation. The area numbered 6 contains the extraction scale. It is marked green if the extraction is at the nanoscale and yellow if the extraction is done. The sixth area is labeled in red for practicing micro or macro scale. The area numbered 7 is related to the solvents used in the extraction stage. If the method is solvent-free, the field is labeled green, yellow when green reagents are used, and red when solvents are used except green. The area numbered 8 relates to the operations required by a method in addition to extraction. If the method requires simple steps such as solvent cleanup or removal, the area is marked yellow, while the area is marked green if it does not require additional processing. When more advanced processing is required, the area is labeled in red (Sajid & Płotka-Wasylka, 2022).

The fourth pentagram shows the amounts of chemicals and solvents used and the effects of these amounts on health. The pentagram consists of three areas, numbered 9, 10, and 11. Field number 9 relates to the volume or quantity of substances used. If this amount is less than 10 mL or 10 grams, the field is marked green. If this ratio is between 10 and 100 mL (g), the area is marked in yellow, while when it exceeds 100 mL, the area is shown in red. The area numbered 10 shows the effects of the substances used on health. If the health hazard score of all chemicals or solvents is 0 or 1, the field is shown in green; if this score is 2 or 3, the field is marked yellow; and if it is 4, the field is marked red. Field 11 indicates the health hazards of chemicals. The area is colored according to its flammability or instability score. If this score is 0 or 1, the field is marked green; if it is 2 or 3, the field is colored yellow; and if it is 4, the field is marked red (Sajid & Płotka-Wasylka, 2022).

The fifth pentagram includes areas 12-15 and information about the amount of power consumed by the devices, occupational hazards, wastes that will be generated, and the procedures these wastes are processed. Field 12 shows the energy consumption per sample. The field is green-marked if the energy consumption is less than 0.1 kWh per sample, yellow if it is less than or equal to 1.5 kWh, and red if it exceeds 1.5 kWh. Field number 13 indicates occupational hazards. It is shown in green or red, depending on the danger situation. If the method does not leak gas or vapor, the area will be marked green; if there is vapor or gas release, the area will be marked red. Field 14 is associated with the amount of waste generated throughout the process. If the amount of waste is less than 10 mL (g), a green color is placed; if it is between 1 and 10 mL (g), the yellow color is placed; and if it is greater than 10 mL (g), a red color is placed. Field 15 gives information about the increase in waste to be generated. If the waste will be recycled, the area is shown in green; if the waste will be processed by degradation or passivation, the area is shown in yellow; if the waste will not be treated at all, the area is shown in red (Sajid & Płotka-Wasylka, 2022).

GAPI has many advantages over the analytical eco scale as it considers the method and process from many aspects. However, it is a disadvantage that the substances used in the synthesis and pre-extraction processes are not taken into account, and, for example, 10.1 mL and 400 mL are shown with the same label in waste generation (Sajid & Płotka-Wasylka, 2022).

Analytical Greenness Calculator Metric (AGREE)

The analytical greenness calculator consists of 12 principles of green analytical chemistry. Each principle is evaluated in the range of 0–1 point; the color chart changes from 1 to 0, from green to red; and the final score consists of 12 principles. As a result, it can be easily evaluated whether the method is suitable for 12 green parameters or not. It has been given in Figure 3 (Sajid & Płotka-Wasylka, 2022).

Figure 3

An Example of AGREE Pictogram And Its Color Scale (Pena-Pereira et al., 2020)

Analytical Method Greenness Score (AMGS)

Analytical method greenness score applied to analytical measurement procedures; It aims to determine the impact of method design and device selection by providing the evaluation in the categories of device energy consumption, the cumulative energy demand of solvents, environmental, health, and safety-related waste production. Although the greenness of analytical methods can be evaluated quantitatively and comprehensively by AMGS, their calculations are complex and have some limitations. Therefore, the analytical method requires much more information to calculate the greenness score. This process of providing too much information delays the time it takes to calculate the greenness score (Shi et al., 2023).

Greenery Index with Spider Diagram

It aims to evaluate a comprehensive measure of greenness by examining reagents under the headings of general properties, odor, fire safety, and stability. Evaluations are shown as -5 and +5 numerical values. -5 is the least green result, and +5 is the greenest result (Shi et al., 2023).

Green Aspects of Gas Chromatography

GC is often seen as more environmentally friendly than LC because it separates analytes in the gas phase without needing solvents. GC uses eco-friendly carrier gases like helium or hydrogen. GAC principles can be applied in GC by choosing the right carrier gases using short columns with small diameters and heating directly (Shaaban et al., 2017).

Selection of Appropriate Carrier Gas

Selection of Suitable Carrier Gas for GC Analysis Choosing the right carrier gas is crucial for environmentally friendly GC. Helium is commonly used because of its inertness and safety besides high linear velocity. However, helium is a non-renewable resource. Nitrogen is also used but has a lower linear velocity than helium resulting in longer analysis times and making it less desirable. Hydrogen on the other hand allows for high flow rates without efficiency loss making it the best option for green GC (Aly & Górecki, 2019; Shaaban et al., 2017).

- ***Speeding up GC Analysis***

GC analysis can be time-consuming and takes 10-30 minutes per run. Speeding up the process can reduce energy consumption and make it more environmentally friendly. Using shorter columns with small diameters is one way to shorten analysis times without compromising resolution and efficiency although small columns have limited loading capacity (Sciarrone et al., 2015).

Two dimensional GC

Conventional gas chromatography (1D-GC) is used for analyzing a broad range of volatile and semi-volatile substances, not ideal for complex samples due to limited peak capacity and selectivity. Comprehensive two-dimensional gas chromatography (GC×GC) is a powerful method for separating volatile and semi-volatile compounds in complex samples especially when paired with mass spectrometry (MS). GC×GC has been around for over 25 years and involves two columns with different retention mechanisms connected through a modulator interface. The modulator periodically collects fractions from the first column and reinjects them into the second column for further separation. With modulation periods ranging from approximately 2 to 8 seconds, GC×GC offers enhanced resolution sensitivity and peak capacity compared to traditional 1D-GC requiring a similar or slightly longer separation time with the same sample volume. The high resolving power of GC×GC particularly when combined with time-of-flight mass spectrometry (TOF-MS) allows for analyzing complex samples with minimal to no sample preparation thereby reducing solvent usage significantly(Dallüge et al., 2003; Tranchida et al., 2015).

Other Aspects

Portable gas chromatography-mass spectrometry (GC-MS) equipment for self-use was introduced in the late 1990s. Subsequently, advancements in heating systems, column construction, and detectors have persisted. To effectively utilize these devices, specific criteria must be fulfilled, including compact size and weight, battery-powered operation, rapid separation speed, and obtaining satisfactory chromatographic resolution for analytes with a broad range of volatility.

The literature also reports on the application of miniaturization as a further method for making GC more environmentally friendly. The analytical chemistry community is increasingly focusing on the diminution of capillary GC, MS analyzers, and other system components including vacuum pumps and electronics. The ion trap is the preferred choice for miniaturization among other mass analyzers because of its simplicity, ability to operate at high pressure, and the potential for tandem MS operation in a portable form. Nevertheless, the reduction in ion storage capacity imposes constraints on the downsizing of ion traps. One way to partially solve this difficulty is by confining the ions using a toroidal shape (Fanali et al., 2015; Ishii & Takeuchi, 1990).

Results

GAC objects to mitigate detrimental impacts on human health and the environment by using environmentally friendly practices in all analytical processes. The utilization of GAC principles in analytical methods is well regarded within the analytical chemistry community. Many researchers are striving to make chromatographic procedures more environmentally friendly by reducing the consumption of organic solvents and minimizing waste output. Several solutions have been suggested in this context to enhance the environmental sustainability of GC analyses.

Nevertheless, there are situations where it is not feasible to eliminate organic solvents. When faced with such situations, the optimum choice is to minimize the quantity of solvent. To decrease solvent usage, one can achieve this by faster analysis without increasing the consumption of the mobile phase, by reducing the usage of solvent and energy.

This technique can be executed by utilizing higher temperatures for the mobile phase and employing innovative column technologies such as porous sub-2-micron particles or superficially porous column packing. Additional methods, such as direct analysis, miniaturization, and online positioning of the chromatograph, serve as valuable tools for real-time monitoring (Aly & Górecki, 2019; Shaaban et al., 2017).

