THEORY AND RESEARCH IN

ENGINEERING

October 2022

EDITOR

PROF. DR. COSKUN ÖZALP

SERÜVEN
YAYINEVİ

Genel Yayın Yönetmeni / Editor in Chief • C. Cansın Selin Temana
Kapak & İç Tasarım / Cover & Interior Design • Serüven Yayınevi
Birinci Basım / First Edition • © Ekim 2022
ISBN • 978-605-4517-86-2

Serüven Yayınevi / Serüven Publishing
Türkiye Adres / Turkey Address: Yalı Mahallesi İstikbal Caddesi No:6 Güzelbahçe / İZMİR
Telefon / Phone: 05437675765
web: www.seruvenyayinevi.com
e-mail: seruvenyayinevi@gmail.com

Baskı & Cilt / Printing & Volume
Sertifika / Certificate No: 47083

Theory and Research in Engineering

October 2022

Editor

Prof. Dr. Coşkun ÖZALP

CONTENTS

Chapter 1

IMAGE PROCESSING WITH ARTIFICIAL INTELLIGENCE: A STEP TOWARDS INTELLIGENT TRANSPORTATION SYSTEMS

Hasan SERDAR..1

Chapter 2

ABUNDANCE AND EFFECTS OF MICROPLASTICS IN TERRESTRIAL ENVIRONMENTS

F. Olcay TOPAÇ 17

Chapter 3

ANALYSIS AND DESIGN OF SMART PV MODULES FOR CLIMATE CONDITIONS IN TURKEY

İbrahim GÜNEŞ..37

Chapter 4

NOVEL DEVICE FOR CAPSULORHEXIS USING SHAPE MEMORY ALLOY (SMA)

Mustafa SOYLAK 49

Chapter 5

A TURKISH CHATBOT DEVELOPED FOR URBAN TRANSPORTATION

Fatih SOYGAZİ & Yılmaz KILIÇASLAN & Bülent DEMİR 61

Chapter 6

COVID 19 AND INDUSTRY 4.0

M. Zühal ERİŞGİN BARAK...75

Chapter 7

CATALYTIC CONVERSION OF JERUSALEM ARTICHOKE WITH A BRÖNSTED ACID CATALYST IN SUBCRITICAL WATER MEDIUM

Nazlıcan ATİK & Nihal CENGİZ & Levent BALLİCE.........................89

Chapter 1

IMAGE PROCESSING WITH ARTIFICIAL INTELLIGENCE: A STEP TOWARDS INTELLIGENT TRANSPORTATION SYSTEMS

Hasan SERDAR[1]

1 Department of Computer Engineerıng, Seydisehir Ahmet Cengiz Faculty of Engineering, Necmettin Erbakan University, Konya / Turkiye, Email: hserdar@erbakan.edu.tr, ORCID: 0000-0003-3253-7390

Introduction

An Intelligent Transportation System (ITS) is a network of hardware and software that uses technology to improve the efficiency and safety of a transportation system (Sumalee & Ho, 2018). ITS can be used to monitor and manage traffic, as well as to provide real-time information to drivers.

ITS systems are often used in conjunction with other technologies, such as traffic signals and road markings, to manage traffic flow. In some cases, ITS systems can also be used to automatically adjust traffic signals based on traffic conditions.

ITS systems can be used to monitor and manage a variety of transportation systems, including:

- Roadways

- Public transit

- Freight and logistics

- Emergency response

ITS systems can improve the efficiency of a transportation system by reducing congestion, improving safety, and reducing travel time. Additionally, ITS systems can help to reduce emissions and conserve energy by reducing the need for idling and stop-and-go driving.

Image processing is important for Intelligent Transportation Systems (ITS) because it can be used to detect and track vehicles, monitor traffic conditions, and provide information to drivers and other road users (Sankaranarayanan, Mala, & Mathew, 2020). By using image processing, ITS can improve safety and efficiency on the roadways.

Artificial intelligence (AI) is rapidly evolving and has the potential to revolutionize many different fields, including image processing (Shimizu & Nakayama, 2020). AI can be used to automatically detect and label objects in images, identify faces, and even generate new images.

Image processing is a key area where AI can have a major impact. For example, AI can be used to automatically remove background clutter from images or to improve the resolution of images. AI can also be used to automatically identify objects in images, which can be helpful for security applications or for cataloguing images (Nadeem, Jalal, & Kim, 2021), (Falzon, et al., 2019), (Akcay & Breckon, 2022).

AI-based image processing is still in its early stages, but the potential applications are numerous and the field is evolving rapidly.

Image processing is a branch of computer science that deals with manipulating digital images. It is a vast field with many sub-fields, such as image compression, image enhancement, and image segmentation. In recent years, there has been a growing interest in using artificial intelligence (AI) for image processing tasks (Sadeghi, et al., 2022), (Darko, Chan, Adabre, Edwards, Hosseini, & Ameyaw, 2020), (Rong, Mendez, Assi, Zhao, & Sawan, 2020). This study is focused on AI-based image processing methods.

Image processing generally refers to the ability to take an image as input and perform some operations on it to produce an output image. The input image can be in various formats, such as a digital photograph, a scanned document, or a 3D model. The output image can also be in various formats, such as a printed photograph, a PDF document, or a 3D model. There are many different types of operations that can be performed on an image, such as image compression, image enhancement, and image segmentation.

Image compression is an important sub-field of image processing. Image compression is the process of reducing the file size of an image without reducing the quality of the image. There are many different methods of image compression, such as lossy and lossless compression. Lossy compression methods, such as JPEG compression, sacrifice some image quality in order to achieve a higher degree of compression (Patwa, Ahuja, Somayazulu, Tickoo, Varadarajan, & Koolagudi, 2020). Lossless compression methods, such as PNG compression, do not sacrifice any image quality but typically achieve a lower degree of compression (Gowda, et al., 2022).

Image enhancement is another important sub-field of image processing. Image enhancement is the process of improving the quality of an image. This can be done in various ways, such as increasing the contrast or sharpness of an image. Image enhancement can also be used to remove noise from an image or to improve the color balance (Wang, Song, Fortino, Qi, Zhang, & Liotta, 2019).

Image segmentation is another sub-field of image processing. Image segmentation is the process of partitioning an image into multiple regions. This can be done for various reasons, such as object recognition or image compression. There are many different methods of image segmentation, such as region-based methods, edge-based methods, and cluster-based methods (Wang, Ma, & Zhu, 2021).

In recent years, there has been a growing interest in using artificial intelligence (AI) for image processing tasks. AI is well suited for image processing tasks because of its ability to learn from data and generalize to new data. There are many different types of AI methods, such as supervised learning, unsupervised learning, and reinforcement learning (Sarker, 2021).

Supervised learning is a type of AI where the data is labeled and the AI algorithm is trained to learn the relationship between the data and the labels. This is the most commonly used type of AI for image processing tasks. For example, a supervised learning algorithm could be used to learn the relationship between images of faces and the labels (e.g., male or female) (Toreini, Aitken, Coopamootoo, Elliott, Zelaya, & Van Moorsel, 2020).

Unsupervised learning is a type of AI where the data is not labeled and the AI algorithm is trained to learn the relationships between the data. This is less commonly used for image processing tasks. For example, an unsupervised learning algorithm could be used to learn the relationships between images of faces (Weber, Welling, & Perona, 2000).

Reinforcement learning is a type of AI where the AI algorithm is trained to learn by trial and error. This is less commonly used for image processing tasks. For example, a reinforcement learning algorithm could be used to learn the best way to segment an image into multiple regions (Tian, Si, Zheng, Chen, & Li, 2020).

There are many different types of AI methods that have been applied to image processing tasks, such as image compression, image enhancement, and image segmentation. Some of the most promising methods are based on deep learning, which is a type of machine learning that is particularly well suited for image processing tasks. Deep learning is a type of AI that is able to learn from data in a way that is similar to the way humans learn. Deep learning algorithms have been able to achieve state-of-the-art results on many image processing tasks, such as image classification, object detection, and image segmentation (Pal, Pramanik, Maiti, & Mitra, 2021).

The use of AI for image processing tasks is a rapidly growing area of research. There are many different AI methods that have been applied to image processing tasks, and the results have been promising. Deep learning algorithms have been particularly successful at image processing tasks. As the research in this area continues to grow, it is expected that the use of AI for image processing tasks will become more widespread.

This study is focused on image classification, object detection, and image segmentation using deep learning methods. This study is also touch on papers that explore the use of generative models for image synthesis and manipulation.

Image classification using deep learning

Image classification is a process of assigning a class label to an image (Bi, Sun, & Xu, 2018). This study reviews the use of deep learning for image classification. The structure of deep learning with n-hidden units are shown Figure 1. Deep learning is a type of machine learning that uses artificial neural networks to learn from data. The simple image classification using deep learning is shown in Figure 2. Neural networks are a type of algorithm that can learn to recognize patterns. They are similar to the way the human brain learns to recognize patterns.

Deep learning has been shown to be effective for image classification (Bi, Sun, & Xu, 2018). One study found that a deep learning algorithm was able to correctly classify images of objects with an accuracy of 97.3% (Inaba, et al., 2020). Another study found that deep learning was able to improve the accuracy of image classification by more than 10% (Amin, Alsulaiman, Muhammad, Mekhtiche, & Hossain, 2019).

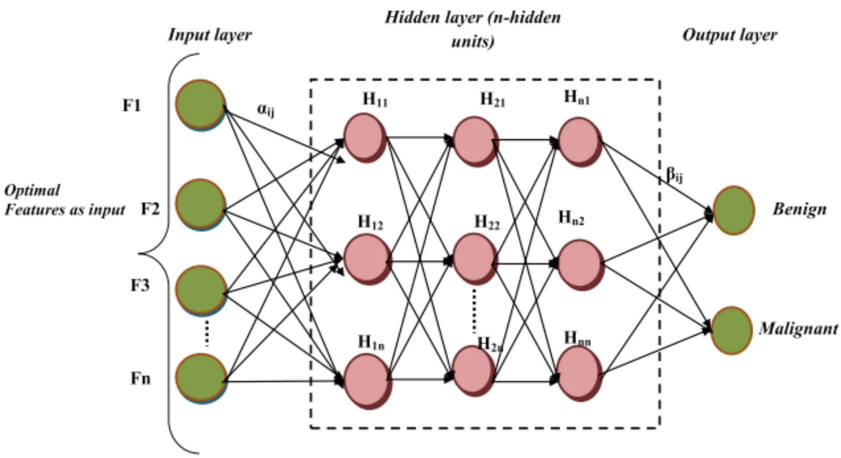


Figure 1. Structure of deep learning (R. J. S. Raj, 2020)

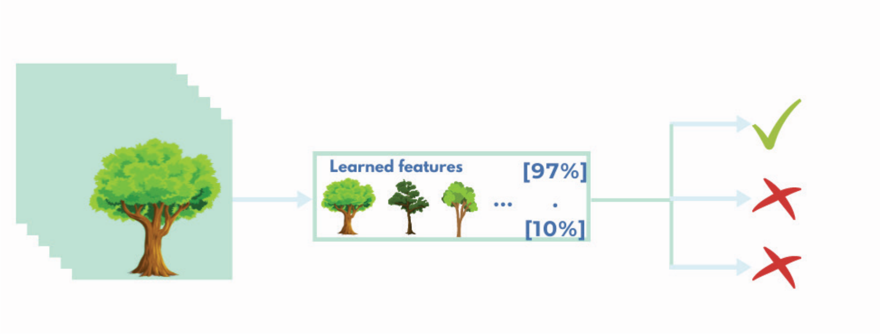


Figure 2. Simple image classification using deep learning

Deep learning algorithms require a large amount of data to learn from. They also require a lot of computing power. For these reasons, deep learning is typically used for large-scale image classification tasks, such as classifying images in a dataset of millions of images.

Object detection using deep learning

Deep learning is a powerful tool for solving various computer vision tasks, including object detection. Deep learning is a type of machine learning that is inspired by the structure and function of the brain. Deep learning algorithms learn to represent data in multiple layers of abstraction, allowing them to extract complex patterns and make predictions. Deep learning has been shown to be effective for a variety of tasks, including image classification, speech recognition, and natural language processing. The sample object detection using deep learning is shown in Figure 3 and 4.

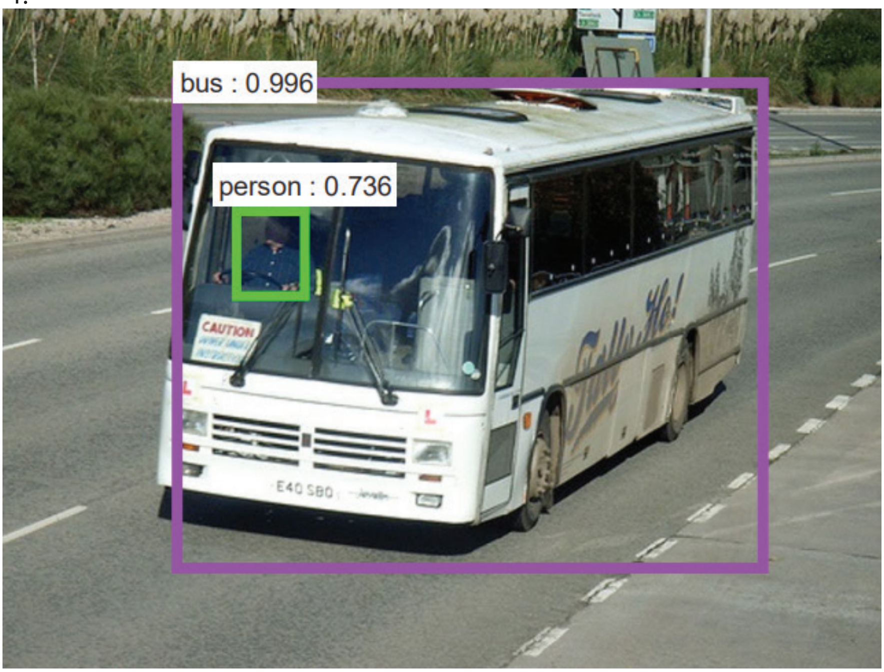


Figure 3. Sample object detection using deep learning (Ren, He, Girshick, & Sun, 2017).

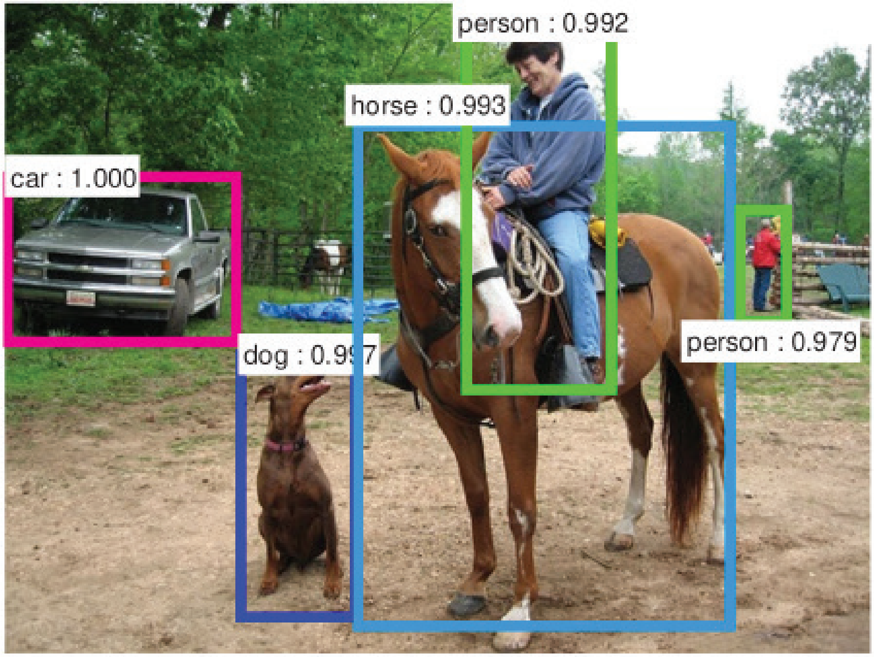


Figure 4. Sample object detection using deep learning (Ren, He, Girshick, & Sun, 2017).

Object detection is the task of identifying objects in images or videos. This is a difficult task for traditional machine learning methods, as the appearance of objects can vary significantly due to factors such as lighting, viewpoint, and scale. Deep learning offers a promising solution to this problem, as it can learn to extract features from images that are invariant to these factors. It is one of the most active areas of research in computer vision, with a large number of papers published every year. Deep learning is a relatively new field that has shown promise in many areas of computer vision, including object detection (Alaskar, Hussain, Almaslukh, Vaiyapuri, Sbai, & Dubey, 2022). Deep learning algorithms can automatically learn to extract features from images, making the feature engineering process much easier.

Image segmentation using deep learning

Image segmentation is the process of partitioning an image into multiple regions. Each region can then be processed separately, which can be useful for many different tasks such as object detection and recognition. There are many different ways to perform image segmentation, but the most common approach is to use some kind of boundary detection algorithm (Ouyang, Zhang, Pan, & Li, 2022). This can be done using a variety of methods, such as active contours, region growing, and graph-based methods. The sample image segmentation results of DeepLabV3 are shown in Figure 5.

Deep learning approaches have been shown to be effective for many different tasks, including image classification and object detection. Recently, there has been a lot of interest in using deep learning for image segmentation. There are a few different ways to do this, but the most common approach is to use a fully convolutional network (FCN) (Liu, Wang, Wang, Ji, & Meng, 2022). FCNs are effective because they are able to take an image of any size and output a segmentation map of the same size. This makes them well-suited for image segmentation tasks.

In recent years, there has been a growing interest in 3D point-cloud segmentation, due to the increasing availability of 3D data from a variety of sources, such as LiDAR, RGB-D cameras, and stereo cameras. The goal of 3D point-cloud segmentation is to partition a point-cloud into a set of meaningful regions, which can then be used for further analysis or 3D reconstruction (Lai, et al., 2022).

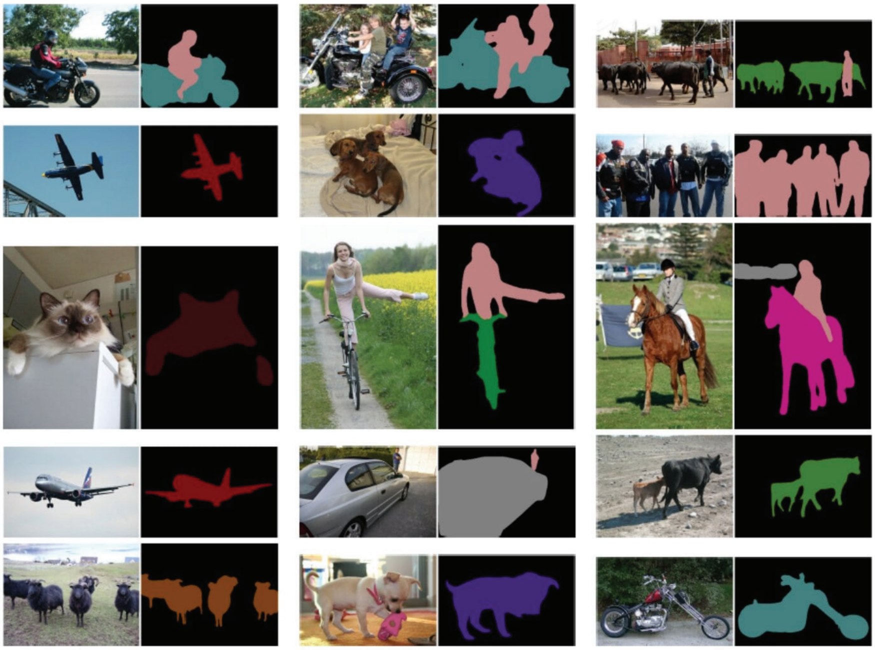


Figure 5. Sample image segmentation results of DeepLabV3 (Chen, Papandreou, Schroff, & Adam, 2017).

There are a variety of approaches for 3D point-cloud segmentation, including region-growing, voxel-based methods, and methods based on graph theory. However, the choice of approach depends on the specific application and the type of data being segmented.

Region-growing methods are well-suited for data that contains well-defined regions, such as objects in a room or buildings in a city. These methods start with a seed point and then grow the region by adding neighboring points that are similar to the seed point.

Voxel-based methods are efficient for data that is evenly spaced, such as data from LiDAR sensors. These methods discretize the point-cloud into a 3D grid of small cubes, or voxels, and then segment the voxels

There are still many challenges that remain in the area of image segmentation. One of the biggest challenges is that of dealing with complex shapes. Another challenge is that of handling images with large amounts of variation, such as those that contain many different objects. Additionally, there is a need for more efficient methods for training and deploying deep learning models.

Despite the challenges that remain, deep learning approaches have shown a lot of promise for image segmentation. In the future, it is likely that we will see more work in this area, which will lead to improved methods and results.

Generative models for image synthesis

A generative model for image synthesis is a computer model that is used to generate new images. These models are based on a set of training images, and they learn to generate new images by extracting the underlying patterns from the training data.

There are a number of different generative models for image synthesis, including deep learning models, generative adversarial networks, and variational autoencoders (Gan & Wang, 2022). Each of these models has its own strengths and weaknesses, and there is no one best model for all applications.

Semantic simultaneous localization and mapping (SLAM) systems aim to simultaneously localize the camera and construct a 3D semantic map. Semantic SLAM system used to estimate the camera pose. The semantic SLAM system is trained with 3D semantic maps generated by the camera-aware method. It is used to the estimated camera pose to generate the 3D semantic map.

In Figure 6, camera-aware method is capable of generating 3D semantic maps with realistic appearance, which can be used as the input of a 3D semantic SLAM system. This allows the method to be applied to long-term SLAM applications. For example, the generated semantic maps can be used as the training data for a semantic SLAM system, to improve the semantic mapping accuracy. Moreover, the generated 3D semantic maps can be used as the input of a 3D semantic SLAM system for more accurate SLAM, e.g., for semantic SLAM with a more accurate camera pose estimation.

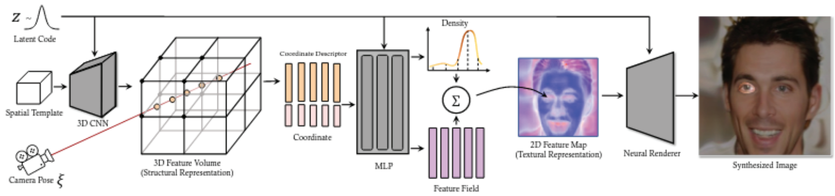


Figure 6. Framework of VolumeGAN (Xu, Peng, Yang, Shen, & Zhou, 2022).

Deep learning models are a powerful tool for image synthesis, but they require a large amount of training data. Generative adversarial networks can generate high-quality images, but they are difficult to train. Variational autoencoders are a good compromise between these two approaches, and they are relatively easy to train.

In conclusion, there is no one best generative model for image synthesis. The choice of model depends on the application, the amount of training data available, and the desired quality of the generated images.

Generative models for manipulation

A generative model is a machine learning model that can generate new data points based on a training set. These models are used for a variety of applications, including image generation, video synthesis, and text generation.

There are a few different types of generative models, including autoencoders, variational autoencoders, and generative adversarial networks (Ahmad, Sun, You, Palade, & Mao, 2022). Each type of model has its own advantages and disadvantages, and there is no one-size-fits-all solution.

Autoencoders are a type of generative model that learn to compress and decompress data. They can be used for data denoising, dimensionality reduction, and generating new data points.

Variational autoencoders are a type of autoencoder that uses a latent space to generate new data points. They are often used for image generation and text generation.

Generative adversarial networks are a type of generative model that pits two neural networks against each other. One network generates new data points, while the other tries to discriminate between real and fake data points. This competition forces the generator to produce better and better data.

Nearest neighbors is also the other method of image processing where each pixel in an image is replaced with the average of the neighboring pixels. This can be used to smooth out an image, or to create a more defined edge. Nearest neighbors is a relatively simple method, but it can be very effective.