Choosing the appropriate carrier gas is crucial to making gas chromatography more environmentally friendly. Hydrogen is often regarded as the most effective carrier gas for gas chromatography (GC) because of its characteristic van Deemter curve, which remains consistent throughout a range of flow rates. This allows the separation process to be conducted at flow rates higher than the optimum level, resulting in reduced analysis time. In contrast to helium a finite resource, hydrogen may be generated sustainably. Another compelling approach to making GC more environmentally friendly is accelerating the analysis. Using short, narrow bore columns, nanotechnology can expedite the analysis process (Shaaban et al., 2017).

When developing a new analytical method, it should be advised to assess the environmental impact of the analytical methods at every stage. Soon, it is anticipated that there will be advancements in the development of small-scale analytical devices for on-site examination. These devices are likely to incorporate novel materials, particularly nanomaterials. When we compared it with GC, LC is less receptive to environmental sustainability efforts because it unavoidably requires using organic solvents. Greening LC substitutes conventional solvents with environmentally friendly alternatives such as ethanol, filtered water, or carbon dioxide (Byrne et al., 2016; Kerton & Marriott, 2015).

Conclusion

Implementing GAC technologies has been demonstrated to be a prudent approach for achieving both ecological and financial advantages. The advancement of novel sample preparation techniques that effectively minimize the usage of reagents and organic solvents also enhances the capabilities of other approaches, such as electrochemical and chromatographic procedures, which are not directly applicable to samples. The progress of streaming techniques has played a role in the development of GAC, but their full potential has not yet been completely utilized.

Chromatographic systems have demonstrated their cost-effectiveness and value as a viable substitute for fully automated analytical procedures in several fields such as pharmaceuticals, food, environmental studies, agree industries, and regular clinical analysis on a wide scale. Furthermore, they exhibit high speed, precision, and accuracy, while demanding less workload and maintenance.

The widespread adoption of GAC technologies for environmental and industrial applications will be facilitated by commercialization and acceptance by quality control laboratories and industrial facilities. This shift is needed within the realm of chemical education. By substituting obsolete experimental methods with appealing techniques that utilize current instrumentation, we may promptly decrease waste and foster essential environmental consciousness among our students for the future. This is crucial for the amount of work, expenses, and the well-being of analysts. Irrespective of the approach employed, it is important to remember that adopting environmentally friendly practices will consistently yield advantages for the practitioners and their laboratories.

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Advanced Crane Systems: The Impact of Modern Technologies on Performance and Safety

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Introduction

Cranes have been important machines used to lift and move loads since the early periods of human history. For several centuries, power has been provided by the physical effort of people or animals. The oldest steam crane was adopted in the 18th or 19th century. Many of the old cranes continued to be used until the late 20th century (URL-1).

Today, cranes are specially designed to meet a wide variety of needs in various industries. Winches are potentially used in construction for the lifting of materials, in transportation for the loading and unloading of loads, and in the assembly of heavy equipment in manufacturing (URL-2).

Cranes generally vary according to their lifting capacities, mobility, and working environments. While some are stationary, others are mobile or portable. Modern cranes enhance efficiency and safety by utilizing advanced technologies such as hydraulic systems, electronic controls, and high-strength materials. Cranes play a critical role in industrial processes and continuously evolve with technological advancements over time (Donell, 1995). At the same time, using these machines can involve risks. Therefore, they are designed to adhere to specific standards and various tests are applied to the final product.

Innovative Aspects of Cranes

Cranes have a history dating back thousands of years to meet the needs of humanity. Crane design has evolved to meet various industrial needs. Modern cranes typically coordinate simple systems to perform complex lifting tasks, even in environments that may be dangerous for workers (Chondros, 2010).

Throughout history, cranes have played a significant role in constructing large-scale structures more quickly and safely; mechanical innovations and material developments have increased their strength and durability, allowing for the lifting of larger loads (URL-3; URL-4).

Figure 1
Modern Cranes (Zhang & Wang, 2020)

Today, modern cranes are extensively used in industrial applications such as construction, port operations, mining, and manufacturing, as well as many others. These cranes are typically provided with complex hydraulic electronic control systems and are designed to ensure human safety and efficiently manage large-scale lifting operations. Modern cranes can operate with high precision and efficiency thanks to automation and remote control technologies (Helling, 2020). In addition, by continuously monitoring the weight, balance, and movement of loads with the help of sensors and software, potential accidents are prevented. Thanks to advanced material science and engineering techniques, these cranes have become lighter, stronger, and more durable. Today's crane technologies use technologies such as machine learning, simulations, artificial intelligence, the Internet of Things, optimization algorithms, and digital twin technologies to control and alert the user (Hasan et al, 2024).

These technologies provide innovative contributions in many areas, such as (Liu et al, 2024):

- Predicting accidents that may occur during crane operation,
- Optimizing, improving, and planning crane operations,
- Detecting and preventing the risk of cranes colliding with other objects,
- Monitoring and controlling the operational status of cranes,
- Ensuring the balance and safety of cranes,
- Optimizing crane performance,
- Real-time monitoring of crane operations

These technological advancements have increased the performance and safety of cranes while reducing their operational costs. Electrically powered cranes that provide energy efficiency and eco-friendly designs have been an important step towards sustainability. The flexibility and versatility of modern cranes have made them an indispensable tool in many industrial processes (URL-5). Thus, it has become possible to overcome more complex and challenging projects.

Crane Safety

Cranes maintain balance through counterweights during the lifting and moving of loads. For any type of crane to operate efficiently and maintain its crucial balance, it must adhere to the laws of physics. In this context, the two most important considerations are that the crane should not lift weights exceeding its nominal capacity and that stressful movements beyond the designated operational plane of each machine should be minimized. Violating these established rules can lead to crane tipping, structural damage, and serious accidents. Therefore, crane operators and technicians must thoroughly understand the limits and capacities of the cranes and always operate within these boundaries (Ramli et al, 2017).

In addition, regular maintenance and periodic inspections are critical for the safe and effective operation of cranes. Ropes, hooks, hydraulic systems, and other components should be continuously inspected and replaced as needed. Moreover, comprehensive training for operators and strict adherence to safety protocols will help prevent potential accidents. The working environment of the cranes should also be considered, with careful evaluation of ground stability and environmental conditions. These measures ensure that cranes serve reliably and safely for extended periods, preventing workplace accidents (Nazlıoğlu, 2014).

Figure 2
Crane Safety (URL-6)

The effective operation and safety of cranes are closely tied to the laws of physics, and there are several key considerations to take into account in crane design:

- **Lifting Capacity**: A crane must have the capacity to lift the weight of the load it is designed to handle. This capacity depends on the durability and strength of the lifting mechanisms, ropes, hooks, and other components on the crane. The crane should be designed and configured to safely bear the weight of a given load while lifting.
- **Balance and Stability**: A crane must be designed to maintain its balance during lifting operations. The tipping or falling of a crane can result in serious damage and safety risks. Therefore, the configuration and placement of the crane should be carefully planned according to the stability of the working area and the solidity of the ground. Additionally, the crane should be designed with safety factors in mind to remain stable during lifting operations.
- **Force and Motion Control**: The force and motion control of cranes ensure the precise and safe movement of loads. Hydraulic and electronic control systems allow for the precise control of crane movements and lifting operations. These systems ensure the correct positioning of loads and the prevention of potential accidents.

- **Safety and Maintenance**: Regular maintenance and safety inspections are necessary for the safe operation of cranes. Ropes, hooks, hydraulic systems, and other components should be periodically checked and replaced when necessary. It is also critical that operators receive proper training to ensure safe usage.
- **Environmental Conditions**: The conditions of the environment in which cranes operate are important for both design and operation. Environmental conditions such as high winds, rain and temperature changes can impact the performance of cranes. Therefore, cranes should be designed to withstand these conditions, and protective measures should be taken if necessary.

Designing and utilizing cranes with these considerations in mind are crucial for both efficiency and safety. Taking these factors into account ensures that cranes serve reliably and safely over their lifespan (URL-7).

Cranes have been customized to meet the varying needs of different sectors as indispensable tools in industrial processes. With high lifting capacities and flexibility of movement, they are used in many fields, including aviation, shipyards, manufacturing plants, and construction. These machines efficiently perform the tasks of transporting, assembling, and positioning finished and semi-finished products. The flexibility and lifting power provided by cranes support the acceleration of production processes, increase efficiency, reduce labor, and enhance operational safety(Doğan, 2023).

Crane Types

Each type of crane is designed for a specific industry or application. Choosing the right crane is crucial for performing work efficiently and safely (Samset, 2013). There are many different types of cranes designed for specific uses.

Gantry Crane

Gantry cranes are a type of overhead crane that travels on a rail system with independent legs or moves on wheels. They typically have a single or double girder structure and operate on a straight line over a rail or rail system embedded in the ground within a specific area. Smaller portable gantry systems work on wheels or tracks, allowing for easy mobility for maintenance or light manufacturing tasks. The design of gantry cranes involves two legs that move on rails embedded flush with the ground surface, enabling equipment like scissor lifts and forklifts to pass underneath (Gerdemeli & Serpil, 2013).

Figure 3
Gantry Crane (URL-8)

Gantry cranes are ideal for load-handling applications both indoors and outdoors. The systems where bridge girders are mounted on gantry legs, which move on the ground over a rail system, offer high portability and flexibility. Double-girder and single-girder gantry cranes are advantageous for load stacking and usage purposes with the flexibility of right/left cantilever use. The design of gantry cranes eliminates the need for support columns and vertical runway beams, as they do not need to be attached to a building's support structure.

These cranes are widely used in various sectors including industrial manufacturing plants, workshops, hydroelectric power stations, dams, marble-cutting facilities, storage warehouses, ports, and similar environments. The flexibility and lifting capacity provided by gantry cranes enhance efficiency and make operational processes more effective in these areas (Burul et al, 2010).

Jib Crane

Jib cranes are primarily used in construction and heavy load-handling applications. They are effective for placing and moving large concrete blocks, beams, or other heavy structural elements. In the industry, they are also used for transporting parts between different machine stations and work areas. Jib cranes are versatile and typically used for repetitive lifting tasks within a smaller work area (Solazzi & Danzi, 2024).

Equipped with one or more rotating arms, jib cranes allow for the movement of loads across a wide area. Usually mounted on a fixed base, these cranes enable precise positioning of loads thanks to their rotating arms. The crane arm contains a robust mechanism and is typically operated by hydraulic or electric systems.

Figure 4

Jib Crane (URL-9)

During the use of jib cranes, the operator can rotate the crane arm in the desired direction and move the load in various directions. The mobility of jib cranes provides advantages, especially in areas where large and heavy loads need to be placed. Installation and operation are typically carried out by professional teams. These cranes, consisting of components such as the column and boom, have capabilities ranging from 250 lbs to 15 tons. Integrated ergonomic design enhances worker productivity in manufacturing environments, reduces workplace injuries, and improves overall safety. Key components include the horizontal boom, mast or support column, bearing system, crane, and controls (Dhanoosha & Reddy, 2016).

Despite their various types, jib cranes vary depending on their area of use. They come in several varieties, including wall-mounted, pillar-type, and freestanding cranes. Selecting the appropriate type of jib crane based on the application and working environment enhances job efficiency and safety (Karpe et al, 2014).

Monorail Crane

Monorail crane systems are ideal for lifting and transporting various products along a fixed track. They operate using wheels that move along the flange beneath an I-beam (Feit et al, 2008). These systems are used to enhance efficiency in manufacturing environments, assembly lines, and other workplaces.

Figure 5
Monorail Crane (URL-9)

Monorail systems are preferred for transporting goods in narrow spaces and production areas requiring continuous operations. They offer a simple and economical solution for transferring materials such as motors, pumps, and valves to specific locations within industrial buildings. These systems can be used without the operational flexibility and cost associated with overhead bridge cranes. Some monorails include both curved and straight sections, providing additional flexibility. The use of monorail cranes increases efficiency in production processes and reduces operational costs (Woolcock et all, 2011).

Overhead Bridge Crane

The fundamental components of bridge cranes include the walkway and the bridge that moves on it. The bridge comprises a traveling trolley and a lifting system connected to the transport trolley. The lifting system is driven by a manual remote control (Öğün, 2014).

The operational mechanism of a bridge crane consists of the operating mechanism and the hoisting mechanism:

Hoisting Mechanism: This mechanism is responsible for hoisting objects vertically. It is therefore the foremost significant and fundamental mechanism of the crane.

Operating Mechanism: This mechanism is used for moving objects horizontally, typically through a crane or hoisting trolley. It could be categorized into two types: rail-based, and rail-free operation.

Figure 6
Double Girder Cranes (URL-9)

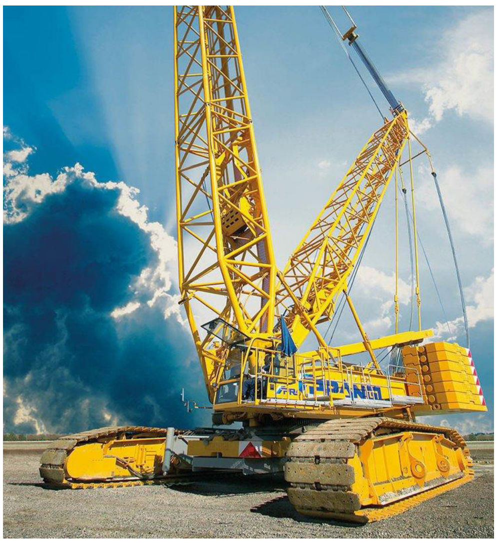
Most gantry cranes start a vertical or horizontal movement after lifting the load. When it reaches its destination point, it unloads the load and then returns to the starting point, completing one working cycle. This is followed by a second lifting operation (Erdil, 2007). Overhead cranes are widely used in factories, warehouses, shipyards, and various production facilities. The efficient working cycles of these cranes speed up operational processes and increase labor productivity. They also ensure safe and fast transportation of loads of different capacities. This minimizes occupational accidents and material damage. Gantry cranes, single-girder cranes, double-girder cranes, and semi-gantry cranes are available in various types (Mojallizadeh & Brogliato, 2023).

Mobile Crane

Mobile cranes are cranes with high mobility, capable of lifting and transporting various loads.

The mobile crane is essential and one of the most widely used construction equipment for handling materials, ingredients, temporary works, etc. on building sites. It can move and maneuver within a site (Gou et al, 2021).

Figure 7
Mobile Crane (URL-10)



Mobile cranes generally have two main characteristics: Firstly, unlike the horizontal lateral support of tower cranes, the inclined boom of mobile cranes generally spans a significantly larger operational area in three dimensions. Secondly, mobile cranes possess the capability to traverse the entire worksite to carry out particular lifting tasks, rather than remaining stationary (Shapira & Jay, 1996).

Selecting the appropriate type and model of mobile crane ensures its efficient utilization, leading to cost savings and a higher likelihood of completing the construction project. The right choice of crane maximizes operational efficiency, increases occupational safety, and minimizes occupational accidents (Dalalah et all, 2010). Truck-mounted Cranes can be categorized as *Telescopic Cranes* and *Crawler Cranes*.

Due to their mobility, they can quickly reach different work sites. They can be used in various works and in different ground conditions. They increase work efficiency due to their short installation and dismantling time. They can lift and carry heavy loads (Balkan, 1996).

Tower Crane

Tower cranes are high crane types that are used when constructing high-rise buildings and can lift large loads. They are widely preferred especially in skyscrapers, bridges, and large-scale construction projects. Tower cranes are mounted on a vertical tower and equipped with a lifting boom for transporting loads (Elliott, 2015). The boom can cover extensive distances at the crane's height and typically rotates 360 degrees. Constructed primarily from steel or aluminum, tower cranes are highly durable and resistant to wind and other environmental factors that may impact them due to their significant height (Kaveh & Vazirinia, 2018).

Figure 8
Tower Crane (Burkhardt et al, 2023).

Tower cranes are designed to lift and transport loads from heights. The crane operator lifts the load with the help of a hook and moves the crane trolley along the boom to move the load to the desired location. The upper part of the crane can rotate 360 degrees horizontally thanks to the rotation mechanism. This feature provides a wide working area (Brain, 2023).

Indispensable for modern construction projects, tower cranes are critical tools for tall buildings and large-scale construction projects. These powerful machines speed up construction processes, increase work efficiency, and ensure the safe transportation of heavy loads.

The advantages of tower cranes include:

- Capacity to lift heavy loads to high points,
- A wide working area thanks to the boom length and rotation mechanism,
- High stability thanks to their robust construction and counterweights,
- Allowing precise positioning of loads

These features make tower cranes indispensable tools for the modern construction industry (Alămoreanu & Vasilescu, 2009).