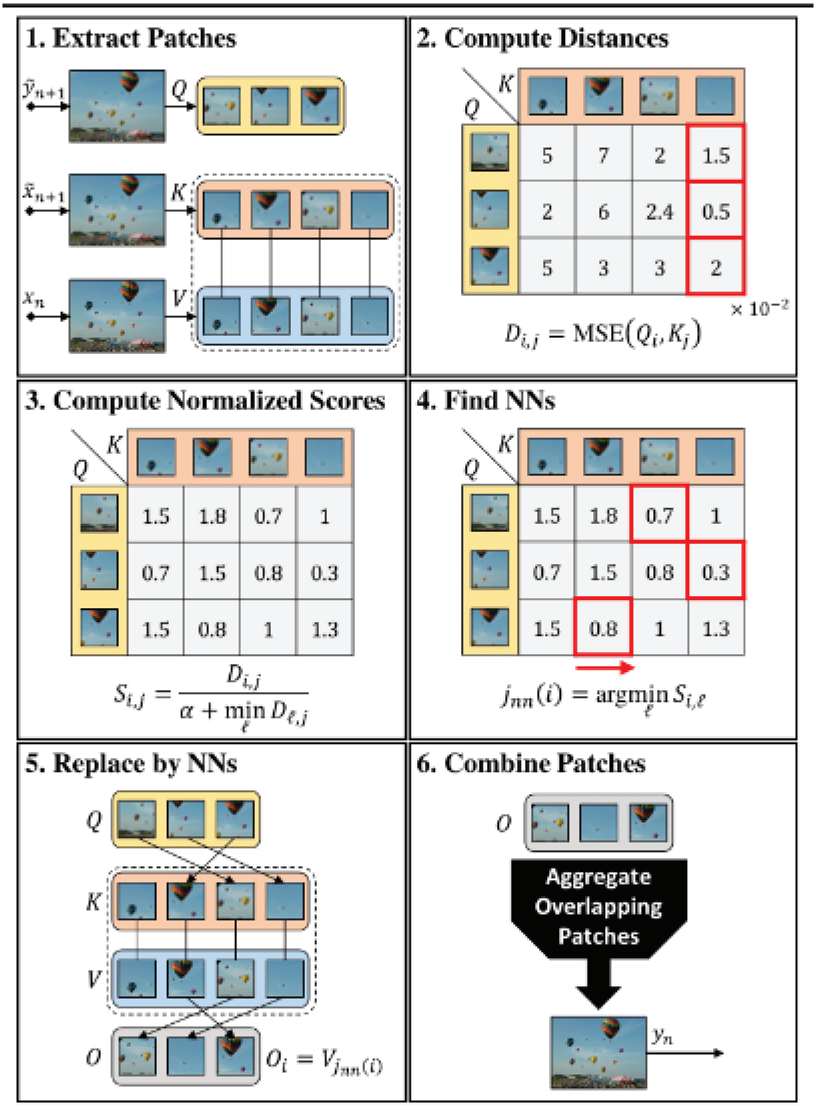


Figure 7. Algorithmic steps of Patch Nearest Neighbors (Granot, Feinstein, Shocher, Bagon, & Irani, 2022).

Patch Nearest Neighbors is a method for computing nearest neighbors in high dimensional space. Algorithmic steps of Patch Nearest Neighbors are shown in Figure 7. Given a set of points, Patch Nearest Neighbors computes the nearest neighbors of each point by exhaustively searching the patches around each point. Patches are defined by a radius and a set of points is said to be in a patch if the distance between the points is less than the radius. The algorithm is designed to work with any distance metric, but is most efficient when the metric is a metric of the Euclidean space.

Conclusion

Artificial intelligence is a process of programming computers to make decisions for themselves. Artificial intelligence has been used in image processing for many years, and its use has grown exponentially in recent years. Image processing is a branch of AI that deals with the manipulation of digital images. Artificial intelligence has the potential to revolutionize image processing. With the ability to learn and improve its performance over time, AI could enable computers to process images more effectively and efficiently than ever before. This could lead to better-quality images and faster image processing times, making it possible to use AI in a wide range of applications such as Intelligent Transportation Systems, medical imaging, security and surveillance, and autonomous vehicles.

In this study, image classification, object detection, and image segmentation using deep learning methods are investigated and presented. This study is also touch on papers that explore the use of generative models for image synthesis and manipulation.

In conclusion, image processing with AI can be used to improve the quality of images, as well as to process large amounts of images quickly and accurately. This technology can be used in a variety of fields, such as Intelligent Transportation Systems, medical imaging, security and surveillance, and search and rescue.

REFERENCES

Ahmad, B., Sun, J., You, Q., Palade, V., & Mao, Z. (2022). Brain Tumor Classification Using a Combination of Variational Autoencoders and Generative Adversarial Networks. *Biomedicines, 10*, 223.

Akcay, S., & Breckon, T. (2022). Towards automatic threat detection: A survey of advances of deep learning within X-ray security imaging. *Pattern Recognition, 122*, 108245.

Alaskar, H., Hussain, A., Almaslukh, B., Vaiyapuri, T., Sbai, Z., & Dubey, A. K. (2022). Deep learning approaches for automatic localization in medical images. *Computational Intelligence and Neuroscience, 2022*.

Amin, S. U., Alsulaiman, M., Muhammad, G., Mekhtiche, M. A., & Hossain, M. S. (2019). Deep Learning for EEG motor imagery classification based on multi-layer CNNs feature fusion. *Future Generation computer systems, 101*, 542–554.

Bi, H., Sun, J., & Xu, Z. (2018). A graph-based semisupervised deep learning model for PolSAR image classification. *IEEE Transactions on Geoscience and Remote Sensing, 57*, 2116–2132.

Chen, L.-C., Papandreou, G., Schroff, F., & Adam, H. (2017). Rethinking Atrous Convolution for Semantic Image Segmentation.

Darko, A., Chan, A. P., Adabre, M. A., Edwards, D. J., Hosseini, M. R., & Ameyaw, E. E. (2020). Artificial intelligence in the AEC industry: Scientometric analysis and visualization of research activities. *Automation in Construction, 112*, 103081.

Falzon, G., Lawson, C., Cheung, K.-W., Vernes, K., Ballard, G. A., Fleming, P. J., et al. (2019). ClassifyMe: a field-scouting software for the identification of wildlife in camera trap images. *Animals, 10*, 58.

Gan, M., & Wang, C. (2022). Esophageal optical coherence tomography image synthesis using an adversarially learned variational autoencoder. *Biomedical Optics Express, 13*, 1188–1201.

Gowda, D., Sharma, A., Rajesh, L., Rahman, M., Yasmin, G., Sarma, P., et al. (2022). A novel method of data compression using ROI for biomedical 2D images. *Measurement: Sensors*, 100439.

Granot, N., Feinstein, B., Shocher, A., Bagon, S., & Irani, M. (2022). Drop the gan: In defense of patches nearest neighbors as single image generative models. *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, (pp. 13460–13469).

Inaba, A., Hori, K., Yoda, Y., Ikematsu, H., Takano, H., Matsuzaki, H., et al. (2020). Artificial intelligence system for detecting superficial laryngopharyngeal cancer with high efficiency of deep learning. *Head & Neck, 42*, 2581–2592.

Lai, X., Liu, J., Jiang, L., Wang, L., Zhao, H., Liu, S., et al. (2022). Stratified Transformer for 3D Point Cloud Segmentation. *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, (pp. 8500–8509).

Liu, Z., Wang, M., Wang, F., Ji, X., & Meng, Z. (2022). A Dual-Channel Fully Convolutional Network for Land Cover Classification Using Multifeature Information. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 15*, 2099–2109.

Nadeem, A., Jalal, A., & Kim, K. (2021). Automatic human posture estimation for sport activity recognition with robust body parts detection and entropy markov model. *Multimedia Tools and Applications, 80*, 21465–21498.

Ouyang, Z., Zhang, P., Pan, W., & Li, Q. (2022). Deep learning-based body part recognition algorithm for three-dimensional medical images. *Medical Physics, 49*, 3067–3079.

Pal, S. K., Pramanik, A., Maiti, J., & Mitra, P. (2021). Deep learning in multi-object detection and tracking: state of the art. *Applied Intelligence, 51*, 6400–6429.

Patwa, N., Ahuja, N., Somayazulu, S., Tickoo, O., Varadarajan, S., & Koolagudi, S. (2020). Semantic-preserving image compression. *2020 IEEE International Conference on Image Processing (ICIP)*, (pp. 1281–1285).

Ren, S., He, K., Girshick, R., & Sun, J. (2017, June). Faster R-CNN: Towards Real-Time Object Detection with Region Proposal Networks. *IEEE transactions on pattern analysis and machine intelligence, 39*(6), 1137-1149.

Rong, G., Mendez, A., Assi, E. B., Zhao, B., & Sawan, M. (2020). Artificial intelligence in healthcare: review and prediction case studies. *Engineering, 6*, 291–301.

Sadeghi, D., Shoeibi, A., Ghassemi, N., Moridian, P., Khadem, A., Alizadehsani, R., et al. (2022). An overview of artificial intelligence techniques for diagnosis of Schizophrenia based on magnetic resonance imaging modalities: Methods, challenges, and future works. *Computers in Biology and Medicine*, 105554.

Sankaranarayanan, M., Mala, C., & Mathew, S. (2020). Significance of Real-Time Systems in Intelligent Transportation Systems. In *Handling priority inversion in time-constrained distributed databases* (pp. 61–85). IGI Global.

Sarker, I. H. (2021). Machine learning: Algorithms, real-world applications and research directions. *SN Computer Science, 2*, 1–21.

Shimizu, H., & Nakayama, K. I. (2020). Artificial intelligence in oncology. *Cancer science, 111*, 1452–1460.

Sumalee, A., & Ho, H. W. (2018). Smarter and more connected: Future intelligent transportation system. *Iatss Research, 42*, 67–71.

Tian, Z., Si, X., Zheng, Y., Chen, Z., & Li, X. (2020). Multi-step medical image segmentation based on reinforcement learning. *Journal of Ambient Intelligence and Humanized Computing*, 1–12.

Toreini, E., Aitken, M., Coopamootoo, K., Elliott, K., Zelaya, C. G., & Van Moorsel, A. (2020). The relationship between trust in AI and trustworthy machine learning technologies. *Proceedings of the 2020 conference on fairness, accountability, and transparency*, (pp. 272–283).

Wang, Y., Song, W., Fortino, G., Qi, L.-Z., Zhang, W., & Liotta, A. (2019). An experimental-based review of image enhancement and image restoration methods for underwater imaging. *IEEE access, 7*, 140233–140251.

Wang, Z., Ma, B., & Zhu, Y. (2021). Review of level set in image segmentation. *Archives of Computational Methods in Engineering, 28*, 2429–2446.

Weber, M., Welling, M., & Perona, P. (2000). Unsupervised learning of models for recognition. *European conference on computer vision*, (pp. 18–32).

Xu, Y., Peng, S., Yang, C., Shen, Y., & Zhou, B. (2022). 3d-aware image synthesis via learning structural and textural representations. *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, (pp. 18430–18439).

Chapter 2

ABUNDANCE AND EFFECTS OF MICROPLASTICS IN TERRESTRIAL ENVIRONMENTS

F. Olcay TOPAÇ[1]

1 Prof. Dr. F. Olcay Topaç, Bursa Uludag University, Department of Environmental Engineering, ORCID: 0000-0002-6364-4087, olcaytopac@uludag.edu.tr

Introduction

Plastic materials have unique properties and are therefore widely used in industrial, medical and agricultural fields around the world. These applications cover a variety of products such as films for foodstuff packaging, long-lasting materials and expensive medical supplies. Plastics have many advantageous properties such as corrosion resistance, low raw material and production cost, and overall durability. Because of this reason; it is expected that they will be preferred more compared to conventional needs such as paperboards, metalic, and wooden materials (Geyer et al., 2017). 368 million tons of plastic materials were manufactured globally in 2020, but it has been reported that only a small portion of this huge amount has been recycled (Plastic facts, 2021). The great increase in global plastic production has caused an increment in the quantity of plastic waste released into the nature (Brandon et al., 2019) and this amount is anticipated to rise even more remarkably in the upcoming time (Isobe et al., 2019). It is predicted that about 12.000 million tons of plastic debris will accumulate in landfill sites and various compartments of environment by the year 2050 (Geyer et al., 2017). Very low recycling rates lead to large amounts of plastic waste formation, and this is accepted as a part of the worldwide environmental deterioration problem because of the poor degradability of plastic-based materials (Barboza et al., 2018).

Although most petroleum-based plastic items can persist in the nature almost forever, they are decomposed into tiny particles by the effects of various chemical, physical and biological events such as microorganism activities, weather conditions, oxidative degradation under ultraviolet irradiation (Rillig et al., 2017; Ahmed et al., 2018). When the diameter of the disintegrated plastic pieces is less than 5 mm, these pieces are specified as microplastics (Barnes, 2009; Andrady, 2017) and microplastic contamination is accepted as a growing threat to environmental systems. The specific surface area of microplastics is greater than that of plastics and various contaminants can easily adhere to the surface of microplastics, making them even more harmful to the environment (Amelia et al., 2021; Tang, 2021). Therefore, the transport of microplastics can cause a redistribution of other organic or inorganic toxic pollutants found on microplastics'surface. In addition, due to their tiny dimensions, microplastics are consumed with ease by many aquatic organisms and accumulate in their bodies.

A great deal of studies have proved that microplastics may lead to many deleterious impacts on fish and other aquatic species such as reduced food intake, growth retardation, oxidative damage, and behavioral impairment (Dioses-Salinas et al., 2019). It has been determined that microplastics can also enter the plant system (Yu et al., 2021). Since some of the aquatic plants and animals are used by humans as food sources, it is possible for microplastics and other pollutants related to microplastics to introduce to the human metabolism and threaten health of mankind (Wang et al., 2019). Therefore, it is crucial to know the existance, sources, abundance and environmental fate of microplastics for protecting public health.

When the literature on microplastic pollution is examined, it is seen that the studies mostly focus on the methods applied for the analysis of microplastics in aquatic ecosystems, as well as their properties, effects and toxicology. However, researches on the presence and ecological consequences of microplastic contamination in soil ecosystem are still scarce. This chapter aims to evaluate the actual scientific papers on the existence, attitude, and alteration routes of microplastics in soil ecosystems, to address knowledge gaps, to explain the environmental effects of microplastics in terrestrial systems and to recommend further studies associated with microplastic pollution.

Types and Sources of Microplastics

Microplastics have a very broad definition and refer to polymers with varying particle sizes, densities and shapes. Microplastics that are found in environmental compartments contain a variety of synthetic polymers and exist predominantly as granules, fragments, filaments and pellets. (Anik et al., 2021; Karim et al., 2019). Statistical data showed that the most frequently used polymers are polyethylene terephthalate, polypropylene, polyethylene, polyvinyl chloride, polystyrene and polyurethane. These polymer types account for roughly 81% of Europe's plastic production in 2016 (Koelmans et al., 2019; Strungaru et al., 2019).

Microplastics are classified into two groups with respect to origin: primary and secondary microplastics. Primary ones are produced directly in small size. Some instances of primary microplastics are those used in personal hygiene products, paints, plastic jogging paths in schools, synthetic grass, or rubber roads. Primary microplastic particles often enter in domestic and industrial drainage systems and eventually wastewater treatment facilities. Therefore, wastewater treatment units are considered as a significant way for the release of microplastics into the nature. Although microplastic removal efficiency can reach 99% in some cases, removal percentages below 30% are also encountered. Therefore, a great deal of microplastic particles are still released into the environment through wastewater treatment facilities and contribute to the pollution of aquatic ecosystems. In addition to the process selection in wastewater treatment plants, microplastic properties such as size, morphology and density determine the removal performance of microplastics (Enfrin et al., 2019; Xu et al., 2021). Secondary microplastics, on the other hand, are formed by the disintegration of municipal waste materials such as plastic pochettes and containers, agricultural films, fishery waste, and other sizeable plastic residues via the influence of biological, chemical and physical factors. In particular, the effects caused by UV radiation and high temperatures make plastics brittle and facilitate their fragmentation (Andrady, 2011; Da Costa et al., 2018; Cheng et al., 2021; Sun et al., 2022). The fragmentation of plastic products increases both the surface area of the particles and also the number of particles per mass unit. The main causes of plastic breakdown in marine waters are exposure to sunlight and wave action. Large temperature fluctuations on the soil surface and UV radiation from sunlight are primarily effective in the plastic fragmentation that takes place on terrestrial environments (Andrady, 2011). Figure 1 indicates the major sources of microplastics.

The Occurence of Microplastics in Terrestrial Ecosystems

In addition to the aquatic habitat, microplastic residues may release into the terrestrial ecosystem owing to uncontrolled dumps and various human activities, causing soil pollution. (Wong et al., 2020). The occurence of microplastic particles in soil systems is today recognized as an important global problem. According to Horton et al. (2017), the amount of microplastics in terrestrial habitats may be much higher (4 to 23 times) than that of in the ocean. It has been stated that the microplastic concentration in highly polluted soils can reach up to 7% of soil weight (De Souza Machado et al., 2018a). Microplastic fragments may enter the terrestrial ecosystem as primary or secondary microplastics. Low-density polyethylene (LDPE) films have been preferred in greenhouses and agricultural mulching systems for many years. Plastic film residues mix with soil aggregates and fragmented under the influence of frequent tillage activities and accumulate in the soil as secondary micropollutants (Meng et al., 2020).

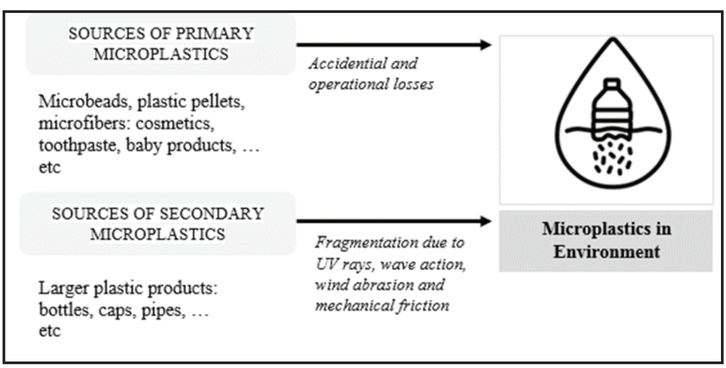


Figure 1. Principle sources of microplastic particles entering to the environment

Besides, when the packaging of soil fertilizers and agrochemicals used in agricultural production activities is not disposed of properly and thrown into the environment, it contributes to the increase of microplastic concentration in agrosystems (Zhou et al., 2020). Since microplastic fibers from garments and microplastic beads from hygenic products are abundant in waste streams, wastewater treatment facilities are also considered to be a significant reason for microplastic pollution (Mason et al., 2016). Moreover, wastewater sludge from the treatment facilities is widely used as a soil amendment and it is thought that a vast amount of microplastics enter the farmlands with this application (Liu et al., 2021). It has been stated that 44,000 to 300,000 and 63,000 to 430,000 tonnes/year of microplastics enter the cultivated farmland in North America and Europe, respectively, by the sewage sludge application (Nizzetto et al.,2016). It was also emphasized in the study that this amount is well above the estimated total microplastic load in the global oceans. Some other ways microplastics enter agricultural soils are through irrigation and airborne deposition (Perez-Reveron et al., 2022; Wright et al., 2020). A recent study investigated the traffic-related microplastic contmination and highlighted that heavy traffic flow, high mobility along roads can cause microplastic contamination in neighboring soils (Chen et al., 2020).

In a study, the upper limit value for microplastic pollution in soil was determined as 0.1 % (by weight) (Wang et al., 2019). In another study, it was stated that the microplastic concentration in the soil varies with depth and reached 7% by weight in the top of the soil profile (Fuller and Gautam, 2016). However, microplastic contamination in the top soils of an agricultural land in Europe was found to be less than ~670 fiber kg-1 concentration (Ren et al., 2018). In another research, the microplastic concentration of 67,500 mg/kg was determined in a field near an industrial zone in Sydney, Australia (Fuller and Gautam 2016). The study of Tiwari et al. (2019) indicated that the amount of microplastics found in beach soils of Mumbai, India was 220 items/kg. Yang et al. (2021) investigated the distribution of microplastics in soil amended with pig slurry and found that approximately 3.5 million microplastic particles $ha^{-1}a^{-1}$ accumulated in the soil in association with the amendment. According to a study performed by Zhou et al. (2020), microplastic levels in mulched and unmulched soils were found to be 571 pieces and 263 pieces per kilogram soil, respectively. In addition, it has been determined that microplastic fibers and films are more abundant in mulched soils. Piehl et al. (2018) studied the distribution of micro and macroplastics in a farmland soil in southeast Germany to investigate the plastic-induced pollution in soils. The results showed that there were 206 macroplastic particles/ha and 0.34 ± 0.36 microplastic particles/kg in the studied land. In addition, it was reported in the study that the most prevalent kind of polymer in the examined field was polyethylene, followed by polystyrene and polypropylene.

Effects of Microplastics on Terrestrial Life

Although there are many detailed studies indicating the impacts of microplastics on the water environment, the potential impacts on the terrestrial habitats have not been fully demonstrated. However, due to the low level of light and oxygen in the soil, it is predicted that microplastics can persist in the soil ecosystem for over 100 years (Castaneda et al. 2014). Figure 2 indicates the sources and effects of microplastics in soil. Various activities such as flooding, air deposition, sewage sludge application, irrigation, erosion and agricultural mulching are listed as the main reasons of microplastic pollution in soil (Blasing and Amelung, 2018; Corradini et al., 2019). Microplastics can affect soil bio-physicochemical properties and the mobility of other pollutants in the soil matrix, thus having considerable impacts on the functions of soil ecosystem. Moreover, soil biota at different trophic levels may be adversely affected by the presence of microplastics, and in parallel, human health may be impaired through the food chain.

Plants

Plants are significant parts of the terrestrial environment, and microplastic contamination in soil can directly influence the growth and development of the plant as well as the stress responses of plant metabolism. Many recent studies analyze the effects of microplastics on several plant parts such as roots, stems and leaves, and examine various physiological indicators. Yang et al. (2021) conducted a pot trial to assess the adverse impacts of microplastic accumulation in the soil-plant system. According to the results obtained, increasing microplastic addition decreased the chlorophyll content of the leaves. It was also emphasized in the study that the risks arising from microplastic pollution may vary relying on the particle size and polymer type. In a study carried out by Kalcíkova et al. (2017), it was determined that the presence of microplastics negatively affected duckweed (*Lemna minor*) growth in terms of root length and stem cell viability.

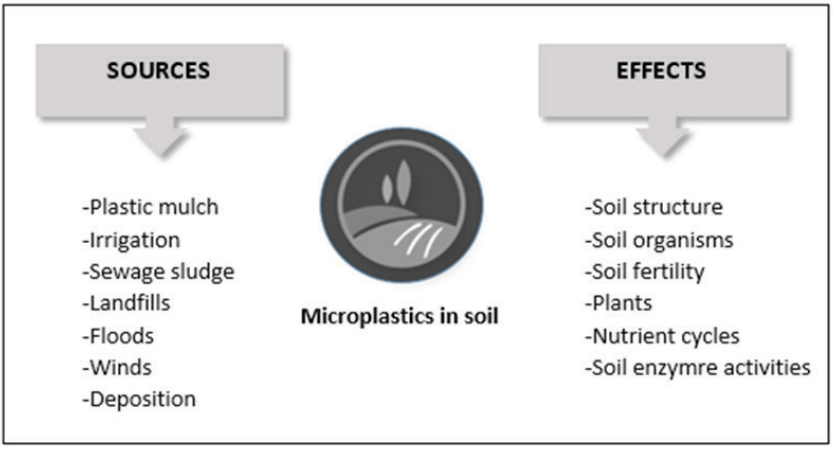


Figure 2. Sources and effects of microplastics in soil.

In another study, five different concentrations (10^3 to 10^7 particles mL^{-1}) of microplastics were applied to the seeds of cress *(Lepidium sativum)*, a terrestrial plant. The obtained results showed that the observed negative effects increased with increasing plastic size. Also, for all plastic sizes, germination rates were markedly lower after 8 hours of microplastic exposure. Confocal microscopy of fluorescent particles showed that the microplastics occluded the tiny holes in the seed coats, resulting in a negative impact on germination (Bosker et al., 2019).