Port Crane

As centers of global trade, ports are critical points where logistics and technology converge. Port cranes are used for loading and unloading cargo onto ships and for construction work. Playing a major role in maritime transportation and logistics, these cranes speed up loading and unloading processes and are often used to transport containers, bulk cargo, and heavy materials (Matheus, 1996).

Figure 9
Port Crane (URL-11)

These cranes, which operate with mechanical systems, increased the volume of trade by accelerating the transportation of goods and reducing the need for labor. The development of harbor cranes made a significant contribution to the growth and enrichment of cities as well as maritime trade (Wei et al, 2023). These technological advances laid the foundations of modern ports and pioneered the advanced crane systems used today.

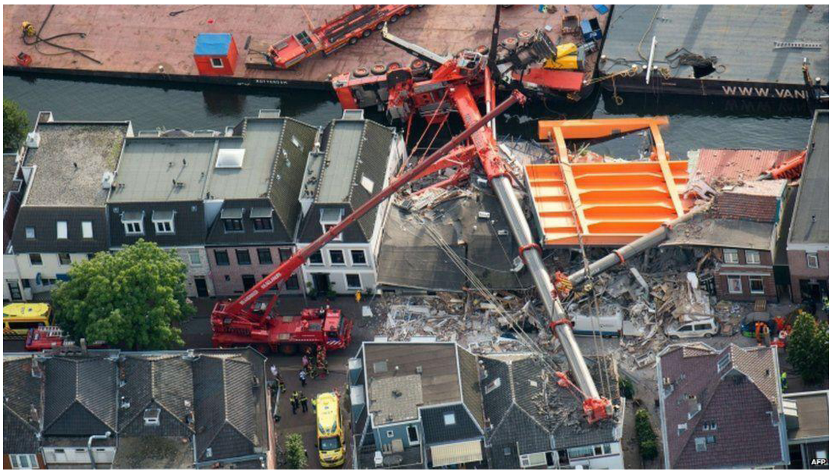
The structure of harbor cranes includes components such as a boom, tower, hook or spreader, trolley, base, and hydraulic and electrical systems. Different types of harbor cranes include gantry cranes, ship-to-shore cranes, telescopic cranes, mobile harbor cranes, and floating cranes. These cranes are used in various areas such as container ports, bulk cargo ports, Ro-Ro ports and because of their high carrying capacity and wide range of operations (Gaspar et al, 2019).

However, as demands for efficiency and sustainability increase, the industry is responding with a range of innovations in the design and operation of harbor cranes. As the port industry adapts and evolves to the challenges of the 21st century, innovations in harbor cranes will continue to play an instrumental role in increasing operational efficiency and environmental sustainability (Meisel & Bierwirth, 2021).

Risks That May Occur in The Use of Cranes

Cranes play a crucial role in various sectors, including industrial and mining enterprises, ports, rail transportation, and real estate (Zhu et al, 2014). While they are indispensable for many industries, cranes must be recognized as high-risk devices. Despite their utility, crane operations present substantial safety concerns, posing significant threats to both individuals and property (Li & Zhao, 2017).

Figure 10
Mobile Crane Accident (URL-12)



One of the primary causes of fatalities in construction is the use of cranes or towers during lifting operations. Studies indicate that over 84% of crane and tower-related fatalities involve the use of mobile cranes with lattice and telescopic booms, as well as truck or crawler cranes. The authors believe that to reduce the crane fatality rate, crane operators and operators need to be qualified and requalified each time (Beavers, 2006).

In some literature studies, the risks and accidents that cranes pose when they are not designed properly or when they are used in harsh weather conditions are mentioned. These transportation systems with large masses can pose great risks. In one study, it was revealed that the crane started to move under the influence of a continuous and very strong wind blowing at a speed of approximately 110 km/h and derailed after traveling approximately 60 meters. Therefore, the catastrophic derailment of a gantry crane was analyzed (Frendo, 2016). Given that gantry tower cranes typically have long, wide spans and large downwind areas on their main girders, they are particularly vulnerable to damage from destructive wind gusts. This vulnerability was highlighted in a study investigating a gantry crane overturning incident in Shenzhen, caused by an explosion. The study found that the overturning moment and shear force on the gantry crane's foundation exceeded the critical values needed to maintain stability, leading to the crane's collapse (Su et al, 2023).

Figure 11
Tower Crane Accident (Swuste, 2013).

Another study describes the collapse of a tower crane at a construction site in Rotterdam. The investigation revealed that the actual flexibility of the crane's mast and horizontal arm configuration was greater than the design engineer's calculations, leading to the crane collapsing while lifting a heavy load (Swuste, 2013).

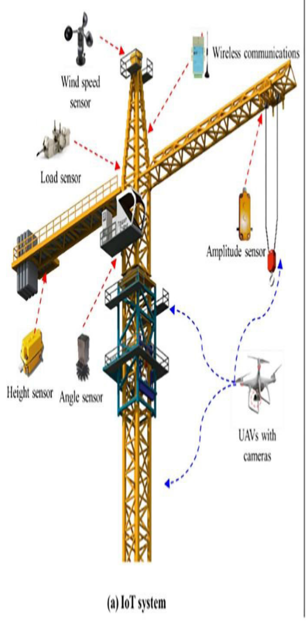
An article details the investigation into the collapse of a tower crane at an office building construction site in Bellevue. The collapse is particularly intriguing because it occurred with no load on the hook and under minimal wind conditions while the operator was shutting down the crane for the night (McDonald & Ross, 2011).

Innovative Technologies Used to Ensure Safety in the Crane Industry

To ensure a crane complies with applicable standards, it is crucial to conduct proper dynamic and structural analysis, considering the fundamental design phenomena (Choi, 2022).

Proper use of lifting machinery is vital for the safe production processes of enterprises. Therefore, it is essential to thoroughly analyze and anticipate the potential hazards and consequences associated with these machines. Assessing the safety of lifting machines involves analyzing risk factors and accident outcomes, evaluating the accident risk, and proposing safety response measures to ensure safe operations (Sadeghi et al, 2021). This comprehensive approach supports administrative departments in supervising the safety of specialized equipment effectively.

Figure 12
Technology in Cranes (Wu et al, 2023).



Contents	Inspection details
Document files	Certificates of operators, single men, and riggers
	Product certification of tower cranes
	Inspection and maintenance logbook
	Repair logbook
	Daily operation records
Hoisting parts	Braking systems
	Electrical parts for hoisting
	Hook height limit switch
	Moment cutout switch and overload cutout switch
	Gearbox oil level and refill
	Hoist winch and main axle, lubrication, and oiling
	Connections for all pulleys, hooks, and pins
	Lubrication, wear, and tear condition of wire ropes
	Swivel/ anti-twist device for wire ropes at jib
	Fixing of the base for hoisting parts, connection pins/bolts for gearbox and footings
Luffing parts	Slewing limit switch
	Electrical parts for slewing
	V-belt to the slewing motor
	Slewing gearbox oil level and refill
	Bolts of slewing bearing
	Slewing bearing with grease
	Slewing ring with grease
	Fixing of connection pins/bolts for gearbox
Steel structure and main structural parts	Tower base and mast base
	Connection of all mast sections and check for any missing split pins / bolts and nuts
	Connections and split pins at jib and other steel structural parts / bolts and nuts
	Welding parts of all structural components
	Deformation at tower mast sections, jib and counter-jib
	Connections of climbing collars
	Pins and bolts of ballast blocks
	Climbing ladders of tower crane
Hook parts	Condition of hook block

(b) Regular safety inspection content

This article describes the innovative and industrial technologies used to eliminate the risks and safety threats that may occur during the use of cranes and the intended use of these technologies (Hamka, 2017).

Accident Forecasts

Machine learning algorithms optimize previous data to predict accidents and define the factors that cause accidents. These algorithms predict the probability and severity of accidents (Tamascelli et al, 2022).

Many techniques are used for accident prediction (BPNN, MIRF, etc.). An IoT-based machine learning model is used to predict the wind response of cranes during typhoons. This model measures the maximum displacement using real-time data from IoT sensors and demonstrates its effectiveness in field measurements. Analyzing past crane accidents predicts operational variables and accident probabilities.

Operation Planning

Machine learning and algorithms enable the use of data-driven techniques to plan, develop, and schedule crane operations. This is focused on making informed choices to maximize the safety, productivity, and efficient operation of crane facilities (Cho & Han, 2022).