Wu et al., (2020) conducted an experimental study to investigate the potential stress effects of polystyrene particles on the growth and development of rice plant (*Oryza sativa* L. II You. 900). The results indicated that the biomass in products exposed to microplastics was 25.9% lower. It was concluded that the existence of microplastics may influence the production of rice by changing the metabolic profile. In the same study, it was emphasized that microplastic concentration is an important factor affecting plant growth. It has been reported that exposure to microplastics at low concentrations may have positive effects on plant roots, while phytotoxicity may occur above a certain quantity of microplastics (Jiang et al., 2019). Gentili et al. (2022) conducted an experiment to study the possible toxic effects of polyvinyl chloride (PVC) microparticles in two wild species *Senecio inaequidens* and *Centaurea cyanus*. The results showed that PVC particles in soil can adversely affect plant growth, plant phenology and photosynthetic activity in the studied weeds.

Soil Organisms

Microplastics can also interact with various soil organisms and the detrimental effects of this interaction can disrupt the functions of the soil. Earthworms plays vital roles in soil by maintaining the structure, fertility, and several functions of soil ecosystem. The presence of microplastics in the soil changes the burrow structure of the earthworms and as a result adversely affects the soil aggregation process (Lwanga et al. 2017). Jiang et al. (2020) investigated the toxicological effects of low-level polystyrene pollution on earthworms (*Eisenia fetida*). According to their results, microplastics having particle sizes larger than 100 nm disrupted the DNA structure of the earthworms and caused oxidative stress. In addition to causing oxidative stress, microplastics also cause a decrease in the activity of acetylcholinesterase (AChE), which plays a role in the neurotransmission process. This effect suggests that microplastics may act as neurotoxic substances (Baeza et al., 2020). In another trial, the effects of soils contaminated with various plastic particles on springtails were examined and it was found that the studied organism showed lower mobility in these contaminated soils (Kim and An, 2019). In addition, it has been reported that various toxic pollutants such as bisphenol A and phthalates seeping from the surface of microplastic can cause estrogenic effects and dysfunctions in the endocrine system in vertebrates (De Souza Machado et al., 2018a).

Soil organisms such as nematodes and rotifers can also be very susceptible to microplastic contamination. These species can respond to microplastic pollution with changes in the gut microbiome, reproductive rate, motility and lifespan, as well as may show stress reactions and defective metabolism (Büks et al., 2020). It has been stated that arbuscular mycorrhizal fungi in the soil are also among the species that are significantly affected by microplastic pollution. In particular, the comparative abundance of soil organisms, and the community composition are adversely affected (Wang et al., 2020).

In addition, PVC, PET and PE type microplastics have been reported to decrease the prevalence of some microbial groups and increase others, thereby altering the diversity as well as functions of soil microorganisms (Ng et al., 2020; Zang et al., 2020, Zhu et al., 2022). There is also some research indicating that new microbial species proliferate in the rhizosphere associated with the existence of microplastics (Ren et al., 2020; Stabnikova et al., 2021).

Soil Structure and Properties

The presence of microplastics in the soil can affect the structure and several characteristics of the soil as well as the plants and organisms in the soil ecosystem. For example, it is possible that microplastics modify the physical soil properties by decreasing or increasing the cohesion forces between soil aggregates. De Souza Machado et al. (2018b) emphasized that microplastics may affect soil aggregation structure, water holding capacity and bulk density, resulting in alterations in soil aeration. Qi et al., (2020) found that microplastic pollution (low density polyethylene) reduced the field capacity of soil. In a similar study, it is stated that microplastics disrupted the soil structure, reduced the infiltration performance and water retention capacity of the studied soil (Liu et al., 2014).

A recent case study (Guo et al., 2022) investigated the impacts of polypropylene particles with varying particle sizes and concentrations on the hydraulic properties in different textured soils.The outcomes showed that the introduction of microplastics diminished the saturated hydraulic conductivity (Ks) of clayey, loamy and sandy soils by 77.11%, 69.79%, and 95.79%, respectively. These negative impacts of microplastics on the leaching characteristics of the investigated soils vary depending on the particle size and weaker effects were observed for larger microplastic particles. In addition, the unfavorable effects of microplastics on the water holding capacity of clay soils were more pronounced. Lozano et al. (2021) studied the impacts of microplastics with different concentrations, polymer types and shapes on soil properties. In the study, it was determined that microplastics reduced the soil aggregation by ~25%, and it was emphasized that the presence of microplastics may have created fracture points in aggregates.

As a result of another study evaluating the effects of low-density microplastics (LDMP), which are abundant in agricultural lands in northeast China, on soil, it was determined that low-density microplastics caused a decrease in the water holding capacity of the soil (Zhang et al. 2020). Some microplastic residues or fragments can change the soil porosity by disrupting the pore continuity of the soil (Jiang et al., 2017). These soil pore alterations can also affect the major components of the soil water cycle, such as evaporation or gravitational action and soil pore water content (Wan et al., 2019).

Soil Enzyme Activities and Nutrient Cycles

Soil enzymes are recognized as an important indicator of soil fertility. Because enzymes released by soil microorganisms and plants are remarkably related to the nutrient cycle and flow of soil energy and respond rapidly to any changes in the soil ecosystem (Cui et al., 2018). Microplastics in the soil considerably affect the soil enzyme activities. Studies have shown that enzymes such as phosphatase, cellobiosidase, β-D-glucosidase and N-acetyl-β-glucosaminidase which are related to the soil nutrient cycles, were adversely modified by the presence of microplastics (Lozano et al., 2021; Liang et al., 2021). Similarly, Dong et al. (2021) reported that the presence of microplastics could inhibit soil enzyme activities and reduce nitrogen and phosphorus concentrations in rhizosphere soil.

The effects of microplastics on soil enzyme activities also depend on the shape of the microplastics and the type of polymer. For example, some studies have shown that polyethylene (PE) and polyvinyl chloride (PVC) type microplastics stimulate urease and acid phosphatase activities in soil (Huang et al., 2019; Fei et al., 2020). In some other studies, it was concluded that polypropylene (PP) and polyester (PES) type microplastics can inhibit fluorescent diacetate hydrolase activity in soil. (De Souza Machado et al., 2019; Liang et al., 2019; Fei et al., 2020). Zhao et al. (2021) conducted a study in which the variation of some soil enzyme activities in microplastic contaminated soils and the effects of different shapes of microplastics were evaluated. According to their results foam microplastics decreased the activity of β-D-glucosidase in the soil, while microplastics in the form of foam, fiber and film inhibited the cellobiosidase activity. The microplastics that had the most inhibitory effect on the N-acetyl-β-glucosaminidase activity in the soil were found to be fibers and fragments. The results also indicated that soil acid phosphatase activity did not vary with the polymer type and shape.

Furthermore, some chemical characteristics of microplastics, such as the molecular chain structure and the type of functional groups they carry, can affect their capacity to absorb other pollutants such as antibiotics and heavy metals (Fred-Ahmadu et al., 2020), which can significantly alter soil microbial activities as well as physical/chemical properties (Pathan et al., 2020). For example, the polycyclic aromatic hydrocarbon (PAH) phenanthrene, which is known to hinder soil microorganisms and several biogeochemical processes (Anyanwu and Semple 2016), is particularly well adsorbed by polyethylene-type microplastics (Wang and Wang 2018).

Conclusion

Microplastics are accepted as a group of emerging pollutants widely dispersed in various compartments of environment. Microplastic contamination has been studied in detail in marine ecosystems, and only lately has attention been focused on terrestrial environments, especially to agro-ecosystems. Recent studies have shown that soil microplastics can affect not only soil microbial biomass, microbial community composition and microbial activity, but also plant growth, physiology and metabolism. Moreover, microplastic pollution in soil can affect various soil properties and nutrient cycles.

Considering the importance of agricultural products in human nutrition and their potential to affect human health, investigating the effects of microplastics on terrestrial environments, especially agro-ecosystems in more detail, will undoubtedly make important contributions to the field. Further studies are needed on the interaction of different microplastics, plastic additives and crop types in the soil to maintain crop health. In addition, the analysis of the risks that microplastics may pose in the soil and groundwater environment should be carried out as soon as possible. Further research is also needed on the potential effects of derivatives resulting from the biodegradation of microplastics in soil. In order to realistically assess the long-term effects of microplastics deposited in the soil, the individual contributions of natural and anthropogenic activities occurring in the soil must also be determined.

It is undoubtedly of great importance to raise public awareness on plastic waste control and treatment, domestic waste classification practices and the discharge of microplastic wastes. In addition, the development of laws, regulations, legal policies, procedures and standards for the control of microplastic-induced pollution should be considered as a priority issue.

REFERENCES

Ahmed, T., Shahid, M., Azeem, F., Rasul, I., Shah, A. A., Noman, M., Hameed, A., Manzoor, N., Manzoor, I & Mohammad, S. (2018). Biodegradation of plastics: Current scenario and future prospects for environmental safety. *Environmental Science and Pollution Research,, 25*, 7287–7298. doi: 10.1007/s11356-018-1234-9.

Amelia, T.S.M., Khalik, W.M.A.W.M., Ong, M.C., Shao, Y.T., Pan, H.J. & Bhubalan, K. (2021). Marine microplastics as vectors of major ocean pollutants and its hazards to the marine ecosystem and humans. *Progress in Earth and Planetary Science, 8,* 12. doi:10.1186/s40645-020-00405-4.

Andrady, A.L. (2017). The plastic in microplastics: A review. *Marine Pollution Bulletin*, *119*(1), 12-22. doi:10.1016/j.marpolbul.2017.01.082.

Andrady, A.L., (2011). Micro-plastics in the marine environment. *Marine Pollution Bulletin*, *62,* 1596–1605. doi: 10.1016/j.marpolbul.2011.05.030.

Anik, A.H, Hossain, S., Alam, M., Sultan, M.B., Hasnine, MD.T. & Rahman, Md.M. (2021). Microplastics pollution: A comprehensive review on the sources, fates, effects, and potential remediation. *Environmental Nanotechnology, Monitoring & Management*, *16*, 100530, doi:10.1016/j.enmm.2021.100530.

Anyanwu, I.N., & Semple, K. T. (2016). Assessment of the effects of phenanthrene and its nitrogen heterocyclic analogues on microbial activity in soil. *SpringerPlus, 5*, 579. doi:10.1186/s40064-016-1918-x.

Baeza, C., Cifuentes, C., González, P., Araneda, A. & Barra, R. (2020). Experimental exposure of lumbricus terrestris to microplastics. *Water Air and Soil Pollution, 231*, 308. doi:10.1007/s11270-020-04673-0.

Barboza, L.G.A., Vethaak, A.D., Lavorante, B.R.B.O., Lundebye, A.K., & Guilhermino, L. (2018). Marine microplastic debris: An emerging issue for food security, food safety and human health. *Marine Pollution Bulletin, 133*, 336–348. doi: 10.1016/j.marpolbul.2018.05.047.

Barnes, D.K.A., Galgani, F., Thompson, R.C. & Barlaz, M. (2009). Accumulation and fragmentation of plastic debris in global environments. *Philosophical Transactions of the Royal Society of London B: Biological Sciences, 364*(1526), 1985-1998. doi: 10.1098/rstb.2008.0205.

Bläsing, M. & Amelung, W. (2018). Plastics in soil: Analytical methods and possible sources. *Science of the Total Environment, 612*, 422-435. doi: 10.1016/j.scitotenv.2017.08.086.

Bosker, T., Bouwman, L.J., Brun, N.R., Behrens, P. & Vijver, M.G. (2019). Microplastics accumulate on pores in seed capsule and delay germination and root growth of the terrestrial vascular plant *Lepidium sativum*. *Chemosphere*, *226*, 774-781, doi:10.1016/j.chemosphere.2019.03.163.

Brandon, J.A., Jones, W. & Ohman, M.D. (2019). Multidecadal increase in plastic particles in coastal ocean sediments. *Science Advances, 5*, 9, eaax0587, doi:10.1126/sciadv.aax0587.

Büks, F., Schaik, N.L.V. & Kaupenjohann, M. (2020). What do we know about how the terrestrial multicellular soil fauna reacts to microplastic? *Soil, 6,* 245–267. doi:10.5194/soil-6-245-2020.

Castaneda, R.A., Avlijas, S., Simard, M.A., Ricciardi, A. & Smith, R., (2014). Micro-plastic pollution in St. Lawrence river sediments. *Canadian Journal of Fisheries and Aquatic Sciences, 71*(12), 1767–1771. doi: 10.1139/cjfas-2014-0281.

Chen, Y.L., Leng, Y.F., Liu, X.N. & Wang, J. (2020). Microplastic pollution in vegetable farmlands of suburb Wuhan, central China. *Environment Pollution., 257*, 113449. doi: 10.1016/j.envpol.2019.113449.

Cheng, F., Zhang, T., Liu, Y., Zhang, Y. & Qu, J. (2021). Non-negligible effects of UV irradiation on transformation and environmental risks of microplastics in the water environment. *Journal of Xenobiotics, 12*(1), 1-12. doi:10.3390/jox12010001.

Corradini, F., Meza, P., Eguiluz, R., Casado, F., Huerta-Lwanga, E. & Geissen, V., (2019). Evidence of micro-plastic accumulation in agricultural soils from sewage sludge disposal. *Science of the Total Environment, 671*, 411–420. doi:10.1016/j. scitotenv.2019.03.368.

Cui, Y., Fang, L., Guo, X., Wang, X. & Wang, Y. (2018). Responses of soil bacterial communities, enzymatic activities, and nutrient to agricultural-to-natural ecosystem conversion in the loess plateau, China. *Journal of Soil and Sediments, 19*, 1427-1440. doi:10.1007/s11368-018-2110-4.

Da Costa, J.P., Nunes, A.R., Santos, P.S.M., Girão, A.V., Duarte, A.C. & Rocha-Santos, T. (2018). Degradation of polyethylene microplastics in seawater: Insights into the environmental degradation of polymers. *Journal of Environmental Science and Health Part A, 53*, 866–875. doi:10.1080/10934529.2018.1455381.

De Souza Machado, A.A., Kloas, W., Zarfl, C., Hempel, S. & Rillig, M.C. (2018a). Microplastics as an emerging threat to terrestrial ecosystems. *Global Change Biology, 24*, 1405–1416. doi:10.1111/gcb.14020.

De Souza Machado, A.A., Lau, C.W., Till, J., Kloas, W., Lehmann, A., Becker, R. & Rillig, M.C. (2018b). Impacts of microplastics on the soil biophysical environment. *Environmental Science and Technology, 52*(17), 9656–9665. doi:10.1021/acs.est.8b02212.

De Souza Machado, A.A., Lau, C.W., Kloas, W., Bergmann, J., Bachelier, J. B., Faltin, E., Becker, R., Görlich, A.S & Rillig, M.C. (2019). Microplastics can change soil properties and affect plant performance. *Environmental Science and Technology, 53*(10), 6044–6052. doi:10.1021/acs.est.9b01339.

Dioses-Salinas, D.C., Pérez-Baca, B.L.D.T. & Enrique, G. (2019). Ecotoxicological effects of microplastics and adsorbed contaminants on aquatic organisms. *Manglar, 16*(2), 173-182. doi:10.17268/manglar.2019.024.

Dong, Y., Gao, M., Qiu, W. & Song, Z. (2021). Effect of microplastics and arsenic on nutrients and microorganisms in rice rhizosphere soil. *Ecotoxicology and Environmental Safety, 211*, 111899. doi:/10.1016/j.ecoenv.2021.111899.

Duis, K. & Coors, A. (2016). Microplastics in the aquatic and terrestrial environment: sources (with a specific focus on personal care products), fate and effects. *Environmental Sciences Europe, 28*, 2. doi:10.1186/s12302-015-0069-y.

Enfrin, M., Dumée, L.F. & Lee, J. (2019). Nano/microplastics in water and wastewater treatment processes – origin, impact and potential solutions. *Water Research, 161*, 621-638. doi:10.1016/j.watres.2019.06.049.

Fei, Y., Huang, S., Zhang, H., Tong, Y., Wen, D., Xia, X., Wang, H. Luo, Y. & Barcelo, D. (2020). Response of soil enzyme activities and bacterial communities to the accumulation of microplastics in an acid cropped soil. *Science of the Total Environment, 707*, 135634. doi:10.1016/j.scitotenv.2019.135634.

Fred-Ahmadu, O.H., Bhagwat, G., Oluyoye, I., Benson, N.U., Ayejuyo, O.O. & Palanisami, T. (2020). Interaction of chemical contaminants with microplastics: Principles and perspectives. *Science of the Total Environment, 706,* 135978. doi:10.1016/j.scitotenv.2019.135978.

Fuller, S. & Gautam, A. (2016). A procedure for measuring microplastics using pressurized fluid extraction. *Environmental Science and Technology, 50*, 5774-5780. doi:10.1021/acs.est.6b00816.

Gentili R., Quaglini L., Cardarelli E, Caronni S., Montagnani C. & Citterio S. (2022). Toxic impact of soil microplastics (PVC) on two weeds: Changes in growth, phenology and photosynthesis efficiency. *Agronomy, 12,* 1219. doi:10.3390/agronomy12051219.

Geyer, R., Jambeck, J.R. & Law, K.L. (2017). Production, use, and fate of all plastics ever made. *Science Advances, ,3*(7), e1700782. doi:10.1126/sciadv.1700782.

Guo, Z., Li, P., Yang, X.M., Wang, Z.H., Lu, B.B., Chen, W.J., Wu, Y., Li, G.W., Zhao, Z.W., Liu, G.B., Ritsema, C., Geissen, V. & Xue, S. (2022). Soil texture is an important factor determining how microplastics affect soil hydraulic characteristics. *Environment International, 165,* 107293. doi:10.1016/j.envint.2022.107293.

Horton, A.A., Svendsen, C., Williams, R.J., Spurgeon, D.J. & Lahive, E. (2017). Large microplastic particles in sediments of tributaries of the River Thames, UK – Abundance, sources and methods for effective quantification. *Marine Pollution Bulletin, 114*, 218– 226. doi:10.1016/j.marpolbul.2016.09.004.

Huang, Y., Zhao, Y., Wang, J., Zhang, M., Jia, W. & Qin, X. (2019). LDPE microplastic films alter microbial community composition and enzymatic activities in soil. *Environmental Pollution, 254* (PtA), 112983. doi:10.1016/j.envpol.2019.112983.

Isobe, A., Iwasaki, S., Uchida, K. & Tokai, T. (2019). Abundance of non-conservative microplastics in the upper ocean from 1957 to 2066. *Nature Communications, 10*(1), 417. doi:10.1038/s41467-019-08316-9.

Jiang, X., Chang, Y., Zhang, T., Qiao, Y. Klobučar, G. & Li, M. (2020).Toxicological effects of polystyrene microplastics on earthworm (Eisenia fetida). *Environmental Pollution, 259,* 113896. doi:10.1016/j.envpol.2019.113896.

Jiang, X., Chen, H., Liao, Y., Ye, Z., Li, M. & Klobucar, G. (2019). Ecotoxicity and genotoxicity of polystyrene microplastics on higher plant *Vicia faba*. *Environmental Pollution, 250*, 831-838. doi:10.1016/j.envpol.2019.04.055

Jiang, X.J., Liu, W., Wang, E., Zhou, T. & Xin P. (2017). Residual plastic mulch fragments effects on soil physical properties and water flow behavior in the Minqin Oasis, northwestern China. *Soil and Tillage Reearch,, 166*, 100-107n. doi: 10.1016/j.still.2016.10.011.

Kalcíkova, G., Gotvajn, A.Z., Kladnik, A. & Jemec, A. (2017). Impact of polyethylene microbeads on the floating freshwater plant duckweed Lemna minor. *Environmental Pollution, 230*, 1108–1115. doi: 10.1016/j.envpol.2017.07.050.

Karim, E.M., Sanjee, A.S., Mahmud, S., Shaha, M., Moniruzzaman, M. & Das, C.K. (2019). Micro-plastics pollution in Bangladesh: current scenario and future research perspective. *Chemistry and Ecology, 36*(1), 83-99. doi:10.1080/02757540.2019.1688309.

Kim, S.W. & An, Y.J. (2019). Soil microplastics inhibit the movement of springtail species. *Environment International, 126,* 699-706, doi:10.1016/j.envint.2019.02.067.

Koelmans, A.A., Nor, N.H.M., Hermsen, E., Kooi, M., Mintenig, S.M. & De France, J. (2019). Microplastics in freshwaters and drinking water: Critical review and assessment of data quality. *Water Research, 155*, 410–422. doi:10.1016/j.watres.2019.02.054.

Liang, Y., Lehmann, A., Yang, G., Leifheit, E F. & Rillig, M.C. (2021). Effects of microplastic fibers on soil aggregation and enzyme activities are organic matter dependent. *Frontiers in Environmental Science, 9*, 650155. doi:10.3389/fenvs.2021.650155.

Liu, H., Wang, Z., Nghiem, L.D., Gao, L., Zamyadi, A., Zhang, Z., Sun, J. & Wang, Q. (2021). Solid-embedded microplastics from sewage sludge to agricultural soils: Setection, occurrence, and impacts. *ACS ES&T Water, 1*(6), 1322–1333. doi:10.1021/acsestwater.0c00218.

Liu, J., Bu, L., Zhu, L., Luo, S., Chen, X. & Li, S. (2014). Optimizing plant density and plastic film mulch to increase maize productivity and water-use efficiency in semiarid areas. *Agronomy Journal, 106(4),* 1138-1146. doi: 10.2134/agronj13.0582.

Lozano, Y.M., Aguilar-Trigueros, C.A., Onandia, G., Maaß, S., Zhao, T. & Rillig, M.C. (2021). Effects of microplastics and drought on soil ecosystem functions and multifunctionality. *Journal of Applied Ecology, 58,* 988–996. doi:10.1111/1365-2664.13839.

Lwanga E.H., Gertsen, H., Gooren, H., Peters, P., Salanki, T., van der Ploeg, M., Besseling, E., Koelmans, A.A. & Geissen, V. (2017). Incorporation of microplastics from litter into burrows of Lumbricus terrestris. *Environmental Pollution, 220*:523-531. doi:10.1016/j.envpol.2016.09.096.

Mason, S.A., Garneau, D., Sutton, R., Chu, Y., Ehmann, K., Barnes, J., Fink, P., Papazissimos, D. & Rogers, D.L. (2016). Microplastic pollution is widely detected in US municipal wastewater treatment plant effluent. *Environmental Pollution, 218,* 1045–1054. doi:10.1016/j.envpol.2016.08.056

Meng, F., Fan, T., Yang, X., Riksen, M., Xu, M. & Geissen, V. (2020). Effects of plastic mulching on the accumulation and distribution of macro and micro plastics in soils of two farming systems in Northwest China. *PeerJ, 1,* 8:e10375. doi:10.7717/peerj.10375.

Ng, E.L., Lin, S.Y., Dungan, A.M., Colwell, J.M., Ede, S., Lwanga, E.H., Meng, K., Geissen, V., Blackall, L.L. & Chen, D., (2020). Microplastic pollution alters forest soil microbiome. *Journal of Hazardous Materials,* 124606. doi:10.1016/j.jhazmat.2020.124606.

Nizzetto, L., Futter, M. & Langaas, S. (2016). Are agricultural soils dumps for microplastics of urban origin? *Environmental Science and Technology, 50*(20), 10777-10779. doi:10.1021/acs.est.6b04140.

Pathan, S.I., Arfaioli, P., Bardelli, T., Ceccherini, M.T., Nannipieri, P. & Pietramellara, G. (2020). Soil pollution from micro- and nanoplastic debris: A hidden and unknown biohazard. *Sustainability, 12,* 7255. doi:10.3390/su12187255.

Pérez-Reverón, R., González-Sálamo, J., Hernández-Sánchez, C., González-Pleiter, M., Hernández-Borges, J. & Díaz-Peña, F.J. (2022). Recycled wastewater as a potential source of microplastics in irrigated soils from an arid-insular territory (Fuerteventura, Spain). *Science of The Total Environment, 817*, 152830. doi:10.1016/j.scitotenv.2021.152830.

Piehl, S., Leibner, A., Löder, M.G.J., Dris, R., Bogber, C. & Laforsch, C. (2018). Identification and quantification of macro- and microplastics on an agricultural farmland. *Scientific Reports, 8,* 17950. doi:10.1038/s41598-018-36172-y.

Plastics the Facts. (2021). *An Analysis of European Plastic Production, Demand and Waste Data*. https://plasticseurope.org/knowledge-hub/plastics-the-facts-2021/Accessed 29 August 2022.

Qi, Y., Beriot, N., Gort, G., Lwanga, E.H., Gooren, H., Yang, X. & Geissen, V., 2020. Impact of plastic mulch film debris on soil physicochemical and hydrological properties. *Environmental Pollution, 266*, 115097. doi:10.1016/j.envpol.2020.115097.

Ren, X., Tang, J., Liu, X. & Liu, Q. (2020). Effects of microplastics on greenhouse gas emissions and the microbial community in fertilized soil. *Environmental Pollution, 256,* 113347. doi:10.1016/j.envpol.2019.113347.

Ren, X.W., Tang, J.C., Yu, C. & He, J. (2018). Advances in research on the ecological effects of microplastic pollution on soil ecosystems. *Journal of Agro-Environment Science, 37*, 6 ,1045-1058. doi:10.11654/jaes.2017-1409.

Rillig, M.C., Ingraffia, R., De, S.M. & Anderson, A. (2017). Microplastic incorporation into soil in agroecosystems. *Frontiers in Plant Science, 8*, 1805. doi:10.3389/fpls.2017.01805.

Stabnikova, O., Stabnikov, V., Marinin, A., Klavins, M., Klavins, L. & Vaseashta, A., (2021). Microbial life on the surface of microplastics in natural waters. *Applied Sciences, 11,* 11692. doi:10.3390/app112411692.

Strungaru, S.A., Jijie, R., Nicoara, M., Plavan, G.I. & Faggio, C. (2019). Micro-(nano) plastics in freshwater ecosystems: Abundance, toxicological impact and quantification methodology. *TrAC Trends in Analytical Chemistry, 110,*16–128. doi:10.1016/j.trac.2018.10.025.

Sun, J., Zheng, H., Xiang, H., Fan, J. & Jiang, H. (2022). The surface degradation and release of microplastics from plastic films studied by UV radiation and mechanical abrasion. *Science of The Total Environment, 838*(3), 156369. doi:10.1016/j.scitotenv.2022.156369.

Tang, K.H.D. (2021). Interactions of microplastics with persistent organic pollutants and the ecotoxicological effects: A review. *Tropical Aquatic and Soil Pollution, 1*(1), 24–34. doi:10.53623/tasp.v1i1.11.

Tiwari, M., Rathod, T.D., Ajmal, P.Y., Bhangare, R.C. & Sahu, S.K. (2019). Distribution and characterization of microplastics in beach sand from three different Indian coastal environments. *Marine Pollution Bulletin, 140*, 262-273. doi:10.1016/j.marpolbul.2019.01.055.

Wan, Y. Wu, C. Xue, Q. & Hui, X. (2019). Effects of plastic contamination on water evaporation and desiccation cracking in soil. *Science of the Total Environment, 654*, 576-582. doi:10.1016/j.scitotenv.2018.11.123.

Wang, F., Zhang, X., Zhang, S., Zhang, S. & Sun, Y. (2020). Interactions of microplastics and cadmium on plant growth and arbuscular mycorrhizal fungal communities in an agricultural soil. *Chemosphere,* 254,126791. doi:10.1016/j.chemosphere.2020.126791.

Wang, W. & Wang, J. (2018). Different partition of polycyclic aromatic hydrocarbon on environmental particulates in freshwater: Microplastics in comparison to natural sediment. *Ecotoxicology and Environmental Safety, 147*, 648–655. doi:10.1016/j.ecoenv.2017.09.029.

Wang, W., Gao, H., Jin, S., Li, R. & Na, G. (2019). The ecotoxicological effects of microplastics on aquatic food web, from primary producer to human: A review. *Ecotoxicology and Environmental Safety,173*, 110-117. doi:10.1016/j.ecoenv.2019.01.113.

Wong, J.K.H., Lee, K.K., Tang, D.H. & Yap, S.P. (2020). Micro-plastics in the freshwater and terrestrial environments: Prevalence, fates, impacts and sustainable solutions. *Science of the Total Environment, 719*, 137512. doi:10.1016/j.scitotenv.2020.137512.

Wright, S.L., Ulke, J., Font, A., Chan, K.L.A. & Kelly, F.J. (2020). Atmospheric microplastic deposition in an urban environment and an evaluation of transport. *Environment International, 136*, 105411. doi:10.1016/j.envint.2019.105411.

Wu, X., Liu, Y., Yin, S., Xiao, K., Xiong, Q., Bian, S., Liang, S., Hou, H., Hu, J. & Yang, J. (2020). Metabolomics revealing the response of rice (*Oryza sativa* L.) exposed to polystyrene microplastics. *Environmental Pollution, 266*(1), 115159. doi:10.1016/j.envpol.2020.115159.

Xu, Z., Bai, X. & Ye, Z. (2021). Removal and generation of microplastics in wastewater treatment plants: A review. *Journal of Cleaner Production, 291,* 125982. doi:10.1016/j.jclepro.2021.125982.

Yang, J.,Li, R., Zhou, Q., Li, L., Li, Y., Tu, C., Zhao, X., Xiong, K., Christie, P. & Luo, Y (2021). Abundance and morphology of microplastics in an agricultural soil following long-term repeated application of pig manure. *Environmental Pollution, 272,* 116028. doi:10.1016/j.envpol.2020.116028.

Yang, M., Huang, D.Y., Tian, Y.B., Zhu, Q.H., Zhang, Q., Zhu, H.H. & Xu, C. (2021). Influences of different source microplastics with different particle sizes and application rates on soil properties and growth of Chinese cabbage (*Brassica chinensis* L.). *Ecotoxicology and Environmental Safety, 222*, 112480. doi:10.1016/j.ecoenv.2021.112480.

Yu ,Z., Song, S., Xu, X., Ma, Q. & Lu, Y. (2021). Sources, migration, accumulation and influence of microplastics in terrestrial plant communities. *Environmental and Experimental Botany, 192*, 104635. doi:/10.1016/j.envexpbot.2021.104635.

Zang, H., Zhou, J., Marshall, M.R., Chadwick, D.R., Wen, Y. & Jones, D.L. (2020). Microplastics in the agroecosystem: are they an emerging threat to the plant-soil system? *Soil Biology and Biochemistry, 148*, 107926. doi:10.1016/j.soilbio.2020.107926.

Zhang, G.S. & Liu, Y.F. (2018). The distribution of microplastics in soil aggregate fractions in southwestern China. *Science of the Total Environment, 642*, 12–20. doi:10.1016/j.scitotenv.2018.06.004.

Zhang, S., Liu, X., Hao, X., Wang, J. & Zhang, Y. (2020). Distribution of low-density microplastics in the mollisol farmlands of northeast China. *Science of The Total Environment, 708*, 135091. doi:10.1016/j.scitotenv.2019.135091.

Zhao, T., Lozano, Y.M. & Rillig, M.C. (2021). Microplastics increase soil pH and decrease microbial activities as a function of microplastic shape, polymer type, and exposure time. *Frontiers in Environmental Sciences, 9,* 675803. doi:10.3389/fenvs.2021.675803.

Zhou B.Y., Wang, J.Q., Zhang, H.B., Shi, H.H., Fei, Y.F., Huang, S.Y., Tong, Y.Z. , Wen, D.S., Luo, Y.M. & Barceló, D. (2020). Microplastics in agricultural soils on the coastal plain of Hangzhou Bay, East China: multiple sources other than plastic mulching film. *Journal of Hazardous Materials, 388*, 121814. doi:10.1016/j.jhazmat.2019.121814.

Zhu, F., Yan, Y., Doyle, E., Zhu, C., Jin, X., Chen, Z., Wang, C., He, H., Zhou, D. & Gu, C. (2022). Microplastics altered soil microbiome and nitrogen cycling: the role of phthalate plasticizer. *Journal of Hazardous Materials, 427,* 127944. doi:10.1016/j. jhazmat.2021.127944.

Chapter 3

ANALYSIS AND DESIGN OF SMART PV MODULES FOR CLIMATE CONDITIONS IN TURKEY

*İbrahim GÜNEŞ[1]**

1 * (Assoc. Prof. Dr.); Istanbul University Cerrahpasa, Engineering Faculty , Electrical and Electronics Engineering Department, Avcilar 34320 Istanbul Turkiye.
E-mail: gunesi@iuc.edu.tr
ORCID: https://orcid.org/0000-0003-1032-1134

Introduction

Analysis and Design of Smart PV Modules for climate conditions in Turkey, in this study, Turkey will be exposed to different climatic zones for the solar panel, receiving angle of the sun's rays, environmental factors from: dust effect, the effect of rainfall, humidity are expected to operate under the influence of parameters such as temperature. The system aims to provide optimum energy production and increase efficiency under these environmental factors. The goal of Turkey's Solar Energy map to specific intelligent design suitable PV modules will be conducted every region of Turkey. This study conducted by TEXAS A&M UNIVERSITY Electrical and Computer Engineering Department, College Station, Texas, U.S.A. Renewable Energy & Advanced Power Electronics Research Lab (REAPER LAB) Laboratories. It is performed in laboratories.

To examine the change in performance of photovoltaic (PV) panels, we need a digital resistor and programmable STM32F4 ARM based micro controller card, (Current-Voltage (I-V) curve tracer). The effects of temperature, humidity, vibration, dust parameters will be examined with the systems containing solar simulators and the environmental factor simulations integrated with this system. This system is the most widely used commercially as PV panels on monocrystalline and polycrystalline photovoltaic panels. Different climatic conditions in the regions in Turkey, humidity, dust, rain, shadows and to investigate the effect of the climatic characteristics will be studied for the formation of the panel design. Environmental external factors that cause the most stringent conditions in terms of environmental conditions (both in terms of local heating of the surface and reducing the light absorption of the panel) will be examined. Experimental work to be performed, analysis, under the different external factors (humidity, temperature, dust, precipitation, wind) by simulations and designs the panel will be measured to determine the efficiency, We will be held optimal design of smart PV modules for different climatic conditions.of Turkey.

Active working with Texas A&M University of Renewable Energy and Advanced Power Electronics Laboratory (REAPER) team and Electrical and Computer Engineering Department will be an important step to examination for test results. Observations made during the study, after our evaluation study team will consist of new ideas and doctoral and master's thesis in the field of renewable energy systems in Turkey will be advised of the students I support the thesis on current issues.

Environmental Impacts in Renewable Energy Systems:

Explaining the impact of dust on PV panels, measuring the impact of this problem can provide a valuable tool to minimize this impact. By doing this, the dust effect can be taken into account when looking at the long-term energy forecast by minimizing the losses associated with dust accumulation on the surface of the PV panel. Also, knowing that dust can affect performance and possibly damage the PV panel, a method can be explored to prevent this. Different approaches can be sought to reduce energy losses due to dust effect. However, knowing how dust selectively weakens the solar spectrum may provide a better approach for technology selection in certain dusty environments.

The diversity of environmental external factors differs from one place to another. Contamination in PV systems near industrial sites may include some of the by-products from factories. Pollution in coastal areas has salt content. In agricultural areas, organic materials accumulate more on the upper surfaces of PV modules. Similarly, the effects on the panel change at different humidity and precipitation levels.

Energy security, global climate change and rapid depletion of fossil fuels have increased the interest in renewable energy technologies for developed and developing countries. Among the environmentally friendly and sustainable clean energy approaches, solar energy technologies continue rapidly in residential, commercial, agricultural and industrial applications. For electricity generation, photovoltaic (PV) and concentrated thermal solar power (CSP) systems are the key technologies used to convert radiation from the sun into useful energy.

Using PV technology, the sun's rays can be converted directly into electricity. It uses solar cells made of semiconductors to absorb the radiation from the sun with PV technology and convert it into electrical energy. However, research into the nature of semiconductors used in solar cells has limited the efficiency of PV systems to 15-20%. The performance of PV systems is affected by structural features such as panel technology, converter topology, battery type, as well as environmental factors such as shading, temperature, wind, aging, radiation and pollution. Any climate change causes changes in solar radiation, so there are differences in solar PV output performance. Therefore, solar tracking and maximum power point tracking systems have been developed to increase the efficiency of PV systems.

The variation in PV panel efficiency depends on the mass and size of the accumulated dust particles. As the mass of accumulated dust increases, the efficiency and power output of the module decreases.

Pillai and Mani studied the effect of dust on photovoltaic system performance according to climate and classified them into regions. Dust effect and pollution removal recommendations are presented according to these regions that affect PV system performance. At the same time, the relationship between the transmission of light from the sun and dust size, composition, deposition density and shape has been clarified.

Mekhilef et al. showed a correlation between the amount of dust accumulated in the PV panel and the efficiency changes in the composite climate. They found that when heavy dust layers accumulate, there is a significant reduction in PV panel efficiency of around 10-20%.

Method and Experimental Studies:

Tests of photovoltaic panels under IEC 60904, ASTM 948-16 standard test conditions of 1000 W/m2, 25 0C temperature and 1.5 mass air ratio TEXAS A&M UNIVERSITY Electrical and Computer Engineering Department, College Station, Texas U.S.A. Renewable Energy & Advanced Power Electronics Research Lab. (REAPER LAB). carried out in laboratories. A digital resistor and necessary equipment were used to record the short circuit current (ISC) and open circuit voltage for the experimental set solar simulator, mono and poly crystal panel, panels. In addition, the device will be followed with a thermal camera to monitor the panel temperature. In this section, the methods used for data processing and analysis, as well as the equipment used for data collection, are referenced to the geographical coordinates available for Turkey and the data in the Solar Energy Potential Atlas.

The annual average insolation map for Turkey specified in the "Solar Energy Potential Atlas" is shown in Figure 1.

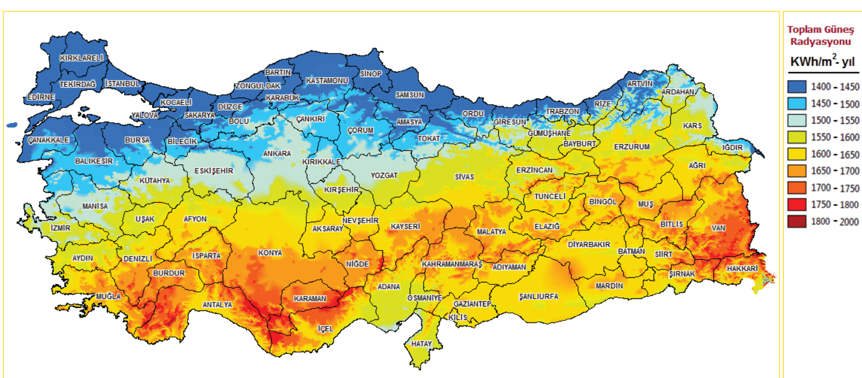


Fig.1. *Solar Energy Potential Atlas*

Pyranometer devices are used to measure the solar radiation values on the panel. It is one of the most important measurement and test devices used continuously in the feasibility, installation or usage stages of solar energy systems. TEXAS A&M UNIVERSITY Electrical and Computer

Engineering Department, College Station, Texas U.S.A. Renewable Energy & Advanced Power Electronics Research Lab. (REAPER LAB). Simulations were carried out at selected coordinates for different climatic regions of our country, using the facilities of PvSyst and Meteonorm programs.

In all experimental studies of PV panels in laboratory conditions, an artificial solar simulator showing solar radiation properties was used, the energy, current and voltage values obtained from PV panels for different climatic regions of Turkey were analyzed and compared with the simulation results. A microcontroller kit was used to measure current and voltage values accurately and precisely. The shunt current measurement method, which is used in avometers and allows us to obtain precise values, was chosen to measure current. The current-voltage characteristics of smart PV modules were analyzed under different humidity, temperature, wind, precipitation and dust factors, and optimum designs were modeled by taking Turkey's geographical coordinates, different climatic conditions and energy map as reference.

With the experimental studies, analyses, simulations and designs, the effect on the panel efficiency under different external factors (humidity, temperature, dust, precipitation, wind) was measured, and the most suitable design for the climate conditions of Turkey was realized.

Within the scope of the project, modules were developed for the use of Smart PV modules by taking the energy needs of field hospitals in different regions as reference. In this context, the thesis project FYL-2018-29239, which was carried out with the support of Scientific Research Projects Unit in Istanbul University – Cerrahpaşa Faculty of Engineering, Department of Electrical and Electronics Engineering, was successfully completed. model requirements, TEXAS A&M UNIVERSITY Electrical and Computer Engineering Department, College Station, Texas U.S.A. Renewable Energy & Advanced Power Electronics Research Lab. (REAPER LAB). Using its facilities, smart PV module design to be used in field hospitals energy needs applications was realized through PvSyst and Meteonorm programs.

The use of simulation programs is also very important in the design and analysis of photovoltaic solar power plants. The PVsyst simulation program stands out among these programs with the tools it offers for photovoltaic system simulation and the opportunity to perform detailed analysis. Within the framework of this study, the PVsyst simulation program simulates the energy use of a field hospital with basic equipment with solar energy.

With the help of PVsyst software, design and analysis evaluations of photovoltaic systems can be made. In addition, shading values can be analyzed by making three-dimensional models with the PVsyst solar energy simulation software. After the consumption profile of the hospital is revealed, the technical features of a solar energy generation system that can produce the needed energy are evaluated. In this way, it will be possible to obtain uninterrupted, clean and reliable energy needs of field hospitals that are likely to be disrupted in situations such as war and natural disasters.

Project Studies:

In this study, TEXAS A&M UNIVERSITY Renewable Energy Research Lab Smart PV modulated test systems were investigated.

Examination and application of new methods used by the study team in smart PV module analysis, Examination of humidity, temperature, precipitation, dust, wind, UV parameters for different climatic regions of Turkey, processing of energy atlas data, definition of variable parameters in experimental setups Testing new data parameters in the Renewable Energy Research Lab, creating test results Comparing the experimental results with the simulation results, creating a model containing environmental factor parameters was carried out.

Necessary precautions have been taken to avoid any risk in the examination of TEXAS A&M UNIVERSITY Renewable Energy Research Lab Smart PV modulated test systems. Testing new data parameters in the Renewable Energy Research Lab and generating test results are optional. The current-voltage graph of the test sample is given in figure 2.

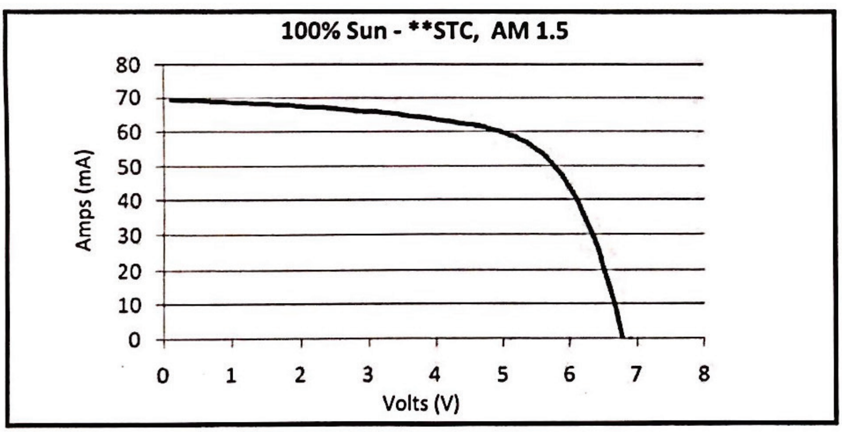


Fig. 2. *Current-Voltage graph of the test sample*

ELECTRICAL

PARAMETER	VALUE	UNIT
Wattage	0.225	W
Voltage	4.8	V
Voltage (oc)	6.4	V
Current	50	mA
Current (sc)	60	mA

Fig. 3. *Electrical parameter of Test Sample*

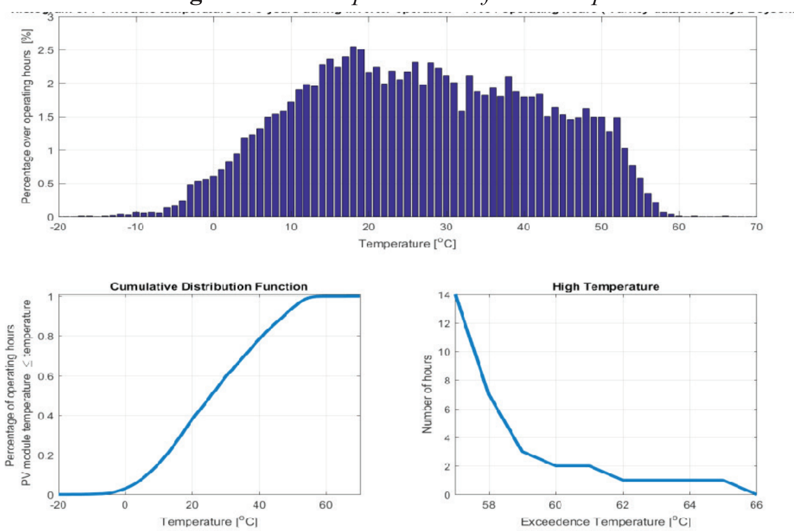


Fig.4. *Average of Turkey Data Set*

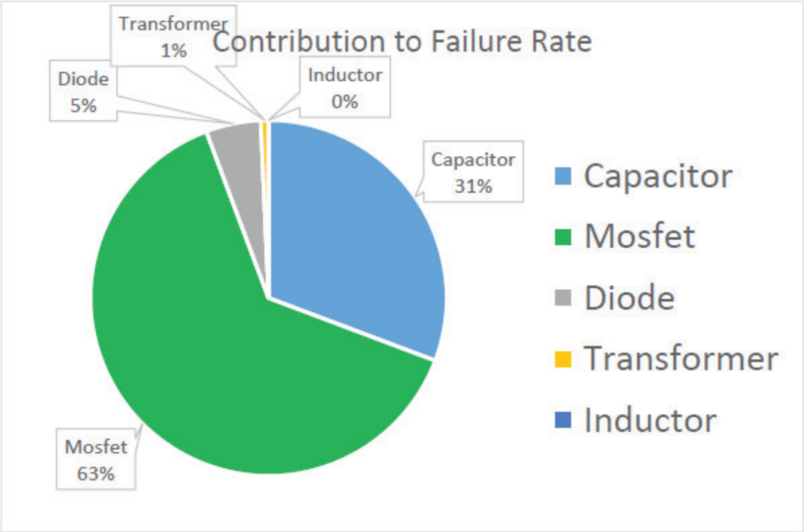


Fig.5. *Component Contributions to the Failure Rate*

The Figure 5 illustrates the contributions of all of the components to the failure rate in Topology 1. This figure indicates that the transformer and inductor did not make a significant contribution to the failure rate.

CONCLUSION

In this study, environmental effect modeling was developed to calculate PV module temperatures, after considering meteorological parameters, heat transfer, and energy balance. The results of calculated PV module temperatures showed that maximum PV module temperature is different for different location for different climate condition.. Unfortunately, there is no meteorological data for other places to calculate PV module temperature. However, results of calculated location gave an idea that as maximum PV module temperature is changed by region and installation parameters, the developed model helps us to estimate maximum PV module temperature. The maximum PV module temperature has an impact on module output voltage as calculated The output voltage of the PV module is crucial as it effects the voltage stress on power electronic components. As thermal model results are different for different cities, voltage stress on components is varied for different locations. After the module temperature and output voltage were obtained, the reliability calculations were completed using the MIL 217 reliability handbook. The reliability results showed the most failure prone component in the candidate micro-inverter and expected lifetime for different cities. Interestingly, commercial inverter topologies in analyzed topologies were found most failure prone inverters for all evaluated cities.

As a result, this environmental effect model can be applied to anywhere in the world, and it helps to determine failure rates of power electronic components in different climatic regions. Thus, specific inverters can be designed to work longer life in those different climatic areas. In addition to these, the model is suitable to change PV module parameters and installation parameters. Hence, parameter effects are observed easily. It eliminates the expensive and time-consuming test beds.

The same analysis can be done for capacitors. Integrated microinverter needs at renew during the PV module lifetime because of the electrolytic aluminum capacitor.

All the results help us to decrease the failure rate when create a design. Some tips are listed in below.

a) It is advised that use possible least number of components since the number of components has an effect on failure rate.

b) The created design needs to a cooling system such as heat sink, fans, and heat spreaders.

REFERENCES

[1] World Energy Council. [Online].Available: https://www.worldenergy.org/data/resources/resource/solar/.