Many algorithms are used in operation planning (CCGA, ABM, 4D-BIM, etc.). Some methods perform motion planning, some provide constraint optimization services for dynamic replanning of crane paths, while others minimize production time and study the effect of supply choices on crane productivity.

On-site Monitoring

On-site monitoring for winch operations includes observation in real time and oversight of crane operations on construction sites. This innovation ensures safety, efficiency, and regulatory compliance through sensors and data collection methods (Chae & Yoshida, 2010).

Furthermore, various sensors such as RFID, load cell sensors, localization sensors, BIM data, accelerometers and are used in integrated systems to create safety zones to warn personnel of risks. These sensors comprehensively analyze load dimensions, clearance distances, and worker movements (Luo et al, 2014). In addition, in-situ monitoring technologies are used to prevent overloading, inspect critical areas, and detect magnetic field changes.

Remote Monitoring

Remote monitoring of crane operations leverages technology and communication systems to oversee and manage crane activities at construction or industrial sites. These systems enhance safety by continuously tracking crane performance, load handling, and operator conduct, offering real-time alerts for swift issue resolution (Sitompul, 2022).

Through sensors, many functions become easy and effective, such as optimizing remote communication protocols, categorizing lifted objects, recording weights, continuously monitoring and diagnosing crane status, and exchanging data between cranes.

Collision Prevention Technologies

Crash avoidance technologies are designed to prevent physical collisions or interference between objects, vehicles, or machinery. These systems utilize sensors, algorithms, and communication networks to detect the proximity of objects and take preventive measures such as issuing warnings, altering trajectories, or halting movement to avoid collisions. When a crane contacts nearby structures, equipment, or objects during operation, the resulting collisions can cause substantial damage to both the crane and surrounding structures, posing a serious risk to the safety of crane operators and onsite personnel (Al Hattab et al, 2018).

With these technologies, it is possible to detect crane parts in the working areas, provide communication between cranes, and thus prevent collisions.

Crane and Load Stability Technologies

Stability Control Technologies encompass a range of advanced systems and features designed to maintain the stability and safety of cranes during lifting and material handling operations. These innovations are critical to prevent accidents and ensure that crane operations are efficient and precise (Shin, 2015).

This system autonomously stabilizes the crane to prevent it from tipping over, especially due to strong winds. Wind sensors continuously monitor and predict dangerous wind gusts so that preventive protective measures can be taken (Sorokin et al, 2018).

In addition, they control load stability and reduce sway by accurately estimating the displacement during crane operations, providing precise measurements of parameters such as angle, trolley position, and hook position (Zhu et al, 2022).

Conclusion

This paper provides a comprehensive overview of crane applications, their critical role in industrial processes, and safety risks. Crane technologies, which have evolved throughout history, are now equipped with machine learning, optimization algorithms, simulations, the Internet of Things (IoT), artificial intelligence (AI), and digital twin technologies. These advancements have not only improved the performance of cranes but also significantly increased their safety. For example, IoT-based machine learning models predict the wind response of cranes with real-time data, preventing accidents and ensuring the safety of operators. Sensors and software continuously monitor the weight, balance and movement of loads, helping to prevent potential accidents. Thanks to advanced materials science and engineering techniques, modern cranes have become lighter, stronger, and more durable. In addition, energy-efficient electric cranes and environmentally friendly designs have been an important step towards sustainability.

On the other hand, given the high fatality rate of crane accidents, operator training and qualification is of critical importance. Therefore, continuous training, advanced safety protocols, and technological solutions are vital requirements to improve safety in crane operations. Ensuring the safe use of cranes both raise occupational safety standards and contributes to the sustainability of industrial processes. In this context, strengthening the technological infrastructure of cranes and continuously updating safety measures are of great importance to prevent future accidents.

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Introduction

Terminal blocks are critical components used in electrical circuits to ensure the safe and organized connection of conductors. These elements are commonly used in industrial automation systems, energy distribution panels, and electrical installations. The historical development of terminal blocks began with the Industrial Revolution and the increasing complexity of electrical systems. In the early days, electrical connections were typically made by soldering, but this method soon became impractical and inadequate. In the early 20th century, with the development of screw-type connectors, terminal blocks became widely used. These products were initially employed for simple connections, but as technology advanced, terminal blocks evolved into integral components of more complex and modular electrical systems (Turton, 1988).

The post-World War II era saw rapid advancements in industrial production and automation, accelerating the evolution of terminal blocks. In the 1950s, the introduction of more durable and robust materials led to the use of plastic and metal combinations in the production of terminal blocks. During this period, spring pressure connection systems were also developed alongside screw-type connections, allowing users to make faster and more reliable connections. Today, terminal blocks are produced in various designs and materials, offering a wide range of application possibilities. In electrical panels, energy distribution systems, machinery control, and industrial automation systems, terminal blocks play a crucial role in both safety and functionality (Smyth, 1996; Hudson, 2012).

Advantages and Disadvantages

Terminal blocks (e.g. Figure 1) offer several advantages, making them a reliable solution for electrical connections. One of the most significant advantages is their modular structure. This modularity increases flexibility in electrical circuits and allows for the quick addition of new connections. Modular terminal blocks are especially preferred in energy distribution panels and control systems, as these systems may expand or change over time, and terminal blocks make it easy to implement such modifications (Brown, 2011).

Figure 1
Simple Screw Connection Terminal Block

Another advantage is the strength and security of the connection. In screw-type terminal a block, the connection point tightens as the screw is fastened, firmly securing the conductor. This improves the quality of the electrical connection and reduces electrical resistance. In spring pressure terminal blocks, the spring mechanism continuously presses the conductor, ensuring a firm connection even under vibration or harsh operating conditions. This feature makes spring pressure terminal blocks particularly suitable for industrial environments where vibrations are prevalent. Additionally, spring pressure terminal blocks expedite the installation and maintenance processes, saving time (Mason, 2015).

However, there are some disadvantages to terminal blocks. First, screw-type connections require regular inspection, as the screws may loosen over time, weakening the connection. While spring pressure terminal blocks mitigate this issue, problems can arise when working with fine or delicate conductors, where the spring mechanism may not hold the conductor as securely as needed. Furthermore, the physical size of terminal blocks can present space management challenges in large and complex electrical panels. In confined spaces, organizing and arranging terminal blocks can become more difficult and complicated (Roberts, 2020).

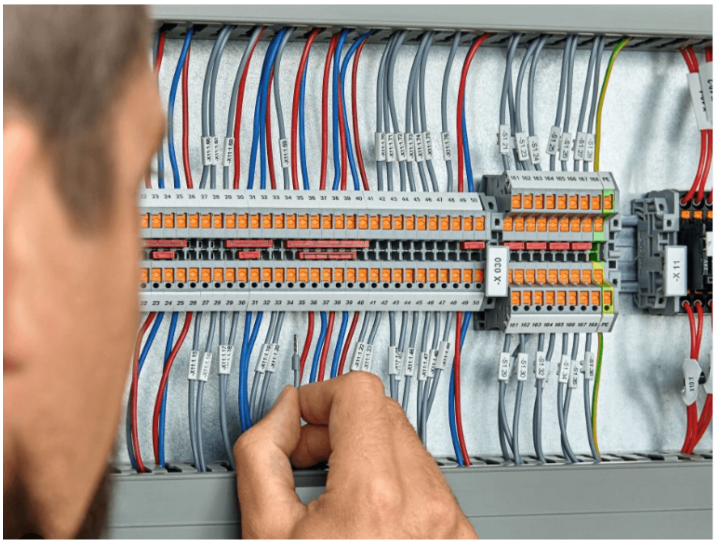
Lastly, the cost of terminal blocks can be higher than more traditional connection methods in some cases. This cost difference becomes more apparent in large projects and extensive systems. However, considering the long-term benefits in terms of safety and functionality, this cost is often viewed as a justified investment (Allen, 2013).

Applications

Terminal blocks are widely used across many industries. One of their most common applications is in industrial automation systems. In factories, terminal blocks ensure safe and organized electrical connections in the control and management of production lines (e.g. Figure 2). The acceleration of production processes and the increasing complexity of modern factories have made terminal blocks a critical component. In addition to industrial automation, terminal blocks are widely used in energy distribution systems. These systems range from high-voltage energy transmission to low-voltage building energy distribution (Grant, 2014).