[2] B. Zhao et al., “Photothermal performance of an amorphous silicon photovoltaic panel integrated in a membrane structure,” Journal of Physics D: Applied Physics, vol. 49, no. 39, 2016. [4] Jordan, D. C. and Kurtz, S. R. (2013), Photovoltaic Degradation Rates—an Analytical Review. Prog. Photovolt: Res. Appl., 21: 12–29.

[3] W. Knaupp, “Operation behaviour of roof installed photovoltaic modules,” Conference Record of the Twenty Fifth IEEE Photovoltaic Specialists Conference - 1996, Washington, DC, 1996, pp. 1445-1448.

[4] M. Mattei, G. Notton, C. Cristofari, M. Muselli, and P. Poggi, “Calculation of the polycrystalline PV module temperature using a simple method of energy balance,” Renewable Energy, vol. 31, no. 4, pp. 553-567, 2006.

[5] Jones, A.D. & Underwood, C.P.. (2001). A Thermal model for photovoltaic systems. Solar Energy. 70. 349-359.

[6] Z. H. Lu and Q. Yao, “Energy analysis of silicon solar cell modules based on an optical model for arbitrary layers,” Solar Energy, vol. 81, no. 5, pp. 636-647, 2007.

[7] JRC Photovoltaic Geographical Information System (PVGIS) – European Commission, “JRC Photovoltaic Geographical Information System (PVGIS) European Commission, “ [Online]. Available: http://re.jrc.ec.europa.eu/

[8] TEİAŞ, “Turkish Electricity Transmission Company- Türkiye Elektrik İletim A.Ş,” [Online]. Available: https://www.teias.gov.tr/. [Accessed on January 8, 2018].

[9] Turkish State Meteorological Service. [Online]. Available: https://mgm.gov.tr.

[10] “Hanwha Q-Cells to inaugurate Turkey panel factory in November,” PV Magazine, August 15, 2017. [Online], Available: https://www.pv-magazine.com/2017/08/15/hanwha-q-cells-to-inaugurate-its-turkey-panel-factory-in-november/.

[11] “Turkey’s biggest solar plant to be built by Kalyon-Hanwha Co.,” Daily Sabah Energy, March 20, 2017. [Online], Available: https://www.dailysabah.com/energy/2017/03/20/turkeys-biggest-solar-plant-to-be-built-by-kalyon-hanwha-co.

[12] United State Dep. of Def., “Military Handbook MIL-HDBK-217F, Reliability Prediction of Electronic Equipment,” Washington, DC, 1991.

[13] E. Skoplaki and J. A. Palyvos, “Operating temperature of photovoltaic modules:A survey of pertinent correlations,” Renewable Energy, vol. 34, no. 1, pp. 23-29, 2009.

[14] R. S. Balog, Yingying, Kuai, Uhrhan, G., “A Photovoltaic Module Thermal Model Using Observed Insolation and Meteorological Data to Support a Long Life, Highly Reliable Module-integrated Inverter Design by Predicting Expected Operating Temperature,” in IEEE Energy Conversion Congress and Exposition, ECCE, 2009, pp. 3343-3349.

[15] B. Zhao, W. Chen, J. Hu, Z. Qiu, Y. Qu, and B. Ge, “A thermal model for amorphous silicon photovoltaic integrated in ETFE cushion roofs,” Energy Conversion and Management, vol. 100, pp. 440-448, 2015.

[16] H. Assila, E. Essadiqi, M. Faqir, M. Meziane, F. Ghanameh and S. Ahzi, “Numerical simulation of photovoltaic panel thermal condition under wind convection,” 2016 International Renewable and Sustainable Energy Conference (IRSEC), Marrakech, 2016, pp. 653-658.

[17] Republic of Turkey Ministry of Forestry and Water Affairs Meteorological Data Information Sales and Presentation System. [Online].Available: https://mevbis.mgm.gov.tr/mevbis/ui/index.html#/Workspace.

[18] G. Mittelman, A. Alshare, and J. H. Davidson, “A model and heat transfer correlation for rooftop integrated photovoltaics with a passive air cooling channel,” Solar Energy, vol. 83, no. 8, pp. 1150-1160, 2009.

[19] S.Harb, “Single-Phase Inverter and Rectifier for High-Reliability Applications,” PhD thesis, Texas A&M University, College Station, Texas, 2014.

[20] E. D. Dunlop, D. Halton and H. A. Ossenbrink, “20 years of life and more: where is the end of life of a PV module?,” Conference Record of the Thirty-first IEEE Photovoltaic Specialists Conference, 2005., 2005, pp. 1593-1596.

[21] S. J. Castillo, R. S. Balog and P. Enjeti, “Predicting capacitor reliability in a module-integrated photovoltaic inverter using stress factors from an environmental usage model,” North American Power Symposium 2010, Arlington, TX, 2010, pp. 1-6.

Chapter 4

NOVEL DEVICE FOR CAPSULORHEXIS USING SHAPE MEMORY ALLOY (SMA)

Mustafa SOYLAK[1]

1 Mechatronic Laboratory, Faculty of Aeronautics and Astronautics, Erciyes University, Kayseri, Turkey, Orcid ID: https://orcid.org/0000-0002-5617-5913, soylakm@erciyes.edu.tr

1. INTRODUCTION

The disease, which results in the formation of blurred particles in the lens of eye, loss of transparency, yellow and brown coloration and, consequently, decreased vision, is called a cataract. The lens, which is normally transparent, transmits the light behind the eye, resulting in clear vision. In the event that some part of the lens is blurred, the light cannot penetrate enough and the vision is affected. As the blur increases, the vision is more affected and the person becomes unable to do their daily work. Cataract, which develops mostly due to age, may occur in some cases as a result of congenital, illness, drug use or traumas. In the case of cataract, the only method for its treatment is surgical intervention. There is no drug treatment. The basic approach in the application of surgical treatment is to replace the natural lens, which has lost its transparency, with an artificial lens that will undertake the same task. There are three surgical techniques for this replacement of a cataract formed natural lens. These methods are; Intracapsular cataract extraction (ICCE), extracapsular cataract extraction (ECCE) and phacoemulsification. In the ICCE application, the lens and capsule are completely removed, and in the later life, the patient has to continue his life completely dependent on thick glasses, and also the postoperative infection, etc. risks are very intense. In extracapsular cataract extraction (ECCE), an incision is made to create a transition area in the lens capsule, and the intersecting lens is broken down by ultrasonic wave and removed from this area by vacuum. . The artificial lens is then placed in the space where the natural lens is removed. Thus, the natural but deformed lens is replaced with an artificial but healthy vision lens. The entire application is usually done with a surgical intervention that does not require stitches. In this method, much better results can be obtained both surgically and optically. ECCE application, a circular incision is created in the anterior capsule and the lens undergoing structural deformation is replaced with a new one by using this circular space. The process of creating this circular incision is called capsulorhexis and this process is one of the most important stages of this surgical application. It is extremely important for this procedure to take place in exactly the desired features in order to get a clear view of the patient's entire life and to eliminate the postoperative negativities. Symmetrically constructed, circular-shaped and smooth-shaped incision can only be achieved with a very successful capsulorhexis procedure [1-4]. Although many different approaches are recommended for the application of capsulorhexis, the most advanced technology is the laser technology. The surgical name of this surgery is FAKO (Phacoemulsification) surgery. In this surgery, the lens, which has visual impairment, is cut into small pieces with the help of laser and is destroyed by vacuuming.

In this operation, where there is no stitch application at any stage of the operation, a lens is placed inside the eye membrane. Thus, the recovery time is shortened and clear vision is obtained. This method of treatment brings high costs as well as huge advantages. It is not possible for every treatment center to meet these costs. In this case, much more economical solutions need to be developed. This is also necessary for an operation that should have millions of people every year to be economically and accordingly more accessible. Today's technology has accomplished significant gains in the production of new devices, thus reducing complications in surgery and after surgery. Thanks to the developing technology, smaller incisions are made, no stitches are required or the need for stitches is reduced, thus; While the treatment processes are shortened, the postoperative negativities decrease [4]. Currently, the use of the ring calliper (the circular ring that indicates the borders of the capsulorhexis) [5,6] and special forceps [7] are extremely necessary equipment in manual operations in capsulorhexis surgeries. However, femtolaser application is also an important capsulorhexis application system [8-10]. The use of laser in the process of preparation for phacoemulsification is still common, but the fact that it is extremely expensive prevents its widespread use. There are sample systems developed such as Capsulaser (thermal laser) [11-12] and Zepto capsulorhexis device and ApetureRx [13]. When the existing capsuloreksis equipment is examined, it is seen that the most common application is Continious Curvilinear Capsulorhexis (C.C.C.). In this application, a needle or capsulorhexis forceps with special tips is used by the surgeon to grasp and tear the anterior capsule. The lens, which loses its transparency, is achieved by performing a circular incision, and then the lens changes. Thus, a barrier is obtained between the back of the eye and the front. This barier prevents the vitreus from going forward and makes an important contribution to the positioning of the artificial lens [14]. C.C.C. is an extremely economical and reliable method. The biggest disadvantage is that it requires a lot of surgical experience. When the studies about the C.C.C. are examined, it is seen that the most important goal is to strive to obtain a transaction quality independent of the operator. In his study, Soylak M. developed a mechatronic system, which is recommended for use in CCC applications. Thanks to this system, the movement of the processor performing the cutting operation in the capsule is defined by a curve form placed in the mechanism and the system is forced to follow. Variable diameters of capsulorhexis can be performed by following different curvilinear forms [15]. Karadayi K. and her colleagues have developed an economical and easy-to-use hand tool in their studies and explained the advantages of this design with their experimental work on sheep's eye [16].

In this study, an experimental study of a completely new design was carried out. Within the scope of the study, an equipment that can enter the cornea through approximately 2 mm incision and perform the circular incision in the desired diameter in this region has been developed. This equipment aims to use shape memory alloys in capsulorhexis application. In case of heat application depending on the material properties of shape memory alloys, returns to its original shape, regardless of its current shape. This transformation is realized by martensite and austenite phase transformations occurring in the crystal structure of the material. While having a low temperature martensite structure, the easily deformed material can be returned to its original shape, which is defined before deformation by passing to austenite phase. Austenite phase is the high temperature phase for material [17,18]. Shape Memory Effect was found by Buehler et al. in the US Naval Weapons Laboratories (Naval Army Laboratory) (NOL) in the 1960s. Nickel (Ni) and Titanium (Ti) alloys were used at this stage. This material has been patented under the name Nitinol by combining the Nickel and Titanium that make up the Alloy and the NOL formed in the initials of the laboratory where the research is conducted [18, 19].

The martensitic transformation is completed in a different temperature range in each alloy. As seen in Figure 1, there is a cycle of repeating the martensite and austenite transformations in the shape memory alloys. When the martensite-shaped shape memory alloys are heated, the crystal structure of the metal is converted to austenite from a certain temperature. The temperature of this transformation is called austenite start temperature (AS) and the temperature at which the transformation ends is called austenite end temperature (AF). If the austenitic shape memory alloys are cooled, the crystal structure of the material will transform into a martensite structure. The temperature at which this transformation occurs is called martensite start temperature (MS) and the temperature at which the transformation ends is called martensite end temperature (MF). During the formation of these temperatures, between the AS-AF and MS-MF temperatures, the Shape Memory Alloys have a mixed order containing martensite and austenite. If we give an example of this transformation temperature for NiTi, MF = 25 ° C, MS = 50 ° C, AS = 58 ° C, AF = 78 ° C [20-22].

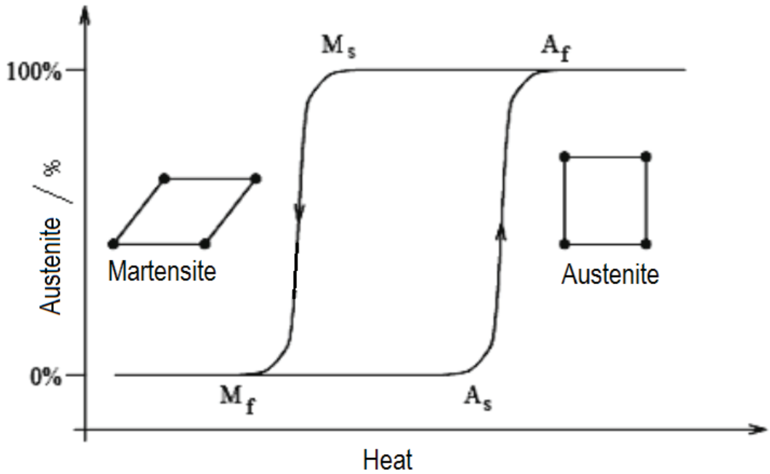


Figure 1. Temperature Changes and Hysteresis Curve of SMA[19,20]

Within the scope of the study, SMA study was carried out using Nitinol. There are many studies about the shape memory metals in literature (in aviation, robotics, medicine, industry, etc.). In this study, a system that makes capsulorhexis with the help of SMA was developed for the application of capsulorhexis, a technique widely used in cataract surgeries. System gains and negative aspects developed by experimental study are explained.

2. DESCRIPTION OF SYSTEM

An entirely new capsulorhexis system has been developed within the scope of the study. This system is named as Shape Memory Alloyed Capsulorhexis (SMAC). The SMAC has been developed using the feature of SMA's returning to the shape memory when heated. It allows the application of capsulorhexis in different diameters by using wires with different memories. In addition, it is one of the most important features of the system to reach the capsule by entering and exiting from a small incision. The image of SMA before and after heating is given in Figure 2.

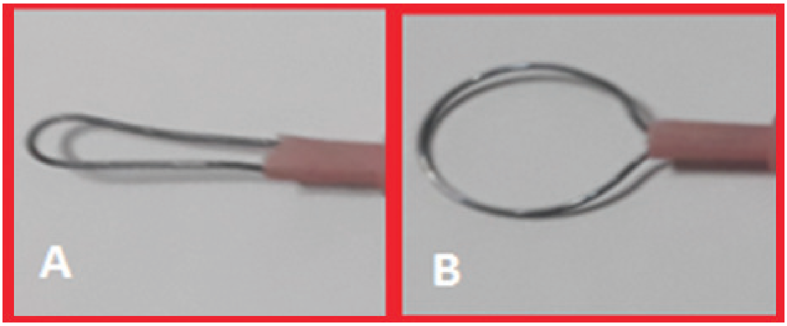


Figure 2. The SMA (A: Before heated, B: After heated)

Nitinol, which has been widely researched today. A 0.5 millimeter diameter and 100 milimeter long Nitinol wire is used in this experimental studies. An electrical current is applied to the nitinol wire and when the current is applied, heat is generated as a result of the electrical resistance. This heat is used to create the desired circular shape for the capsulorhexis inside the eye and subsequently for the surgical incision. With the termination of the electric current, SMA passes into the martensitic phase. DC-DC PWM module was used to adjust the current intensity (0- 2A) and the electrical power obtained accordingly. The resistance value of the SMA wire measured 1 ohm. Electrical power can be calculated from the equation;

$$P = I^2.R$$

In this equation, P = Electrical Power (Watt), I = Electrical Current (Amper) and R = Electrical resistance (Ohm). The SMAC system (A) and electronic circuit diagram (B) are shown in Figure 3.

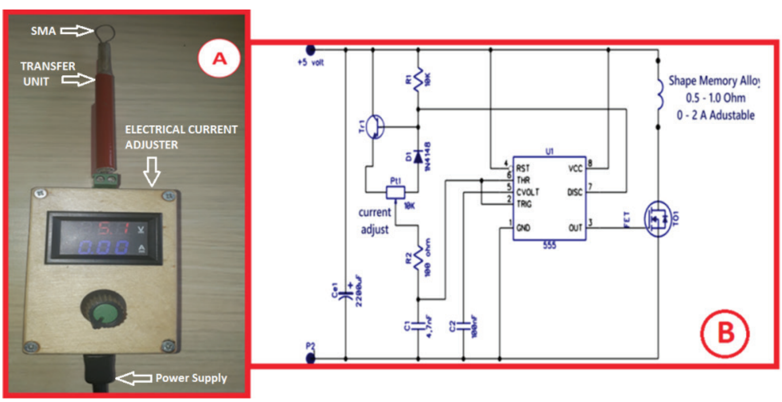


Figure 3. SMAC and electronic circuit diagram.

The components on the SMAC mechanism and their functions are as follows;

Transfer Unit: It enables the SMA to be positioned in the eye and withdraw after applying the necessary force.

Electrical Current Adjuster: Adjusts the electrical current value of the system.

SMA: It performs capsulorhexis application in case the circular shape in its memory is activated.

Power Supply Unit: It provides electric power (5 V).

Temperature change of the SMAC is measured by thermal camera. SANTECH-ST-980 thermal camera system was used to measure the temperature change due to electrical current (Figure 4).

Figure 4. Temperature measurement using Santech ST-980 Thermal Camera

The electrical current-temperature change graph obtained for the SMA wire during the experimental study is given in Figure 5.

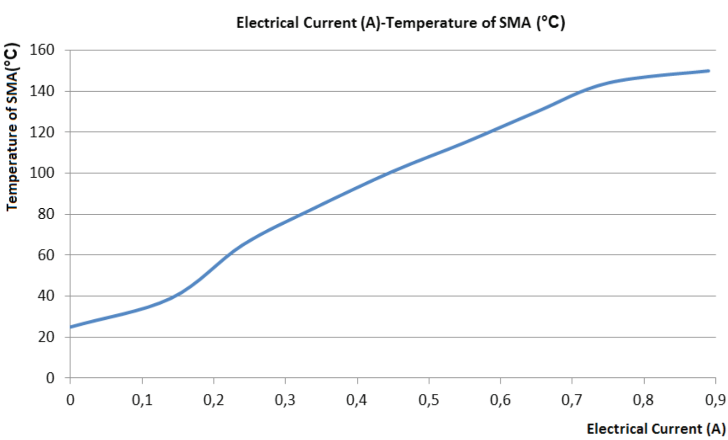


Figure 5. Graphic of the relation of electrical current - temperature of SMA

3. MATERIALS AND METHODS

In order to create the required capsulorhexis incision, the SMAC is inserted through the approximately 2,5 mm incision opened into the eye while it is closed and in its initial position. The SMA wire is then positioned in the eye manually. With the electric current applied to the SMA wire, a circular form is formed with the diameter in the wire memory. The heating process continues and the circular incision is created with the help of this heat. Then the electrical current in the wire and accordingly the heat is removed. Thus, capsulorhexis process will be completed. In the experimental test studies, operations were carried out with a ceramic-based, thermal insulation transfer unit. Working tests of the system have been applied on dead sheep eyes. The image related to these experimental studies is given in Figure 6.

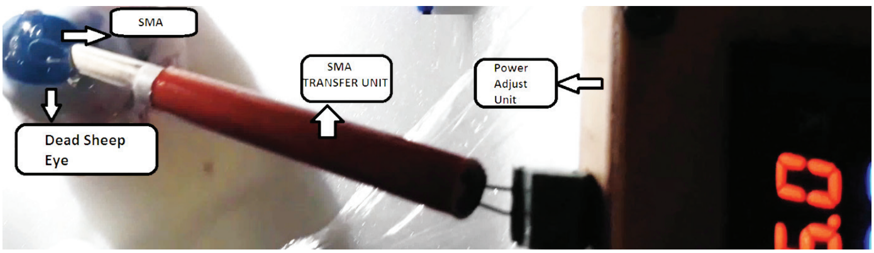


Figure 6. Experimental application on dead sheep eye

The image of the thermal camera temperature measurement studies performed in the experimental studies is given in Figure 7.

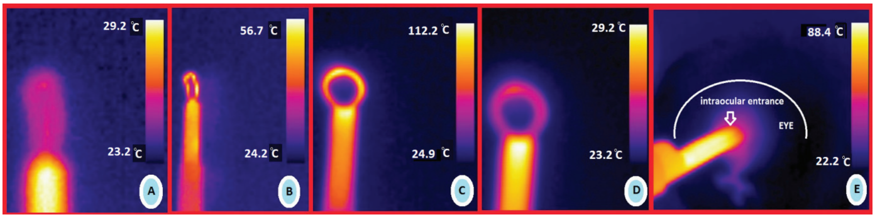


Figure 7. Thermal camera images taken during the experiment (A: 0.05 A, B: 0.19 A, C: 0.5 A, D: 0.05 A, E: SMA in-eye thermal camera view)

As can be seen in Figure 7 (E), after the SMA enters the eye, the thermal camera image cannot be taken. For this reason, the temperature change due to electrical current was carried out according to the data obtained in the external environment.

Using SMAC, an experimental study was carried out in the operating room in the dead sheep's eyes. During the experimental study, the following results were obtained by performing the following operations (see Figure 8);

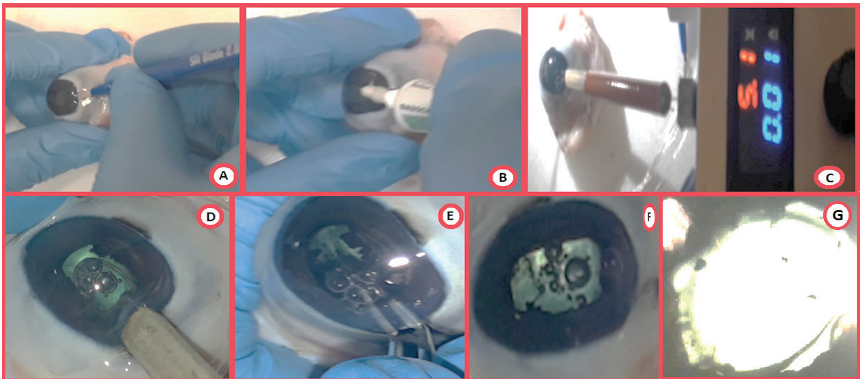


Figure 8. Capsulorhexis using SMAC

A. Intraocular incision created (2.5 mm.)

B. Filling the opional area with eye gel (Viscotears 2 mg / g)

C. The SMAC SMA module inserted through the 2.5 mm incision into the eye.

D. Electrical current was applied to the SMA wire. With increasing temperature, the SMA wire took its circular shape and cutting in circular form took place.

E. The tissue remaining in the area cut with SMA wire was removed with appropriate equipment.

F. Intra capsuler washing was completed.

G. The capsulorhexis incision formed was visualized.

The following parameters were analyzed using the SMAC; diameter, centration, and regularity of the capsulorhexis, and duration of the rhexis procedure, as well as intraoperative complications (capsular tear, posterior capsule rupture).

4. RESULTS AND DISCUSSIONS

The development of economical and easy-to-use systems that reduce the need for surgical experience in capsulorhexis applications is a current research subject. At the same time, there are many studies investigating the possibilities of using shape memory metals in different applications. In this study, a capsulorhexis system, which uses the shape memory metal wire, was developed. It is very important to obtain hygienic, silent, controllable, high corrosion resistance and low weight structures in systems using shape memory metals. In this study, an experimental system was designed and fabricated. Thanks to this system, the SMA wire received a circular form inside the eye. Entrance and exit through a 2,5 mm incision was provided. This is an application that has not yet been implemented and is the first in the literature. The entire operation time was calculated as 2 minutes. While the system shortens the operation time, it can be used very efficiently even when the operator experience is at a minimum level. After each application, equal quality capsulorhexis can be obtained and the circular structure can be obtained completely. Capsulorhexis occurred in the temperature range of about 80 ° C-100 ° C. No extra hard ware is required to use the developed system. It is extremely easy to use. Thanks to the developed system, it has been determined that capsulorhexis can be applied with low cost, with minimum experience requirement, in the shortest time and in accordance with the desired geometric demands. Two drawbacks were detected in the use of the SMAC system. These problems will be eliminated in future studies. The first of these; The temperature of the operation area can not be measured with the help of the thermal camera, and it is applied with the data of the external environment. The second drawback; A system should be developed to remove the circular shaped SMA wire from the intracapsular area after capsulorhexis application. SMA becomes smaller by applying very little force during extraction. However, a system providing solutions to improve reliability will be developed. The shape completeness of the capsulorhexis formed is good. It has been determined that the operator's use of this technique and technology for a while will increase the system efficiency. Results showed that the SMAC can perform capsulorhexis. After the system has completed the necessary animal and human experiments, it can be used widely.

Future Works: New designs and prototypes will be performed. Thus, the negativities stated in the previous section will be eliminated.
Acknowledgement: The author would like to thank Dr. Sait Nafiz MUTLU, Assist . Prof. Dr. Mehmet Ali SOYTURK and Kayseri MAYA Eye Hospital for their support of this research.

REFERENCES

1. Gimbel, H. V., & Neuhann, T. (1990). Development, advantages, and methods of the continuous circular capsulorhexis technique. *Journal of Cataract & Refractive Surgery*, *16*(1), 31-37.
2. Pande, M. (1993). Continuous curvilinear (circular) capsulorhexis and planned extracapsular cataract extraction--are they compatible?. *British journal of ophthalmology*, *77*(3), 152-157.
3. Gimbel, H. V. (2007). The history of the capsulorhexis technique. *Cataract Refract Surg Today*, *7*, 39-41.
4. Gimbel HV, Neuhann T (1991) Continuous curvilinear capsulorhexis. J Cataract Refract Surg 17(1):110-111
5. Tassignon, M. J., Rozema, J. J., & Gobin, L. (2006). Ring-shaped caliper for better anterior capsulorhexis sizing and centration. *Journal of Cataract & Refractive Surgery*, *32*(8), 1253-1255.
6. Dhubhghaill, S. S. N., Taal, M., & Tassignon, M. J. (2015). Regarding the open ring–shaped guider for a continuous curvilinear capsulorhexis. *Journal of Cataract & Refractive Surgery*, *41*(11), 2592.
7. Packard R (2015) The Evolution of the Capsulotomy: Means of capsular opening have progressed from crude forceps to precision laser. XXXIII Congress of the ESCRS, Barcelona, Spain
8. Donaldson K.E, Braga-Mele R, Cabot F (2013) Femtosecond laser-assisted cataract surgery. J Cataract Refract Surg 39:1753-1763
9. Grewal, D. S., Schultz, T., Basti, S., & Dick, H. B. (2016). Femtosecond laser–assisted cataract surgery—current status and future directions. *Survey of ophthalmology*, *61*(2), 103-131.
10. Ranka, M., & Donnenfeld, E. D. (2015). Femtosecond laser will be the standard method for cataract extraction ten years from now. *Survey of ophthalmology*, *60*(4), 356-360.
11. GLANCE, A. THE EVOLUTION OF THE CAPSULOTOMY.
12. Cavallini, G. M., Verdina, T., Forlini, M., Volante, V., De Maria, M., Torlai, G., ... & Delvecchio, G. (2016). Long-term follow-up for bimanual microincision cataract surgery: comparison of results obtained by surgeons in training and experienced surgeons. *Clinical Ophthalmology (Auckland, NZ)*, *10*, 979.
13. Kontos M (2015)Integrating Precision-Pulse Technology in Capsulotomy Creation: With one pulse of energy, the Zepto can create an accurate and reproducible capsular opening. XXXIII Congress of the ESCRS Barcelona, Spain
14. Capsulorhexis. (2018, 1 Ağustos)Erişim adresi:https://en.wikipedia.org/wiki/capsulorhexis

15. Soylak, M. (2016). Novel device for creating continuous curvilinear capsulorhexis. *Springerplus*, *5*(1), 1-5.

16. Karadayi, K., GÜLTEKİN, Ç., & Aytac, E. (2018). Bimanual Capsulorhexis Using a New Hand Tool: An Experimental Study in Sheep Eye. *Kafkas Üniversitesi Veteriner Fakültesi Dergisi*, *24*(5).

17. Akdoğan A (2004) Akıllı Malzemeler (In Turkish). MakinaTek, Vol: Sayı 85

18. Hodgson, D. E., & Brown, J. (2002). Shape Memory Applications. *Inc., Wu, MH, Memory Technologies, and Biermann RJ, Harrison Alloys, Inc*.

19. Mihálcz, I. (2001). Fundamental characteristics and design method for nickel-titanium shape memory alloy. *Periodica Polytechnica Mechanical Engineering*, *45*(1), 75-86.

20. Gorbet, R. B. (1995). *A study of the stability and design of shape memory alloy actuators* (pp. 1303-1303). University of Waterloo.

21. Soylak, M. U. S. T. A. F. A. (2020). DEVELOPING A GRIPPER USING SHAPE MEMORY ALLOY (SMA). *International Journal of Advanced Research and Review*, *5*(6).

22. TOPTAŞ, E., & AKKUŞ, N. (2013). Şekil Hafızalı Metallerin Mekanik Yapısındaki Faz Değişimlerinin Sonlu Elemanlar Yöntemi İle İncelenmesi. *Makine Teknolojileri Elektronik Dergisi*, *10*(1), 25-33.

Chapter 5

A TURKISH CHATBOT DEVELOPED FOR URBAN TRANSPORTATION

Fatih SOYGAZI[1]

Yılmaz KILIÇASLAN[2]

Bülent DEMIR[3]

1 Dr. Öğr. Üyesi Fatih Soygazi, Aydın Adnan Menderes Üniversitesi, Bilgisayar Mühendisliği Bölümü, Aydın, https://orcid.org/0000-0001-8426-2283

2 Prof. Dr. Yılmaz Kılıçaslan, Aydın Adnan Menderes Üniversitesi, Bilgisayar Mühendisliği Bölümü, Aydın, https://orcid.org/0000-0002-5020-6547

3 Bülent Demir, DDI Teknoloji, Aydın, https://orcid.org/0000-0003-4591-8782

1. INTRODUCTION

Artificial Intelligence (AI) affects our lives more and more. New AI applications emerge in various areas of life. Among the most widespread AI applications are chatbots. Most generally, a chatbot is a computer program that is designed to communicate with human agents as naturally as possible. The medium of communication with chatbots can be vocal or textual.

The use of chatbots is growing massively and spreading in disparate areas involving education, health, e-commerce, tourism, etc. Chatbots are intended to provide quick and prompt responses to the questions of people and, thereby, make their lives easier. Besides, the use of chatbots reduces customer support costs to a great extent, which is a driving force behind the increase of its use in business.

Although deep learning based chatbots are so popular in these days, there are also some drawbacks of deep learning for this research area. Firstly, the strength of deep learning comes from huge amount of data and the powerful processing units. It is not possible to collect lots of data about any context easily. The domain specific chatbots do not mostly have a lot of open set of answers to the questions, correspondingly. In that case, deep learning can be thought of as "nailling a pin with a sledge". That is, applying a deep learning technique to some areas of application may amount to increasing the complexity unnecessarily.

Departing from this point of view, we have developed a rule-based chatbot for a well-defined application domain, which is presented in this paper. Our chatbot aims to answering questions by people in Turkish about public transportation. Our objective is to model the chatbot in Turkish at phonological and morphological levels using rule-based natural language processing techniques.

As we do natural language processing for all Turkish sentences in our project, we do not have a special scope, but we have determined our scope as the urban transportation service of the municipalities to be used in the test phase of the project.

In this book chapter, Section 2 offers a quick overview of the literature concerning chatbots. Section 3 is devoted to the presentation of the analysis of the system. Section 4 gives the top-down design of the chatbot. Section 5 presents detailed design issues along with relevant linguistic explanations. The presentation culminates in a concluding section, Section 6, in which avenues for future work is also hinted at.

2. RELATED WORK

The chatbot is an artificial intelligence software that can simulate a conversation (or a chat) with a user in natural language through command line interface, messaging applications, websites, mobile apps or phone.

In 1950, Alan Turing's famous article named "Computing Machinery and Intelligence" was published, which proposed what is now called the "Turing test" as a criterion of intelligence (Turing, 1950). The criterion depends on the ability of a computer program to imitate a human in a real-time written conversation with a human judge to the extent that the judge cannot distinguish between the program and a real human based on the conversational content alone.

Turing Test stimulated great interest in Joseph Weizenbaum's program named "E.L.I.Z.A.", which seemed to be able to cheat users into believing that they were conversing with a real human. However, Weizenbaum did not claim that E.L.I.Z.A was intelligent, and presented it as more of a debugging exercise in the introduction of (Weizenbaum, 1966).

There are various application domains in which chatbots can be effectively used nowadays. As the core engine of our chatbot incorporates a set of linguistic rules concerning Turkish, it can be adapted to various domains of application by appropriately changing the set of keywords. For the work presented, the domain of our application has been chosen to be urban transportation service offered by the Aydın Municipality.

Almansor and F. K. Hussain classified chatbots into two categories: namely, task-oriented and non-task-oriented chatbots (Almansor and Hussain, 2019). Task-oriented chatbots present answers to help users achieve their goals in specific domains. Virtual assistants (e.g., Siri, Alexa, Google Now, Cortana) for private users or the chatbots for users/business owners in different areas like finance, tourism, stock market, insurance are categorized in task-oriented chatbots. There are supervised and unsupervised machine learning approaches adopted to develop such chatbots. The supervised approach to developing a chatbot can be implemented by probabilistic (Roy, Pineau, and Thrun, 2000) or learning-based techniques (Eric and Manning, 2017). A burden on such applications can be to label sentences in accordance with the chosen set of learning features. This is mostly a costly task. It may require a high amount of human labor and, hence, can be prone to human errors. Non-task oriented chatbots are the general-purpose ones. As they are not designed for a specific task, they are mostly intended to chat aimlessly. Therefore, they need be equipped with generation capability. E.L.I.Z.A is the most well-known example of such chatbots (Weizenbaum, 1966).

S. Hussain et. al. classified the chatbots from a different perspective as rule-based or AI (machine learning, deep learning etc.) based softwares (Hussein, Ameri, and Ababneh, 2019). Rule-based chatbots using linguistic analysis recognize lexical forms in the input text and respond the requestor in a way based on a fixed set of predefined rules. Hien et. al. developed a rule-based chatbot for higher-education environments for students to take administrative support (Hien et al., 2018). The user-message- analysis component of the chatbot analyzes a message with NLP techniques. In this way, the intent of the user and the context of the use are determined. Then, a response is returned by the response-generation component.

Task-oriented chatbots can be modeled with a linguistic approach in rule-based manner. The tasks are represented as imperative sentences mostly like expressing a command or a request. “Book a table at Restaurant X” or “Set the alarm at 8 o’clock” are some of them that are easily understood by the popular chatbots. As long as they are so simple requests, the request can be easily and quickly responded.

Not all rule-based chatbots involve linguistic knowledge, for example, ALICE (Wallace, 2009), a well-known rule-based chatbot, relies on a pattern matching algorithm developed with Artificial Intelligence Markup Language (AIML) (Marietto et al., 2013) and without relying on any linguistic knowledge. AIML is an XML-based markup language where the tags are defined as the basic units of dialogues called categories. AIML enables the chatbot to capture the question and answer patterns with its tag based pattern matching technique.

Our aim is to develop a domain-specific chatbot, using the rule-based techniques developed from the linguistic perspective to understand and respond the user request.

3. ANALYSIS OF THE CHATBOT

In this work, we focus on the urban transportation service of Aydın and we generate domain specific question-answer pairs and prepare our model for some sample bus transportation lines for the use case of this chatbot architecture.

We have generated sample question-answer pairs and test the accuracy of the answers. In our model, the following main information and more is included to give appropriate answers for the questions:

- Bus line stops
- Arrival times within each bus lines’ respective stops
- Pricing of bus lines within their own stops

Based on this kind of information, we have generated a dataset involving 1074 question-answer pairs.

The chatbot system developed in this study has capabilities like text-to-speech generation, speech recognition, word-correction, and morpho-phonological analysis. The latter two are the natural language processing functionalities designed and implemented by the project team as contribution to Turkish-based chatbot research and technology.

Our chatbot can handle dialogues either vocally or textually thanks to its text-to-speech and speech-to-text capabilities. It attempts to respond each input question by looking up in a list of candidate informative sentences. The appropriate answer sentence for a given question is determined on the basis of a given list of keywords.

To this effect, it is designed to perform the following functions of natural language processing: tokenize the input sentence, apply a word-correction operation on the tokens, analyse the set of resulting words into their stems and suffixes, identify keywords possibly occurring in the set of stems.

A question-answer generation program is created based on our data set in order to receive a question-answer pair from the data set gradually and not to repeat the same questions in the next stages as shown in Figure 1.

Our question-answer generator provides automatic evaluation of the chatbot acting similar to the Response Generator. Thirty questions are randomly selected from the question-answer dataset and the keyword groups are created accordingly. The accuracy score of the chatbot is 96.6%.

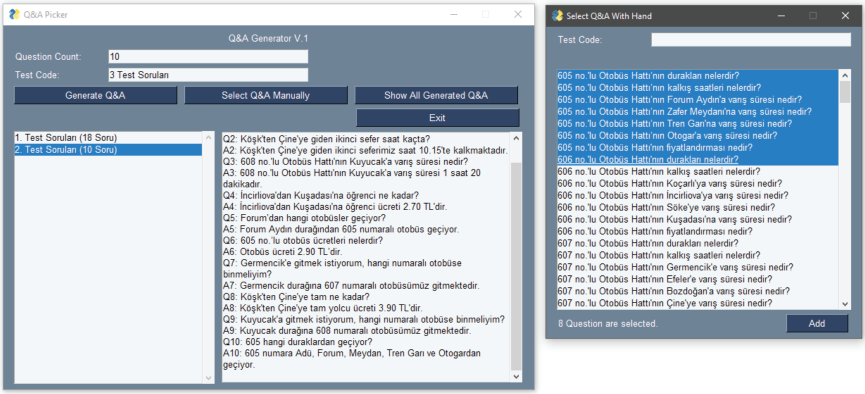


Figure 1. *User interface of question-answer generator*

4. ARCHITECTURAL VIEW OF THE CHATBOT

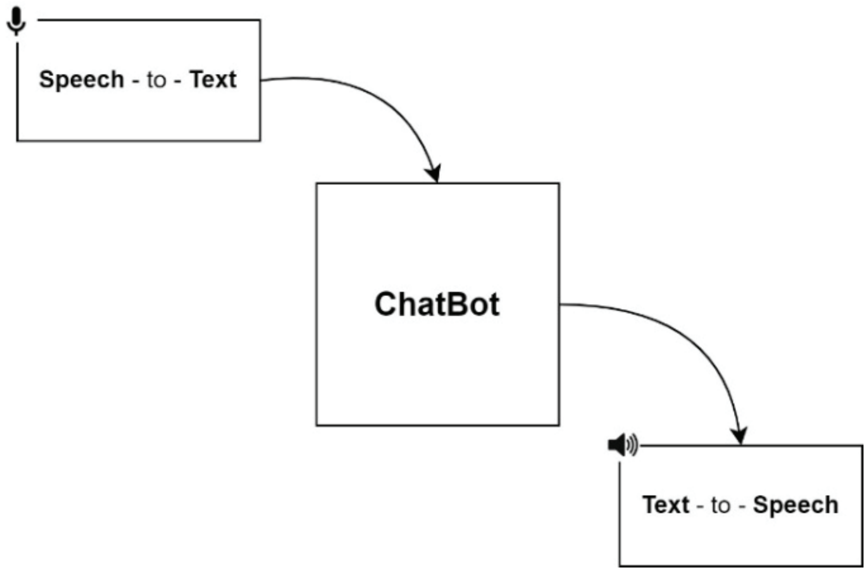


Figure 2. General view of our chatbot

The general view of our chatbot is shown in Figure 2. Our chatbot has some external and internal components. The external ones are the text-to-speech and speech-to-text components. As can be understood from their names, they serve to convert between vocal and textual messages. They are both third-party products developed by Google Inc.

The internal components of our chatbot are represented in Figure 3. The phase following speech-to-text operation is tokenization. Tokenization in our system amounts to splitting a sentence into its words. It is from among the items of these words that the keywords will be picked out. Words may be comprised of considerably many morphemes. Therefore, a stemming operation might be necessary to detect the keyword in a given word.

The subsequent phase is that of word correction. The Word Corrector tries to find out the correct form of a misspelled token. It interacts with the Morphophonological Analyzer when doing this.

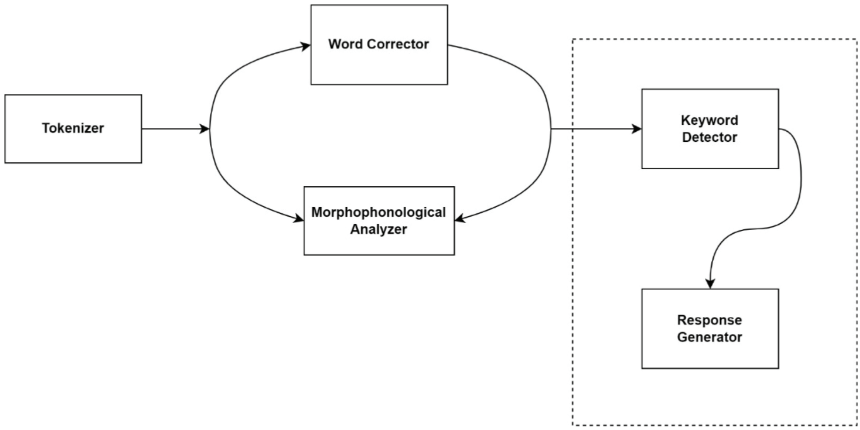


Figure 3. Internal view of our chatbot

The Morphophonological Analyzer analyzes the candidate keywords to morphemes. The keywords are uncovered from a given query in the Keyword Detector with the help of the Morphophonological Analyzer. Then, these keywords are fed to the Response Generator. The Response Generator keeps a list of question-response pairs. Its main function is to detect which question is the best paraphrase of the given query. It carries out this detection process by checking if the keywords appear in a question. If that is determined to be the case, the response associated with that question is issued as an answer to the given query. Finally, the obtained answer is read aloud by the text-to-speech tool gTTS (Google Text-to-Speech), a Python library.

5. LINGUISTIC DETAILS ON INTERNAL VIEW OF OUR CHATBOT

Kılıçaslan et. al. proposed a three-layered morphophonological analyzer for Turkish where these layers are phonetics, phonology and morphology (Kılıçaslan, Açıkgöz, and Aydin, 2014).

Phonetics is the most concrete level of language that involves the physical sounds we hear in nature. Phonology is the organizations of sounds that signal changes in meaning rather than physical properties of sounds covered in phonetics. The most basic units in phonology are phonemes. A phoneme is a group of different sounds perceived to have the same function by speakers of a language. Phonemes are represented by sequences of letters and each phoneme is represented by a single letter whereas a phoneme is the smallest (abstract) unit of the sound system of a language, the smallest unit of the language that is meaningful by itself is called a morpheme. The subfield of linguistics dedicated to the study of morphemes is morphology.

Morphological analysis is the process of determining the morphemes that construct a word. The stem and the suffixes of the words in a language can be captured in this way. Then, the meaning of the sentence starting from the word level is reached by using morphophonological analysis. All of these levels are responsible for combining linguistic units into larger fragments relevant to the corresponding level of language. We have designed and implemented (in Prolog) various types of automata to handle linguistic processes at these three levels.

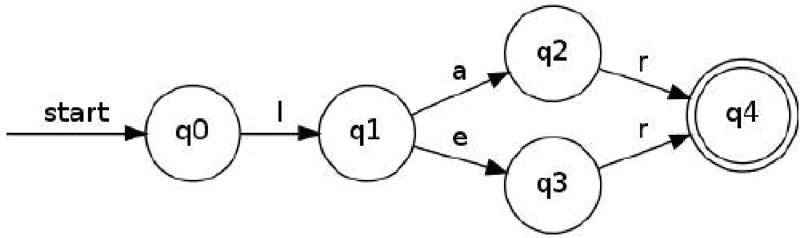


Figure 4. The automaton for the plural morpheme

Each letter in the Turkish alphabet represents, more or less, a distinct phoneme. Mathematically speaking, the allomorphs of each Turkish morpheme can be constructed with an acyclic automaton. The automaton for the plural morpheme is shown in Figure 4.

MORPHEMES OF THE VERB PARADIGM (IN TURKISH):

1. VERB STEM.
2. DERIVATION: reflexive *–In*, reciprocal *–Iş*, causative *–DIr*, passive *–Il*.
3. TENSE: aorist *–Ir*, progressive *–Iyor*, definite past *–DI*, narrative past *–mIş*, future *–(y)EcEk*, optative *–(y)E*, necessitative *–mElI*, conditional *–sE*
   (Notice that not all of these are tenses in the strict sense of the term.)
4. AUXILIARY: past *–(y)mIş*, conditional *–(y)sE*, adverbial *-(y)ken*.
5. PERSON

Figure 5. Morphemes of the noun paradigm

MORPHEMES OF THE NOUN PARADIGM (IN TURKISH):

1. NOUN STEM.
2. PLURAL: *–lEr*.
3. POSSESSIVE.
4. CASE: objective/accusative *–(y)I*, genitive *–(n)In*, dative *–(y)E*, locative *–DE*, ablative *–DEn*, instrumental/comitative *–(y)lE*.
5. RELATIVE: *-ki*. (This suffix is added only to genitive or locative suffixes.)

Figure 6. Morphemes of the verb paradigm

Turkish is a suffixal language. That is, morphemes are right-attached to the words. The suffixes in Turkish can be divided into two paradigms: a verb paradigm and a noun paradigm. The descriptions of the verb paradigm and noun paradigm are as shown in Figure 5 and Figure 6.

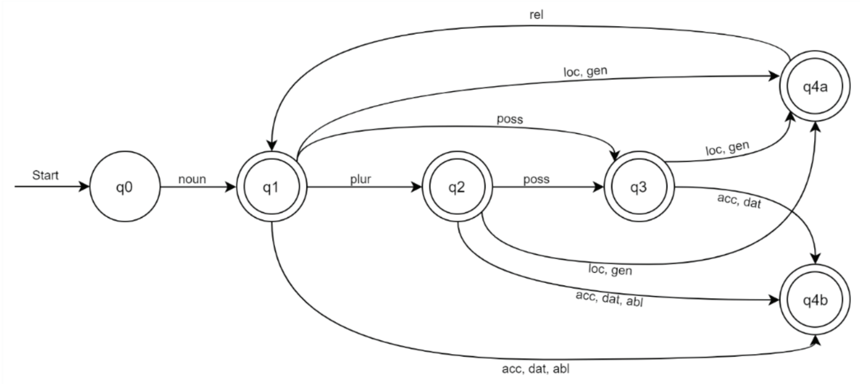


Figure 7. The automaton for nouns

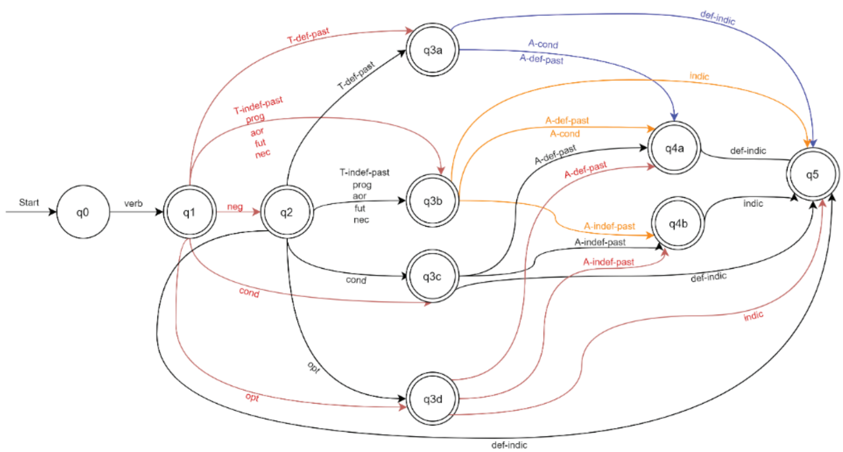


Figure 8. The automaton for verbs

Turkish words can be infinitely longer in theory. However, they can still be generated by a finite-state automaton. Figure 7 represents the finite-state automaton for nouns in Turkish and the finite-state automaton for verbs in Turkish is as shown in Figure 8.