Today, terminal blocks also play a crucial role in renewable energy systems. In particular, they are used in solar and wind energy projects, where they ensure reliable connections in energy storage and distribution systems. Terminal blocks in these systems help increase energy efficiency and minimize the risk of failures. In solar energy systems, terminal blocks are essential for the proper transmission and distribution of electricity from the panels. In wind energy systems, spring pressure terminal blocks are often preferred due to their resistance to vibrations (Thompson, 2018).

Figure 2
Terminal Block Application In A Control Panel



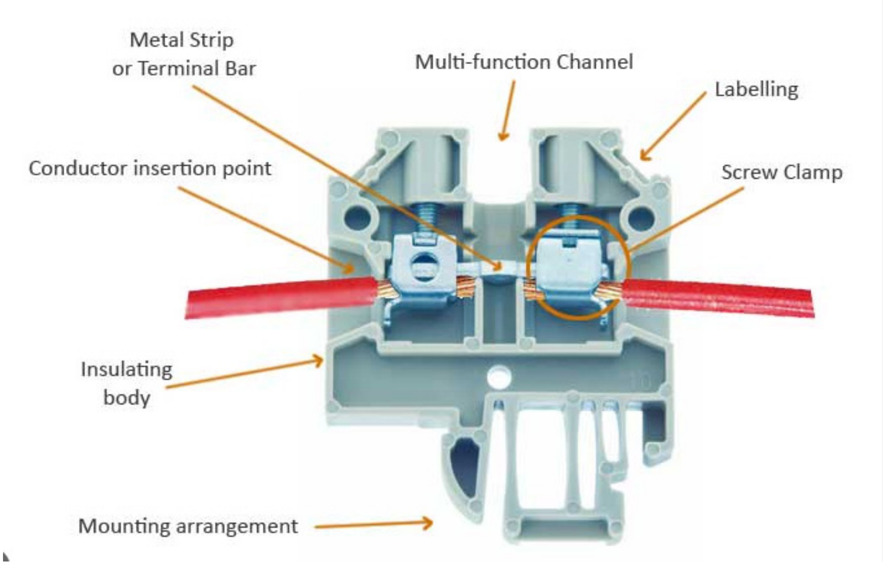
Terminal blocks are also commonly used in building automation, railway signaling, automotive electronics, and the maritime industry. In building automation systems, terminal blocks are frequently used for the electrical connections of heating, cooling, lighting, and security systems. In the railway and automotive industries, spring pressure terminal blocks are preferred for their durability and resistance to vibrations in harsh operating conditions (Taylor, 2005).

Operating Principle

Terminal blocks operate using simple yet effective mechanisms (e.g. Figure 3) to connect conductors electrically. There are two main connection mechanisms: screw connections and spring pressure connections. In screw-type terminal blocks, the conductor is tightened by a screw, creating an electrical connection. The screw presses the conductor onto the base of the terminal block, forming a tight electrical contact. This mechanism is commonly used in circuits with thicker cables and higher currents, as the pressure provided by the screw ensures high electrical conductivity. The main advantage of screw-type terminal blocks is that the clamping force can be manually adjusted, allowing users to adapt to different types and sizes of conductors (Smith, 2017).

Spring pressure terminal blocks, on the other hand, offer a faster and maintenance-free solution. In these blocks, the conductor is pressed tightly onto the terminal base by a spring mechanism. The spring holds the conductor with constant pressure, ensuring durability even under vibrations and environmental factors. Spring pressure terminal blocks are preferred in environments where continuous connections are important, and they reduce the need for maintenance. The connection process in spring-loaded terminals is generally quick, making the installation time shorter compared to screw-type terminals (Johnson, 2019).

Figure 3
Working Principle Of A Simple Rail Terminal Block



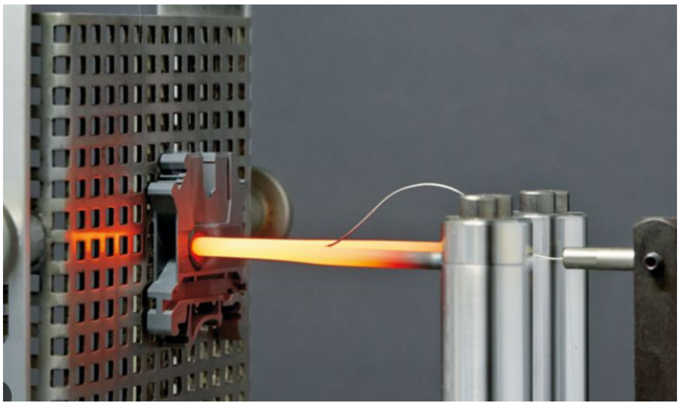
Another crucial aspect of the operation of terminal blocks is the rail structure itself. Rails, often referred to as DIN rails (Figure 4), are metal strips used to secure and organize the terminal blocks. These rails allow for easy mounting and adjustment of terminal blocks on electrical panels. This mounting system facilitates the installation maintenance and expansion processes (Wilson, 2016).

Figure 4
Terminal Blocks Arrayed On The Mounting Rail

Design Features

The materials and structural features used in the design of terminal blocks are critical to the product's durability and performance. The outer body of the terminal blocks is typically made of plastics such as Polyamide 6.6, which are resistant to high temperatures and mechanical stress. Polyamide 6.6 stands out for its excellent insulating properties and chemical resistance. This material offers long-lasting and reliable use even in harsh industrial environments. Additionally, flame-retardant versions of Polyamide 6.6 (e.g. Figure 5) are preferred in applications where fire safety is critical (Green, 2020).

Figure 5
Glow Wire Test On Terminal Block

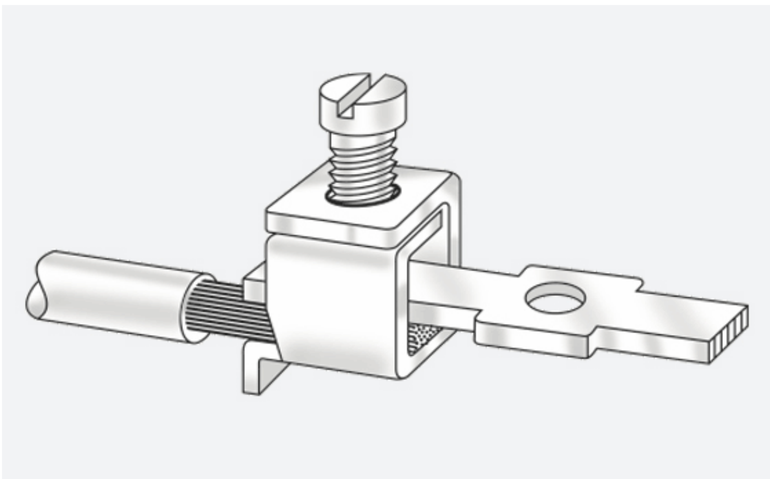


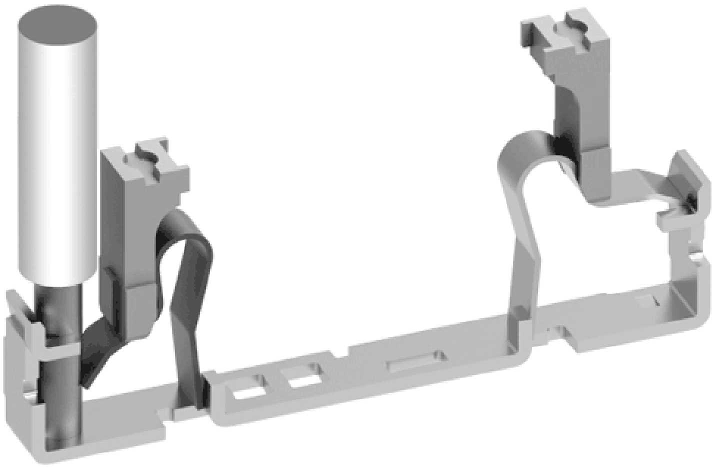
Inside the terminal blocks, copper and steel materials are used to ensure reliable connections for conductors. Copper is known for its high electrical conductivity and is commonly used at the contact points of terminal blocks. Steel is used to enhance mechanical durability. Copper is typically coated with tin or nickel to protect against oxidation. These coatings ensure that terminal blocks can operate reliably over long periods (Davis, 2017).

Terminal blocks come in two main types: screw-type and spring-pressure (e.g. Figure 6) connections. Screw-type blocks are suitable for applications requiring manual adjustment, while spring pressure blocks offer faster and maintenance-free solutions. Another important consideration in design is ease of installation. Most terminal blocks are designed to be compatible with DIN rails. These rails allow terminal blocks to be mounted quickly and easily. Moreover, the modular design of terminal blocks simplifies expansion or rearrangement processes (IEC, 2002a).