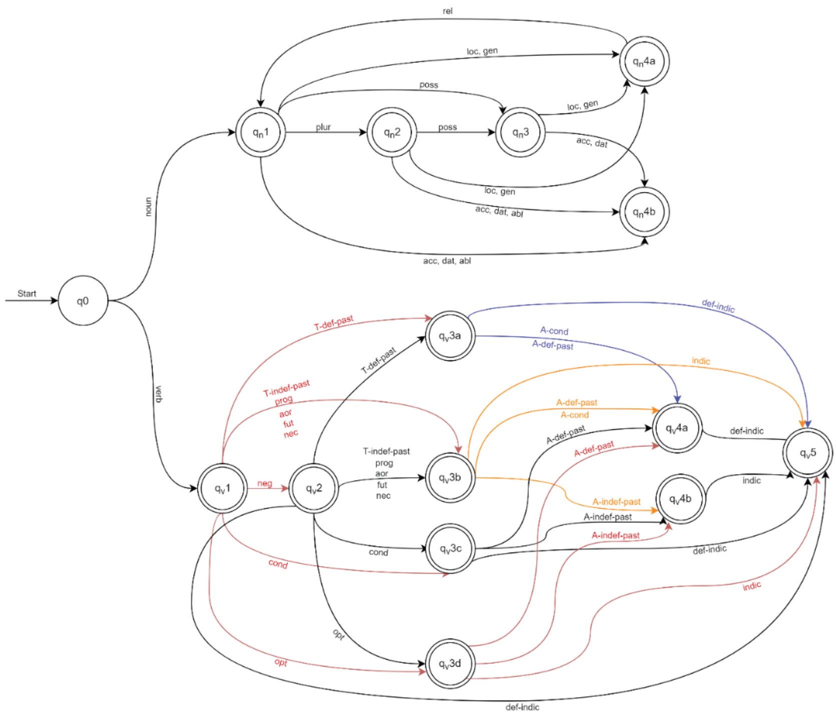


Figure 9. Illustration of certain suffixes that turn nouns to verbs or vica versa

Turkish has also certain suffixes that turn nouns to verbs and vice versa. The automaton in Figure 9 illustrates how to realize such situations. This automaton mainly describes possible word formations in Turkish with inflectional suffixes.

Phonological analysis is provided by sound harmony between suffixes. Cebiroğlu [11] proposed the automata for modelling the vowel harmony and consonant harmony, respectively (Cebiroğlu, 2002). The automata in (Cebiroğlu, 2002) indicates the precedence rules among the vowels and consonants in Turkish in accordance with the morphological constraints. In fact, such rules of harmony are affected in a morpho-phonological context. Figure 10 illustrates the interaction of the morphological and phonological levels in a process of phonetic harmony for word "köpekler".

There are rules of vowel harmony for the words in Turkish. However, the stems of the many words we use today do not conform to these rules and we continue to use them. For this reason, the existence and use of these words have become a social position, and vowel harmony that we will strictly apply will fail in these words. However, these words show a vowel harmony with their suffixes. This shows that the situation here is cognitive and for phonological analysis, better results are tried to be obtained by checking the harmony between words only with their suffixes.

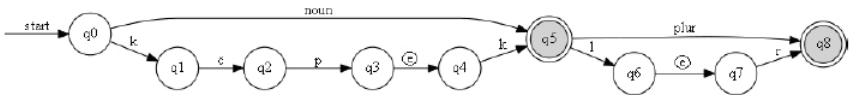


Figure 10. An example for phonetic harmony in Turkish

Our proposed automaton for vowel harmony concerning the all of the cases in detail is shown in Figure 11. Another harmony that is importantly considered is consonant harmony shown in Figure 12.

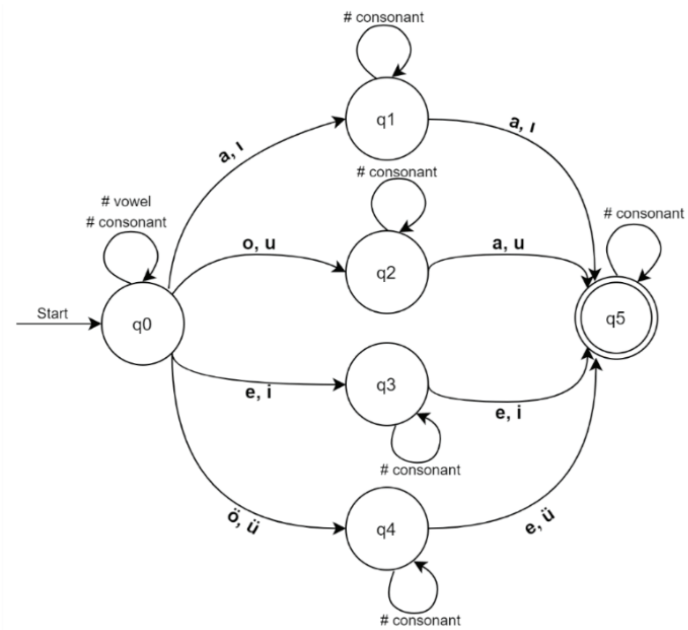


Figure 11. The automaton for vowel harmony

In our chatbot, a data set of 195 words including phonetic events such as consonant softening (durağında), consonant harmony (Köşk'ten) and vowel drop are considered to improve the evaluation results considering the harmony between the suffixes in the keywords.

6. CONCLUSION

Turkish is an aggluginative language. Thus, any work involving this language is supposed to deal with the task of morphophonological analysis. We have presented in this paper a rule-based chatbot having morphophonological analysis. Natural language processing involves both natural language understanding (NLU) and natural language generation (NLG). Chatbots constitute one of the best application areas in which both of these can be practiced. The presented work is intended to have mostly NLU capabilities. However, a possible avenue for the future can be to evolve the chatbot system to a level where it can also display NLG behaviors. This will certainly necessitate to equip our chatbot with abilities to discover contextual clues, like the identity, gender, age of the speaker.

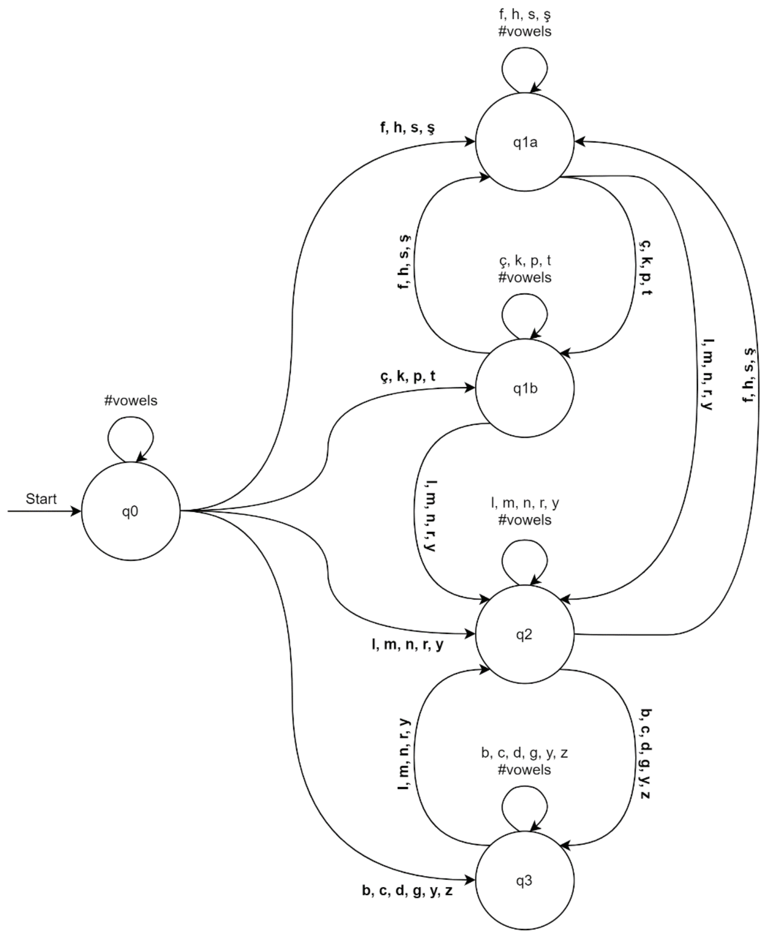


Figure 12. The automaton for consonant harmony

REFERENCES

Almansor, Ebtesam H., and Farookh Khadeer Hussain. (2019). Survey on Intelligent Chatbots: State-of-the-art and Future Research Directions. *Conference on Complex, Intelligent, and Software Intensive Systems*. Springer, Cham, 534-543.

Cebiroğlu, G. (2002). Sözlüksüz Köke Ulaşma Yöntemi (Doctoral dissertation, Fen Bilimleri Enstitüsü).

Eric, M., Manning, C.D.: (2017). A Copy-Augmented Sequence-to-Sequence Architecture Gives Good Performance on Task-Oriented Dialogue. arXiv preprint arXiv:1701.04024.

Hien, H.T., Cuong, P.-N., Nam, L.N.H., Nhung, H.L.T.K., Thang, L.D.: Intelligent assistants in higher-vowel harmoeducation environments: the FIT-EBot, a chatbot for administrative and learning support. (2018). *In: Proceedings of the Ninth International Symposium on Information and Communication Technology* ACM, New York, 69–76.

Hussain, S., Ameri Sianaki, O., & Ababneh, N. (2019). A survey on conversational agents/chatbots classification and design techniques. *In Workshops of the International Conference on Advanced Information Networking and Applications*, Springer, Cham, 946-956.

Kılıçaslan, Y., Açıkgöz, Ö., Aydin, Ö. (2014). A Three Layered Morpho-phonological Analyzer for Turkish*, Journal of International Scientific Publications: Materials, Methods and Technologies*.

Marietto, M. D. G. B., de Aguiar, R. V., Barbosa, G. D. O., Botelho, W. T., Pimentel, E., França, R. D. S., & da Silva, V. L. (2013). Artificial intelligence markup language: a brief tutorial. arXiv preprint arXiv:1307.3091.

Roy, N., Pineau, J., Thrun, S. (2000). Spoken Dialogue Management using Probabilistic Reasoning. *In Proceedings of the 38th Annual Meeting of the Association for Computational Linguistics*, 93-100.

Turing, A. M. (1950). Computing Machinery and Intelligence. *Mind* 59 (236), 433-460.

Wallace, R.S. (2009). The anatomy of A.L.I.C.E. In: Epstein, R., Roberts, G., Beber, G. (eds.)

Parsing the Turing Test: Philosophical and Methodological Issues in the Quest for the Thinking Computer, Springer, Cham. https://doi.org/10.1007/978-1-4020-6710-5_13.

Weizenbaum, J. (1966). ELIZA—A Computer Program for the Study of Natural Language Communication between Man and Machine. *Communications of the ACM*, 9 (1), 36-45.

Chapter 6

COVID 19 AND INDUSTRY 4.0

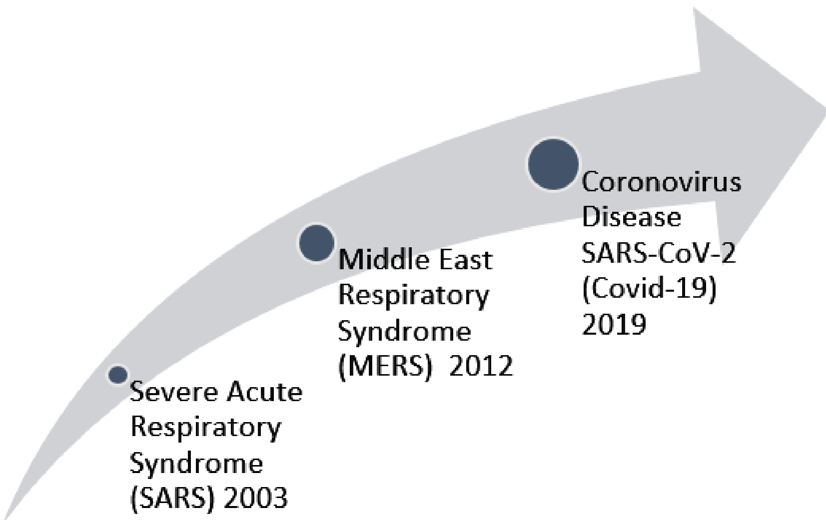
M. Zühal ERİŞGİN BARAK[1]

1 Dr. M. Zühal ERİŞGİN BARAK

Orcid ID: 0000-0002-2039-0785

1. INTRODUCTION

The SARS-CoV-2 virus which comes from the same family as MERS (Middle East Respiratory Syndrome) and SARS (Severe Acute Respiratory Syndrome), triggered a major pandemic that first emerged from Wuhan in December 2019 and the entire World has been affected. (Yiğitol & Sarı, 2020)



Graph 1. Chronological Order of Diseases

Covid-19 is a respiratory disease that spreads quickly by droplets. As a result, it has quickly wrapped the entire world under its influence, leading to a pandemic. According to WHO's worldwide picture of Covid-19, there have been more than 500 million confirmed cases of Covid-19, with 6 million deaths as of October 2022. ("World Health Organization," 2022)

In this part, it was investigated which aspects of Industry 4.0 technologies were affected by the Covid-19 pandemic. With the difficult effects of Covid-19, the process of the pandemic on digital transformation was investigated.

Technology, which started to occupy a large place in our lives, especially with industry 4.0, was used to find solutions to the problems that emerged during the pandemic process, and also showed enhancement in points such as online shopping with the differentiation of some behaviors in the Covid-19 pandemic. (Gong et al., 2020; Talmele, Shrawankar, & Technologies, 2022).

Technological developments, which boost at an accelerated pace day by day, increased at different points with the pandemic. During the pandemic process, major problems, interruptions, and difficulties have arisen in many areas. The subjects such as health and education were in trouble, but with help of online applications many areas have kept on. For example, education could be continued online thanks to online technology tools. (Yiğitol & Sarı, 2020)

Since the industrial revolution, mechanized industry has developed rapidly. In today's world, industrial developments specializing in every field have now gained a different dimension with machine learning.(Li, Liu, Chen, & Jiao, 2020) With the learning of machines, smart production systems have emerged. With smart production systems, faster and less faulty production systems have arisen. System controls have become easier and the pace of the system has accelerated. Production systems that are very dangerous for workers due to very high temperatures or poisoned gases have started to be made with smart machinery. So, dangerous production systems have become safer with advanced technology. (Li et al., 2020)

The industry has passed through various phases up to the current day to arrive at its present situation. With the invention of the loom in 1784, the first phase of the industrial revolution, called Industry 1.0, began. In Industry 1.0, systems have the feature of making mechanical production. Then, with the technological transformation created by the cheap steel production method invented by Henry Bessemer in 1860, the railways developed rapidly. (Yuksel, Sener, & Finance, 2017) Thus, with the acceleration of trade and the introduction of petroleum and its derivatives to the economy, the automotive sector developed, and as a result,

Industry 2.0 started. In 1969, with the first programmable logic controller (PLC), the introduction of electronics and information technologies, which succeeded in carrying the automation of production to the next level, started.(Yuksel et al., 2017)

Industry 3.0 started with the replacement of analog systems with digital systems in production systems. In recent history, with the development of information technologies and machine learning, production has reached a more advanced level. (Yuksel et al., 2017)

Since "Industry 4.0" was mentioned for the first time at the technology fair held in Germany in 2011, it has been on the agenda of the whole world. Industry 4.0 aims to bring together information Technologies (IT) and industry. Industry 4.0 aims to bring together Information Technologies (IT) and Industry. (Talmele, Shrawankar, & Technologies, 2022)

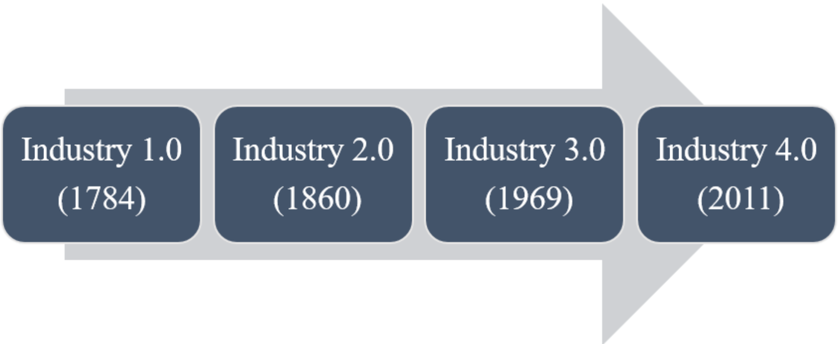
2. INDUSTRY 4.0

Industry 1.0 began with the invention of the first loom in 1784. Industry 1.0, the first step of the industrial revolution, gained momentum with the introduction of mechanical production facilities working with water and steam power. It is the revolution in which machine production was dominant instead of tool production before the industrial revolution, and then factory production instead of workshop-style production. The first steam engine developed by James Watt is accepted as the beginning of this era. (Yiğitol & Sarı, 2020)

Industry 2.0, the second step of the industrial revolution, started after the cheap steel production method invented by Henry Bessemer in 1860. With the technological transformation created by cheap steel production, the railways developed and trade gained momentum. As a result of this situation, the automotive sector developed with the introduction of petroleum and its derivatives into the economy. The introduction of the first production line in 1870, started with the introduction of mass production with electrical energy based on the division of labor. After the 1973 oil crisis, the second industrial revolution came to an end.(Yiğitol & Sarı, 2020)

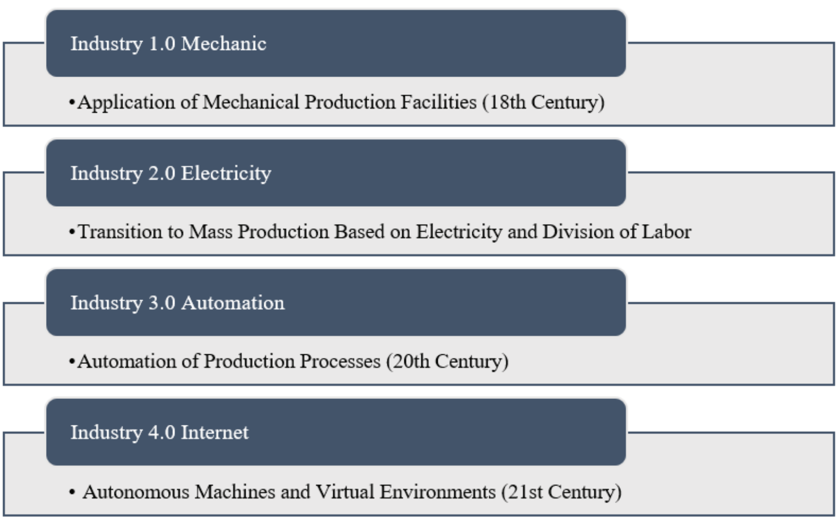
Industry 3.0 is the third step of the industrial revolution. This stage started with the replacement of analog systems with digital systems in production systems. Industry 3.0 started in 1969 with the introduction of electronics and information technologies, which managed to carry the automation of the manufacturing system to the next level with the first programmable logic controller (PLC). Following the introduction of the first microprocessor in 1972, the first microcomputer was launched in 1976 and the first computer company was established. With the development of 3D printers, the production of car parts has increased, and large productions have begun to be made with one click. In 1984, the first 3D printer was made using SLA (stereolithography) technology. (Yiğitol & Sarı, 2020)

With the emergence of the varieties of manufacturing that incorporate Cyber-Physical Systems, Industry 4.0 has started. Following advancements in the fields of Artificial Intelligence, 3D (three-dimensional) printers, Robotics, Biotechnology, Nanotechnology, and Space technology, Industry 4.0 is defined as the intelligent production era where each both animate and inanimate objects can communicate and interact with other objects through internet connections. "Industry 4.0", also known as the "4th Industrial Revolution", was defined for the first time at the technology fair held in Germany in 2011. (Yiğitol & Sarı, 2020) Industry 4.0 has been called digital change, and it is also changing industry fields. Extremely increased computer performance and improved networking have a huge improvement over automation.



Graph 1. Industry Steps

With Industry 4.0, which will bring the new world order, all of the production and living areas will have smart devices and the systems will work in an integrated manner. (Lasi, Fettke, Kemper, Feld, & Hoffmann, 2014) The objective of Industry 4.0 is to include robots that can interact with each other, detect their surroundings with sensors and realize the needs instantly by analyzing data, and as a consequence, a more efficient, quicker, higher-quality, and less wasteful production system can be possible. (Li et al., 2020)



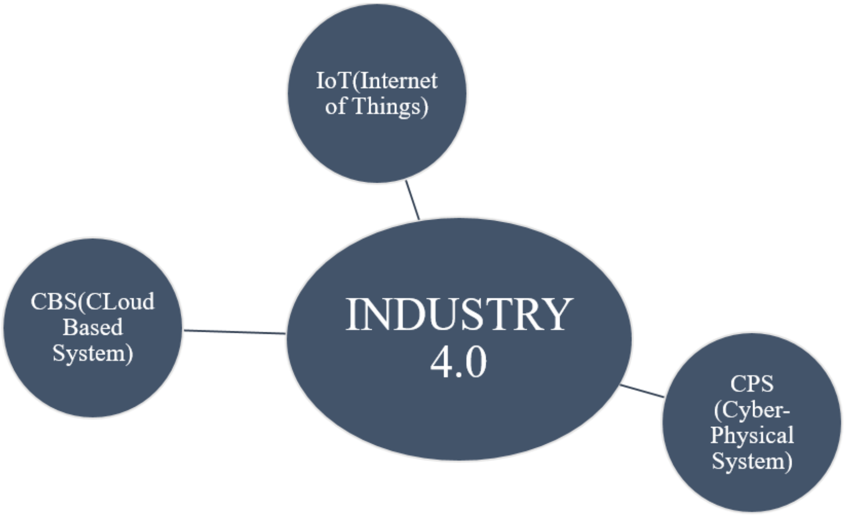
Graph1. The flow of the Industrial Revolution Until Industry 4.0

Industry 4.0 provides several advantages. These advantages also provide enhancing system monitoring, fault detection, self-awareness of system components, environmental friendliness, sustainability with resource-saving behaviors, offering higher efficiency, increasing production flexibility, lowering costs, and creating new service and business models. (Alçin, 2016) Also, expenses will certainly drop, and new market segments and business models will emerge as production becomes more adaptable, effective, and ecologically friendly. While a more environmentally friendly, flexible, and efficiency-based production takes place; costs will inevitably decrease and new business lines and business models will emerge. In addition to ensuring the health and safety of human workers in hazardous environments, it is quite possible to facilitate the controls of supply chains. Thanks to computer control, more consistent, reliable, and efficient outputs can be obtained. On the other hand, market share and earnings may increase for many businesses. (Lasi et al., 2014)

With the launch of the Industry 4.0 concept, production has become more and more dynamic, interactive, and sophisticated, with more interdependencies, unpredicted, and massive amounts of data being produced. Latest developments in commercial artificial intelligence have revealed this technology's ability to assist companies to overcome the challenges created by the digital transformation of Cyber-Physical Systems.

Data is the most important part while working with artificial intelligence. The process data recorded on the Internet or in the system, a very large data pool can be formed. However, it is very difficult to understand and analyze the pool of data and to select the necessary and accurate data from the pool. Big data also can be defined as bringing together logical and meaningful data and using it as a source for research, classification, and storage by some software and companies

IoT- Internet of Things, CBM Cloud-Based Systems, and Cyber-Physical Systems are the three distinct system clusters that make up Industry 4.0.



Graph2. Industry 4.0 And Main Components

IoT - The Internet of Things is the name given to the systems in which a physical phenomenon existing in the system is controlled by computer-based algorithms and tracked by sensors. It is an automated method that is easier to measure and scale, which is making rapid progress, especially in areas such as manufacturing and wearable electronics. IoT has several important aspects: collecting information in the system, transferring, storing, and analyzing. (Singh et al., 2020)

CBS-Cloud Based Systems or another term Cloud Computing is the general definition given to all internet-based services that can be accessed by all internet-based devices at any time and shared among other connected ones. (Škrjanc et al., 2018)

Cyber-Physical Systems (CPS) is a special name given to systems that perform their operations and follow-up through sensors that can self-manage and control as a virtual environment that is a copy of real-world systems. (Talmele et al., 2022) A cyber-physical system (CPS) combines computation with physical processes through computer systems and the cyber world. Through feedback mechanisms, integrated computers and networks are also used to track and manage the physical processes. Sensors are used to collect various forms of data from the outside world and the data are then sent into the digital world where they are collected and evaluated. The purpose of the CPS is to accomplish crucial activities by integrating intelligence into common objects and services. (Dey, Ashour, Shi, Fong, & Tavares, 2018)

3. INDUSTRY 4.0 FOR COVID-19

3.1. Internet Of Things (IoT) In The Covid-19 Pandemic

The Covid-19 pandemic has had a severe social, spiritual, and radical worldwide impact. Especially, the pandemic has had a particularly major effect on the health system. It was vital to gather a lot of information quickly to make decisions quickly to deal with this dilemma.