The design of terminal blocks must comply with international standards. These standards define the safety, performance, and durability requirements for the products. For example, IEC 60947-7-1 and IEC 60947-7-2 standards specify the electrical properties and safety criteria for terminal blocks. Additionally, international certifications such as UL and CE enhance the global reliability of terminal blocks. These certifications are essential for ensuring that the products can be used in international markets (IEC, 2002b; UL, 2015).

Figure 6
Screw Type And Spring Type Pressure Systems





Conclusion

Terminal blocks are critical components that provide safety, functionality, and durability in electrical connections. Their historical development has paralleled the evolution of industrial automation and energy distribution systems. With their wide range of applications, various connection types, and durable materials, terminal blocks play a vital role in modern electrical systems. They offer secure connections, easy installation, and maintenance, making them essential in organizing electrical circuits. Moreover, their compliance with international standards enhances their reliability in global markets. With these features, terminal blocks will continue to be a key component of the electrical industry.

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Chapter 11

Use Of Artificial Intelligence in Physiotherapy and Rehabilitation

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Introduction

Artificial intelligence (AI) is revolutionising biomedical research and treatment. Machine learning (ML) and advanced algorithms are being used to analyse large amounts of health and medical data more efficiently. In particular, for headache disorders such as migraine, AI has promising potential in various applications such as understanding disease mechanisms (Park et al., 2020) and predicting treatment response (Thakur et al., 2020; Tso et al., 2021). The next generation of AI applications in headache research and treatment can contribute to clinical practice by providing patient-specific treatments (Davenport & Kalakota, 2019; Bajwa et al., 2021), thereby improving patient and public health outcomes and reducing clinician workload (Messina & Filippi, 2020).

In another definition, artificial intelligence (AI) is a research field focused on creating systems that emulate human intelligence (Rowe, Nicholls & Shaw, 2021). AI involves mathematical methods that can enhance the healthcare system by supporting evaluation, decision-making, and patient participation (Ravali et al., 2022). It can automate healthcare decisions and provide predictions based on patient data (Barradell, 2017; Ramanandi, 2021). However, challenges such as ethics, privacy, and security are critical considerations in the application of AI in healthcare (Özdemir & Bilgin, 2021). In specialized fields like pediatric physiotherapy, AI offers benefits such as time efficiency, increased patient motivation, and suitability for infectious scenarios (Söderlund, 2019). Artificial intelligence is primarily recognized for its use of machine learning and deep learning methods.

Machine Learning:

Machine learning can be defined as the ability of computer systems to apply knowledge gained from previous experiences or data to similar situations in the future.

This learning technique may include the assistance of a trainer with examples. The learning algorithm consists of data sources, input information and results. In machine learning, systems generalise by inferring from previous experience. Accordingly, machine learning systems use datasets consisting of training data; these datasets include the codes of observational samples and various formats that enable their interpretation (Akgöbek & Çakır, 2009). Machine learning algorithms are categorized into four main types based on their objectives: supervised learning, unsupervised learning, clustering (classification), and regression learning (Anderson, 2019).

Deep Learning:

Deep learning employs computational models with multiple processing layers to analyze data at different levels of abstraction (Krizhevsky et al., 2012; Szegedy et al., 2015). These methods have greatly advanced technologies in areas like speech and visual recognition, object detection, drug discovery, and genomics (Helmstaedter et al., 2013). By applying the back-propagation algorithm, deep learning uncovers complex patterns in extensive datasets, enabling each layer to derive representations from the preceding one. While deep convolutional networks have driven significant progress in processing images, videos, audio, and speech, recurrent networks effectively handle sequential data, including language and audio inputs (Lecun et al., 2015). Deep learning techniques are being utilized in research to develop robotic limbs equipped with sensors. For example, artificial neural networks, sensors, and deep learning techniques are crucial in the development of prosthetic hands, often known as 'wearable hand technology.' These prosthetic hands employ convolutional neural networks to grasp objects (Degol et al., 2016; Tang et al., 2016). Deep learning has numerous applications in healthcare, and the integration of these technologies offers a promising opportunity, especially in rehabilitation services.

Connecting physiotherapy and rehabilitation with artificial intelligence: At the crossroads of physical therapy and artificial intelligence (AI), AI's data analysis capabilities and machine learning algorithms offer specialized insights into physical functionality and disease conditions. Physical therapy is based on developing treatment strategies for the individual needs of patients in their recovery process. AI helps to create treatment plans specific to each patient by taking these individual differences into account. For example, AI algorithms fed with data from EHRs and wearable sensors create personalised treatment plans by analysing movement and biometric data (Korteling et al., 2021; Lanotte et al., 2023).

The integration of AI into physical therapy enables continuous monitoring and enhancement of the recovery process following illness or injury. Wearable sensors track movement patterns and physical activities in a patient's daily life, while AI systems analyse this data and provide objective data to update treatment plans. For example, sensor-based AI applications monitor the development of a patient's movement skills through functional assessments such as gait analysis in neurological diseases, and determine the most appropriate treatment to improve treatment efficacy (Albert et al., 2014; Lanotte et al., 2023).

AI algorithms also contribute significantly to diagnostic processes in physiotherapy. Image analysis systems assist in identifying musculoskeletal disorders, while motion tracking systems and video-based AI solutions are crucial for evaluating neurological conditions (Ehteshami Bejnordi et al., 2017; Lonini et al., 2018). These AI-supported applications, when blended with big data, enable the development of individualised treatment approaches and provide data-driven support for clinical decisions (Lanotte et al., 2023).

The use of AI in Physiotherapy Assessment:

The application of artificial intelligence in physiotherapy assessment can be categorized under the following subheadings:.

Gaitkeeper: GaitKeeper is an AI-powered mobile application designed to assess health status by evaluating walking speed. Walking speed is closely associated with important health indicators such as fall risk, frailty, cognitive decline, and cardiovascular health, particularly in older adults (Fritz & Lusardi, 2009; Rockwood & Mitnitski, 2007). The app standardizes these assessments by using an augmented reality virtual gait lab for quick analysis. It provides highly accurate results, outperforming traditional systems like Vicon and GAITRite, with a Spearman correlation coefficient of 0.947. In addition, it ensures user privacy through secure data processing and encryption features. The app's portable design allows for use not only in clinical settings but also in home care and remote monitoring, promoting proactive health management.

Using AI in the Perinatal Period:

AI technologies are applied across a range of fields, including disease screening and management, remote monitoring, fetal health assessment, and genetic screening in women's health and obstetrics during the perinatal period (Tejera et al., 2011; Moreira et al., 2016). For example, artificial intelligence networks are used to identify pregnancy-related complications early, such as hypertensive disorders and gestational diabetes. (Polak and Mendyk, 2004; Moreira et al., 2018). Artificial intelligence-supported monitoring technologies such as cardiotocography allow instant control of fetal health by analysing fetal heart movements (Warrick et al., 2010). Models developed to evaluate the toxic effects of medications used during pregnancy on the fetus have demonstrated high accuracy in determining the safety categories of these drugs. (Boland, 2017). These AI-supported solutions facilitate access to healthcare services by reducing hospital visits during pregnancy (Caballero-Ruiz et al., 2017).

In the framework of treatment, AI-enabled models enable early diagnosis and management of complications in high-risk pregnancies (Paydar et al., 2017).

For example, fuzzy logic-based algorithms have been created to assess the risk of HELLP syndrome during pregnancy, and these models have proven effective in achieving successful outcomes. (Moreira et al., 2018). Remote monitoring systems in pregnancy are applied in areas like managing gestational diabetes and monitoring fetal health, thus facilitating the early intervention of both maternal and fetal complications (Kazantev et al., 2012). The implementation of such artificial intelligence technologies is pivotal in reducing maternal and fetal mortality and morbidity rates (Davidson and Boland, 2021).

The Use of AI in Rehabilitation:

AI is increasingly being used in the field of physical rehabilitation, especially because of It can process large and complex data sets, make objective assessments and individualise treatment (Aung et al., 2021; Garcia-Vidal et al., 2019; Bajwa et al., 2021). Machine learning algorithms enable the development of personalised treatment plans by analysing patients' movement and health data, precisely monitor the healing process and offer remote monitoring. For example, data collected with technologies such as wearable devices or smartwatches enable more precise assessment of the level of participation and response to treatment (Lo et al., 2018; Sandal et al., 2021). Furthermore, AI-enabled mobile applications encourage users to access treatment more easily and adhere to personalised exercise programmes (Anan et al., 2021; Lo et al., 2018).

In robotic prostheses, AI analyses biological signals such as muscle signals (EMG) or brain waves (EEG), enabling the prostheses to move more in line with user intent (Kristoffersen et al., 2021; Tombini et al., 2012). Although these developments increase the functionality of prostheses, challenges such as continuous calibration, lack of portability, and user fatigue in long-term use are encountered (Kristoffersen et al., 2021; Song et al., 2005). Again, AI-supported game-based systems increase the participation of users by making rehabilitation processes fun and offer low-cost alternatives; however, these systems have factors that negatively affect the user experience such as visual clarity problems and lack of personalisation (Avola et al., 2019; Yeh et al., 2014).

The article emphasises that the clinical effects of AI in rehabilitation have not yet been fully evaluated, so more extensive research in real-world settings is needed (Sumner et al., 2023). These technologies have a high potential to support personalised and effective treatment approaches in the future.

Use in Pediatric Rehabilitation: Artificial intelligence (AI) technologies in pediatric physiotherapy offer innovative solutions to improve physiotherapy processes for children. Following the widespread use of artificial intelligence in other healthcare fields, its use in pediatric physiotherapy has also increased. In this field, AI-powered exoskeletons help children move their arms, legs and hands, while virtual reality-based video games support participation and motivation in therapy (Rowe et al., 2021). While EMG (electromyography) technology measures how efficiently muscles are working, brain-computer interfaces contribute to orthotic-prosthetic decision-making processes (Ravali et al., 2022). In addition, telerehabilitation applications provide remote therapy and maintain the continuity between the patient and the therapist in long-term and infectious diseases (Barradell, 2017).

While AI lightens the therapists' workload, it also enables reaching more patients during the treatment process and enhances patient compliance. It offers advantages such as time savings in intensive and long-term pediatric physiotherapy, boosting patient motivation, and providing opportunities for use in high-risk infection environments (Ramanandi, 2021). However, ethical, privacy, and security concerns also play a substantial role in the implementation of artificial intelligence technologies. Although these technologies come with drawbacks like high expenses and limited availability, issues related to ethics and data protection are also critical factors to address (Özdemir & Bilgin, 2021; Söderlund, 2019).

Consequently, the implementation of AI-driven applications in pediatric physiotherapy brings about a major transformation in the fields of assessment, intervention design, and patient monitoring. With the advantages provided by AI, personalized evaluation methods enable the creation of effective treatment plans, while the quality and availability of pediatric physiotherapy services are enhanced through continuous tracking of patient progress (Karabulut, 2024).

Telerehabilitation: Artificial intelligence technologies in telerehabilitation applications have the potential to manage the rehabilitation process of patients in a remote and individualised manner. Özden et al (2020) highlight the role of AI-based systems in telerehabilitation, particularly in the field of orthopaedic physiotherapy, to develop and manage automated exercise protocols based on patient data. These systems create specific exercise instructions based on patient data and make them accessible to patients through a secure platform (Skwortsow and Molin, 2015).

Artificial intelligence applications can automatically update treatment protocols by tracking patient adherence during the telerehabilitation process. These systems allow physiotherapists to remotely monitor patients' treatment compliance and, if needed, adjust the treatment plan based on adherence levels. Additionally, AI-based applications offer advantages such as cost reduction and time efficiency in the telerehabilitation process (Wells et al., 2018; Novak & Riener, 2015).

Artificial intelligence systems integrated with mobile devices can utilize sensors like accelerometers and gyroscopes to track patient movements and support them in executing exercises accurately. For instance, in an application created by Ongvisatepaiboon et al. (2015), artificial intelligence technology was used to estimate shoulder rotation angle using only an accelerometer sensor. Such systems increase the effectiveness of treatment by allowing patients to accurately perform rehabilitation exercises at home without physiotherapist intervention, and support ongoing communication between the patient and physiotherapist (Ongvisatepaiboon et al., 2015).

Use of Artificial Intelligence in Headache: Artificial intelligence (AI) applications in patients with headaches hold significant potential, especially in managing conditions like migraines. According to Petrušić et al. (2024), AI stands out as a technology that can revolutionise headache research and treatment, helping to better understand disease mechanisms and predict patient response. The analysis of health data using machine learning (ML) and advanced algorithms offers opportunities to both improve patient care and enhance clinical applications (Park et al., 2020; Thakur et al., 2020; Tso et al., 2021).

The use of AI in headache management accelerates clinical decision making by rapidly analysing large data sets, allowing clinicians to focus on more complex cases. For example, Cohen (2023) noted that AI-based diagnostic models can make headache treatment more accessible by improving the diagnostic accuracy of non-headache specialists (Cohen, 2023; Katsuki et al., 2023).

Digital applications and virtual health assistants have an important place in headache management. In a study by Stone et al (2003), electronic diaries were found to increase patient compliance to 94%, compared with 11% for paper diaries (Stone et al, 2003). In addition, Roesch et al. (2020) algorithms based on the ICHD-3 criteria were found to be very successful in classifying migraine and tension-type headaches (Roesch et al., 2020).

Wearable devices and virtual reality (VR) technologies are also emerging as adjuncts to headache management. For example, Noseda et al. (2016) showed that lenses specifically designed to manage photophobia in migraineurs reduced pain and light sensitivity by filtering blue light (Noseda et al., 2016). VR devices allow patients to manage their stress levels by receiving biofeedback in the home environment, and such devices have been observed to reduce symptoms of depression (Cuneo et al., 2023). According to Petrušić et al. AI-assisted tools not only improve patients' quality of life in headache management, but also reduce physicians' workload and provide more personalised treatment options (Petrušić et al., 2024). It is emphasised that data protection and ethical issues should also be considered for the successful integration of these technologies (Tana et al., 2024; Martelletti et al., 2023).

Results

Health services are vital to national economies, as they are central to human life. Advances in technology and science are pushing the healthcare sector beyond expectations, much like in other fields such as industry, services, education, and manufacturing. In this regard, systems referred to as "artificial intelligence" provide intelligent solutions for healthcare. AI applications are utilized across all subsectors of healthcare (Akalın & Veranyurt, 2020) and are especially involved in processes such as diagnosis, treatment, and classification, with a strong presence in various rehabilitation areas (Russell & Norvig, 2010). Specifically, this technology can be applied in any area where human-computer interaction is possible (Nicolas & Gil, 2012).

It is crucial to make machine learning methods, patient data measurement, and clinical decision support systems practical and usable in routine clinical practice. AI-powered systems are designed to enhance the accuracy and efficiency of clinical assessments in areas like balance, gait, daily activities, and the functional capabilities of both upper and lower extremities. By analyzing patient data, these systems allow for real-time tracking of rehabilitation progress, provide predictive insights into clinical advancements, and enable continuous monitoring, all of which contribute to personalized care and timely intervention in the rehabilitation process. (Köse, 2018).

The use of artificial intelligence-based intelligent technologies in rehabilitation services offers many benefits when evaluated from a health care management perspective. For example, wearable technologies that can be adapted to an individual's level and abilities can help reduce production costs. In addition, it provides benefits such as flexible adjustment of parameters such as duration, intensity, difficulty and speed of treatment; obtaining objective data with reliable and valid user detection devices; providing immediate feedback; facilitating training with real-life simulations; reducing patient and therapist burnout (Tarakçı, 2021).

The application of artificial intelligence in physiotherapy and rehabilitation significantly contributes to the individualization of treatment processes and the objective monitoring of patients. By analyzing patients' movement data, AI, along with advanced data analysis, machine learning, and deep learning algorithms, enables the development of personalized treatment plans.. Additionally, AI-driven solutions such as wearable devices and robotic technologies make rehabilitation processes more dynamic and improve patient adherence by monitoring their daily activities. In specific areas such as telerehabilitation, pediatric physiotherapy, and stroke rehabilitation, AI reduces therapists' workload and improves treatment effectiveness. AI-based systems offer more accessible and cost-effective treatments by providing remote monitoring, automated assessments, and instant feedback. However, ethical and privacy concerns are critical when incorporating these technologies into healthcare systems. In summary, although AI applications in physiotherapy present groundbreaking solutions that may enhance patients' quality of life, additional thorough research is essential to evaluate their clinical impact in the future.

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