Collecting big data is crucial in making the accurate decision. One of the main challenges in gathering huge data is the obligation to protect healthcare professionals by minimizing direct contact with patients. Advancements in technology have played a major part in the ability to tackle this pandemic problem. By using a network structure, a healthcare system with the Internet of Things (IoT) features can easily track Covid-19 patients. The Health Authorities' safety rules and precautions are made simple to follow through IoT. It has been used extensively in the fight against Covid-19. (Singh et al., 2020)

IoT has been used very actively in the follow-up of strict quarantine measures applied to prevent the spread of this respiratory disease transmitted by droplets. As an example, tracking with drones in the detection of citizens who do not comply with the quarantine or mask rules shows how effectively IoTs are used during the pandemic (Singh et al., 2020).

It has enabled the collection of a lot of data during the Covid-19 pandemic in mobile applications. On the other hand, it has been used very effectively during the pandemic, especially in mobile applications. With mobile applications, patients who did not comply with the quarantine were detected even in the people they came into contact with. Applications such as the vaccination number of sick individuals or the number of times they have been vaccinated, the institutions where they can be vaccinated, or the prevention of carriers at the entrance to public areas are provided by mobile applications. In some cases, it has been tried to determine whether a person is infected with the help of applications. By measuring the body temperature of the people at the entrance to the public areas, infected persons with high fever and risk of carrying the disease could be determined. Or even people sitting on their balconies can take remote fever measurements via drones. (Yiğitol & Sarı, 2020)

With the help of mobile applications developed by the states, it has become easier to collect information with mobile applications in a very short time. Thus, it became easier to interpret information and take precautions, such as the creation of risk maps. In addition, as a result of the collection and processing of data during this pandemic, it is of great importance to be able to make quick decisions and be prepared for future pandemics.

The follow-up of hospitalized patients has also become considerably simpler as a consequence of wearable technology with IoT. The ability to remotely monitor patient data like blood pressure, heart rate, respiration rate, and pulse reduces the workload in hospitals. All health data can be gathered and evaluated due to the developed applications. So, healthcare professionals are better able to make decisions and follow their patients easily. (Škrjanc et al., 2018)

Another benefit of IoT is that it may be utilized to lighten the workload and boost organizational efficiency, all while lowering the risk of infection for medical staff. Technology advancement is thought to have a crucial role in reducing healthcare issues by enhancing infrastructures with widely used automated health monitoring systems.

All of the data can be shown on a single screen thanks to technological advancements in health centers. A prompt diagnosis shortens the hospital stay. Treatments can be carried out rapidly with a quick diagnosis. Today IoT technology leads to boosting covid patient satisfaction with Covid-19.

It required a unique technological method to produce the vaccine that was used to fight the outbreak. In all areas, including vaccine manufacturing, distribution, and priority group identification, technology has been heavily utilized.

3.2. CBS-Cloud-Based Systems In The Covid-19 Pandemic

A cloud-based system, generally also termed cloud computing, is a word expression for any system that integrates the internet-based transmission of hosted services. (Gong et al., 2020) The new paradigm that will be crucial to the success of Industry 4.0 is Cloud-Based Systems (CBS). CBS makes it possible to allocate resources efficiently, boost productivity, cut expenses associated with the lifecycle of a product, and adapt to changing customer demand in systems. It can be characterized as a networked paradigm that uses on-demand access to a common collection of diverse and dispersed resources to establish movable, reversible cyber-physical lines.

Due to its special characteristics, the Covid-19 pandemic has considerably raised interest in cloud computing. The primary cause of this growth is that, during the ongoing coronavirus pandemic, using cloud technology has become a need rather than a choice. Cloud computing, a division of the Information Technologies (IT) structure, has quickly become the center of attention for all industries thanks to the contribution of its technical tools as a result of the preference turning into a need (Škrjanc et al., 2018).

Many different industries now prefer cloud computing apps more than they did before the outbreak. The importance of cloud computing (an end-to-end online IT solution), increased as the demand for physical hardware decreased. The need for more virtual space has been boosted because more mobility connected to business models and data storage during the pandemic has increased because of working remotely. (Gong et al., 2020)

The Covid-19 pandemic has negatively impacted the majority of industries, despite being frequently encountered in business and social life. This raises the question of what will happen to the commercial agreements made for software and platforms offered in the cloud model, which offers access to cutting-edge technology at a low cost and is an alluring information application. It is feasible to claim that in the initial stage, the impact on the cloud computing solutions and service models used is quite little and gradual.

In recent years it has seen an amazing breakthrough in communication and informatics. The Internet has extended across various networks in a wide range of fields, having a substantial impact on all aspects of daily life, particularly in the field of medicine.

With the Covid-19 pandemic placing enormous stress on the healthcare system, making quick and accurate decisions becomes vital. An effective decision depends on gathering information and necessitates a system for coronavirus disease control and surveillance.

Since coronavirus is a disease that spreads quickly via the respiratory system and has a high fatality rate, it has been crucial to assign patients to categories according to their priority as the healthcare centers rapidly have overfilled. It is a disease that rapidly is transmitted through the respiratory tract and has a high mortality rate. As a result, health centers have rapidly been filling up. It has become a necessity to make a selection by determining the order of importance among the patients. To make a priority decision between patients, It is important to ensure that relevant data is collected and evaluated by the right algorithms or applications. Clinical decision support applications need accurate data. These data can be collected by cloud-based systems. (Škrjanc et al., 2018) Also, deciding the prioritization of resources in a pandemic like vaccine resources or resources in health centers is important. Collecting accurate data must be fast and easier in giving decisions or applying some protection precautions or taking measures.

3.3. Cyber-Physical System in the Covid-19 Pandemic

Physical systems that are tracked, managed, and recorded by computers or algorithms are generally known as “Cyber-Physical Systems” (SFS). (Talmele et al., 2022)

Cyber-Physical Systems (CPS) is a term used to refer to systems that carry out operations and follow-up using sensors that have the ability to self-manage and control a virtual environment that is a replica of actual systems. Through computer systems and the internet, physical processes are combined with computation in a cyber-physical system (CPS). The physical processes are also monitored and managed by integrated computers and networks through feedback mechanisms. The employment of sensors allows for the collection of a wide range of data from the outside environment, which is subsequently transmitted into the digital sphere for analysis. By incorporating intelligence into everyday products and services, the CPS aims to complete important tasks. (Dey et al., 2018)

Social services, particularly in the areas of medicine and healthcare, can benefit from the CPS, which plays a significant role in many information technology applications. Most nations experience an extreme scarcity of healthcare professionals, which causes medical care quality to decline and healthcare expenses to climb. The capability to alter new technology for systems for health monitoring has developed. (Dey et al., 2018)

The cyber-physical system is advancing technology in the healthcare system because of recent improvements in the internet of things, cloud computing, and deep learning. Especially in the Covid-19 Pandemic, thanks to the developments in the internet of things, cloud computing, and machine learning, the cyber-physical system makes a very important and even indispensable technology that is developing in the health system as it is in all systems. For example; some cyber-physical systems process vital patient data in real-time, including blood pressure, temperature, and blood sugar, to save patients' lives in the health care system.

Medical cyber-physical systems (MCPS) combine a network of medical devices, which is fundamental to healthcare. Hospitals deploy medical cyber-physical systems increasingly to ensure consistent, high-quality healthcare.

Due to the curfew and quarantine restrictions announced for the first time due to Covid, online disks and document management systems have started to be used to make the information previously available in paper documents jointly accessible in companies working from home or at a certain distance. Thanks to the developing systems, the meetings that could not be held face-to-face during the covid process were held in the form of remote meetings. Online platforms have started to be used intensively, both in meetings with a few people and in one-on-one meetings or conferences. It is foreseen that this way of working and the development of online meeting applications will accelerate in the future. Remote working has been preferred as it is known that the closed environment in the offices will increase the risk of contamination during the pick time of the Covid 19 pandemic. Although remote work is a type of work with less interaction. In this way, the interaction in unnecessary office or healthcare centers environments has decreased and interaction with communication tools has been ensured as much as necessary.(Yiğitol & Sarı, 2020)

Remote work may not be suitable for all business types. For example, remote work is not very suitable for work types that are produced manually in factories or require work labor. However, as robots and other industrial devices that can perform human-like tasks become more prevalent, the necessity for human labor is dwindling. In factories today that are too risky for people to operate in, machines and robots are preferred. Now, machines and robots can work in situations with hazardous gases, extremely high temperatures, and other harmful conditions.(Yiğitol & Sarı, 2020) On the other hand, robotic and intelligent factories have begun to create completely without the assistance of humans.

Mobile cyber systems which are being employed by both the public and private sectors are extremely common. The usage of mobile applications has also been prevalent in the coronavirus follow-up of those who have contracted it. Applications like location detection and GPRS technology have made it faster to track people and help to collect huge data without contact with covid patients.

4. Conclusion

Industry 4.0 has been used a lot in the fight against the epidemic and its importance has emerged with its use. It has been used extensively both in the diagnosis of the disease and in the follow-up of patients during the pandemic. Industry 4.0 is a technological development that facilitates human life, increases productivity, and also even protects human health. The operation of robots in dangerous areas in factories and remote diagnosis and information gathering of healthcare workers can be given as examples of this situation.

Industry 4.0 is certain to help people in every difficult situation in the future. It will become an indispensable part of human life with its facilitating effect in all areas of life. It can be predicted that Industry 4.0 will be very helpful in future epidemics or pandemics, thanks to the convenience it provides in the collection of data.

With the increase in Industry 4.0 artificial intelligence studies, studies on subjects such as vaccines have also accelerated. Thanks to this pace gained, making more accurate and faster decisions has also provided great convenience in the fight against the pandemic.

With the Covid-19 pandemic, it is anticipated that the good level of growth in cloud computing would continue in the post-pandemic period and become a permanent component of business models. One key element in this transformation is the view of cloud computing as a rescuer held by top businesses across many industries. Additionally, the advantages brought about by cloud technologies' fundamental qualities have a significant impact on how cloud computing is perceived and used. This might be considered the rationale behind the belief that end-to-end cloud solutions will become crucial following the pandemic.

The actions implemented in response to the global coronavirus pandemic make way for normalization. It is well recognized that Industry 4.0 can increase the production of solutions using technologies that will benefit circumstances that put life on hold, like the Covid-19 pandemic. Given the connection between Industry 4.0 and the coronavirus, the usefulness of technology is even more apparent when a pandemic is in progress. Workplace practices are increasingly integrating technology, education is expanding into the home, new behavioral patterns are emerging, and new economic models are emerging. Industry 4.0 can be very helpful in the new era in overcoming these challenges.

The effective and practical application of Industry 4.0 for Covid-19 surveillance and control has been increasingly accepted. The checkpoints on the entire chain of Covid-19 control, including "early review, notification, isolation, and medical intervention" during the outbreak and the long-term follow-up after the pandemic, were strengthened by new applications.

Since the application of informatics systems to combat the Covid-19 pandemic is still in its development, it is important to note that the techniques used in studies need to be further examined to evaluate their clinical suitability and efficacy. The groundwork for the repetition of new applications in places where Covid-19 is emerging and for associated disease pandemics in the future was offered by the integrated informatics technologies, cost-effective solutions, and ease of deployment.

Industry 4.0 is being catalyzed globally by the Covid-19 pandemic. While the world's digitalization has been progressing extremely slowly, it is apparent that the impact of Covid-19 is causing a very rapid transition. Also, the speed of this evolution of Industry 4.0 will quicken along with technological advancements. Globally, several investments have been made to further this technology.

REFERENCES

Alçin, S. J. J. o. l. E. (2016). Üretim için yeni bir izlek: Sanayi 4.0. *3*(2), 19-30.

Dey, N., Ashour, A. S., Shi, F., Fong, S. J., & Tavares, J. (2018). Medical cyber-physical systems: A survey. *J Med Syst, 42*(4), 74. doi:10.1007/s10916-018-0921-x

Gong, M., Liu, L., Sun, X., Yang, Y., Wang, S., & Zhu, H. (2020). Cloud-Based System for Effective Surveillance and Control of COVID-19: Useful Experiences From Hubei, China. *J Med Internet Res, 22*(4), e18948. doi:10.2196/18948

Lasi, H., Fettke, P., Kemper, H.-G., Feld, T., & Hoffmann, M. (2014). Industry 4.0. *Business & Information Systems Engineering, 6*(4), 239-242. doi:10.1007/s12599-014-0334-4

Li, N., Liu, K., Chen, Z., & Jiao, W. J. I. A. (2020). Environmental-Perception Modeling and Reference Architecture for Cyber Physical Systems. *8*, 200322-200337.

Singh, R. P., Javaid, M., Haleem, A., Suman, R. J. D., Research, M. S. C., & Reviews. (2020). Internet of things (IoT) applications to fight against COVID-19 pandemic. *14*(4), 521-524.

Škrjanc, I., Andonovski, G., Ledezma, A., Sipele, O., Iglesias, J. A., & Sanchis, A. (2018). Evolving cloud-based system for the recognition of drivers' actions. *Expert Systems with Applications, 99*, 231-238. doi:https://doi.org/10.1016/j.eswa.2017.11.008

Talmele, G., Shrawankar, U. J. I. J. o. W.-B. L., & Technologies, T. (2022). Real-Time Cyber-Physical System for Healthcare Monitoring in COVID-19. *17*(5), 1-10.

World Health Organization. (2022). Retrieved from https://www.who.int

Yiğitol, B., & Sarı, T. (2020). KÜRESEL SALGINLAR İLE MÜCADELEDE ENDÜSTRİ 4.0 TEKNOLOJİLERİNİN ROLÜ. *Pamukkale Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*(41), 53-73.

Yuksel, A. N., Sener, E. J. J. o. B. E., & Finance. (2017). The reflections of digitalization at organizational level: industry 4.0 in Turkey. *6*(3), 291-300.

Chapter 7

CATALYTIC CONVERSION OF JERUSALEM ARTICHOKE WITH A BRÖNSTED ACID CATALYST IN SUBCRITICAL WATER MEDIUM

Nazlıcan ATİK[1]

Nihal CENGİZ[2]

Levent BALLİCE[3]

1 Ege University, İZMİR/Turkey, nazlicanatik@gmail.com, ORCID: 0000-0002-8692-011X

2 Ege University, İZMİR/Turkey, nihal.cengiz@ege.edu.tr, ORCID: 0000-0002-6572-7046

3 Ege University, İZMİR/Turkey, levent.ballice@ege.edu.tr, ORCID: 0000-0002-3137-1352

Catalytic hydrothermal conversion of biomass and model compounds with Brönsted and Lewis acid to platform chemicals / Biyokütle ve model bileşiklerin Brönsted ve Lewis asitleri ile platform kimyasallara katalitik hidrotermal dönüşümü
Yazar:NAZLICAN ATİK, Danışman: PROF. DR. LEVENT BALLİCE
Yer Bilgisi: Ege Üniversitesi / Fen Bilimleri Enstitüsü / Kimya Mühendisliği Ana Bilim Dalı / Kimya Mühendisliği Bilim Dalı
Konu:Kimya Mühendisliği = Chemical Engineering
Yüksek Lisans, 2021, İngilizce, Tez No: 675494

1. Introduction

Due to rapid development in population and industrialization, global energy demand is constantly rising. Most of the energy needs are met by non-renewable energy resources including charcoal, crude oil, and natural gas which are depleted over time. Because gradual consuming of fossil fuel reserves and increasing the level of air pollutants (i.e, CO, SOx, NOx) caused by fossil fuel combustion resulting in global warming, have prompted researchers to seek sustainable alternative sources for energy and chemicals. The potency of biomass as an alternative energy source is quite important for energy and chemical feedstock.

The term biomass is used for describing all organic matter obtained from organisms such as agricultural crop residue, poultry waste, or algae. Biomass can be transferred into lots of beneficial products for energy formation and chemicals such as biogas or alcohol. Its conversion methods mainly consist of biochemical methods and thermochemical methods. Anaerobic digestion and fermentations are defined as methods for biochemical conversion. By that method, biomass degradation occurs in the presence of enzymes of the bacteria and other microorganisms. Thermochemical conversion processes break down biomass with heat and generally consist of pyrolysis, gasification, liquefaction, and combustion.

Lignocellulosic biomass usually consists of lignin, cellulose, and hemicellulose, and their composition of changes from one plant to another. Biomass is transformed into sugars and other intermediate products such as furan before the production of valuable chemicals. In the process of conversion from cellulose to HMF, cellulose first undergoes a hydrolysis process, usually in the presence of a Brönsted acid, resulting in oligosaccharides and monosaccharides. Glucose as a monosaccharide from the hydrolysis process product is converted into fructose by an isomerization reaction, and then the formed fructose undergoes sequential dehydration reactions to form 5-HMF (Choudhary et al., 2013). Equimolar amounts of levulinic acid and formic acid occur from the reaction between 5-HMF and water (Girisuta et al., 2007). Under the same reaction conditions, the 5-HMF yield from fructose is greater than those obtained from glucose or other hexoses. However, it is stated that fructose is not an ideal feedstock owing to its high price and low abundance in nature. Unlike fructose, glucose is the cheapest hexose sugar and the most abundant monosaccharide. Besides, Inulin is a fructose oligomer produced by different types of plants including, wheat, onion, banana, garlic, Jerusalem artichoke, and chicory. It consists of 2-60 fructose molecules and 1 glucose molecule (Meyer et al., 2009). Owing to, the conversion yield of production of 5-HMF and then LA from fructose being considerably higher than other sugars, real biomasses with high inulin content are preferable.

In the studies carried out by the US Department of Energy (DOE), 300 candidate chemicals that can be produced from lignocellulosic biomass have been determined. By examining their production processes, the number of those that could be important was reduced to 30 and then a list of 12 leading chemicals (Building Blocks) was published in 2004. These chemicals will form the

basis of biorefineries that are planned to replace petrochemical refineries very soon. One of these 12 chemicals is levulinic acid (LA). LA has been described as a crucial intermediate product in the production of many chemicals commonly used in hydrocarbon fuels, fuel additives, agriculture, pharmaceuticals, and cosmetics. It is a five-carboned organic acid ($C_5H_8O_3$) with two functional groups carboxylic acid and a ketone. Thus, It is classified as a keto acid. It is soluble in water and polar solvents.

Levulinic acid can be obtained by the hydrothermal decomposition of fructose and glucose with different yields in the presence of HCl, H_2SO_4, and phosphoric acid behaves as homogeneous catalysts under subcritical water conditions.

It undergoes a wide variety of reactions due to its functional groups. LA can be chemically converted to 2-methyl-tetrahydrofuran and various levulinate esters used as gasoline and biodiesel additives. This is one of the most important applications of LA and its derivatives. Also, derivatives of LA such as MTHF, angelica lactone (AL), γ -valerolactone (GVL), ethyl levulinate (EL), butyl levulinate, and other esters can be used as fuel additives (Morone et al., 2015).

5- Hydroxy Methyl Furfural (5-HMF) is a platform chemical derived from lignocellulosic biomass. It is an important intermediate product for biofuel and chemical production It can be synthesized from sugars especially hexoses by acid-catalysed dehydration. The chemical structure of HMF, consisting of a furan ring with two functional groups: one aldehyde group and one alcohol group, makes 5-HMF an ideal candidate to produce chemicals and polymers in the chemical, pharmaceutical, and food and packaging industries (Trivedi et al., 2020).

Three reaction steps in LA production from lignocellulosic biomass can be classified as the hydrolysis of lignocellulose in an acidic environment, dehydration of the C6 sugars formed because of hydrolysis (by losing 3 moles of water) to form 5-HMF, and the transformation of this intermediate product into LA by rehydration (taking 2 moles of water).

In addition, C5 sugars are formed by the hydrolysis of hemicellulose. C5 sugars that are formed by hydrolysis lose three water molecules and dehydrate then turn into furfural. After that furfural can be converted to furfuryl alcohol and lastly levulinic acid (Bui et al., 2013).

The effect of reaction temperature on LA yield has been extensively investigated. Optimal reaction temperature differs according to raw materials such as glucose, fructose, or real biomass (Girisuta, 2007; Peng, 2010). For example, while working with C6 sugars, a temperature range between 140°C and 160°C is sufficient, however, if cellulose is used as raw material, it is necessary to work in slightly higher temperature conditions (180-220°C). Optimum reaction temperatures vary depending on the amount of cellulose, hemicellulose, and lignin content in biomass. High temperatures are required to break down lignin. The working temperature must be increased as the lignin content of the biomass increases. When the temperature is above 200°C, LA yield tends to decrease due to the occurrence of side reactions and human formation. LA can stay undisturbed for 24 hours at 180 °C, nevertheless, the formation of α and β angelica lactone from levulinic acid by dehydration occurs at temperatures above 230°C (Yan et al., 2008).

In this study, the production of platform chemicals such as levulinic acid and 5-HMF from Jerusalem artichoke as a real biomass feedstock by catalytic hydrothermal conversion has been investigated. The conversion process of biomass at different reaction conditions in the presence of an H_2SO_4 catalyst was carried out in a batch reactor system. The formation yield of sugars and total organic acids was determined.

2. Material and Method

2.1 Feedstocks

Sulphuric acid was used as a Brönsted acid and obtained from Merck, Darmstadt, Germany. Jerusalem artichoke which has high inulin content was selected as a real biomass feedstock. After providing Jerusalem artichoke, it was washed with tap water and divided into smaller pieces then dried at 40°C in a Fischer brand hot air tray dryer for 3 days. Dried biomass samples were crushed with an MF-IKA brand rotary miller to a particle size of less than 1 mm.

The elemental analysis of Jerusalem artichoke was performed in a Leco CHNS-932, MI, USA elemental analyzer, and the results are given in Table 2.1.

Table 2.1. *Elemental analysis results of Jerusalem artichoke.*

Elements (% wt)	Jerusalem Artichoke
C	42.66
H	6.41
N	1.752
S	-
O	49.18

To obtain the ash content of Jerusalem artichoke, milled and dried biomass was burned at 550 °C in a high-temperature muffle furnace. The moisture content of Jerusalem artichoke was determined by drying biomass at 105 °C. Extracts are a group of cell wall chemicals made up of essential oils, fatty acids, fatty alcohols, phenols, terpenes, steroids, resin acids, waxes, and many other small organic compounds (Rowell et al., 2012). By water and solvent extraction (Toluene/Ethanol, 2:1) total extractive percentage in the biomass was calculated. Van Soest Detergent Analysis was performed on Jerusalem artichoke. Van Soest Detergent Analysis is a method for establishing the percentages of cellulose, hemicellulose, and lignin which are the major components of the biomass cell wall. All the characterization results of Jerusalem artichoke are given in Table 2.2.

Table 2.2. *Characterization of Jerusalem artichoke.*

Properties	Jerusalem Artichoke
Moisture (%wt)	6.5
Ash (%wt)	11.82
Total Extractives (% wt)	30.1
Van Soest Detergent Analysis Results	**Jerusalem Artichoke**
Lignin, %	3.16
Cellulose, %	7.82
Hemicellulose, %	6.98

2.2 Experimental System

Experiments were carried out in a reactor system that has 3 reactors and 50 ml inside the volume, under subcritical water conditions (under 374 °C and 221 atm). Reactors are made of stainless steel (SS316) and constructed to endure 150 bar and 250 °C. Tanks have jacket heated and heat control units. To obtain adequate agitation in an N_2 atmosphere, a round magnetic stirring bar was placed in the bottom of the reactor before adding reactants and chemicals. Liquid samples were taken with bottom tubes in the reactor reservoirs.

2.3 Experimental procedure

In this experimental study, the optimal reaction conditions for the production of platform chemicals such as Levulinic acid, and 5-HMF by catalytic hydrothermal conversion from lignocellulosic biomass were investigated. Biomass/solvent ratio, pH of solvent, reaction time, and temperature were investigated as reaction parameters. For accuracy, each run was repeated three times.

Catalytic hydrothermal conversion of Jerusalem artichoke was performed in a batch reactor system. Experiments under subcritical thermal conditions were carried out at 140°C, 160°C, and 180°C in the presence of sulfuric acid (H_2SO_4) as a Brönsted acid catalyst at different pH values of 0.5-1.5. The desired amount of biomass sample and volume of solvent (ranging from 1 to 2 grams of biomass and 22 mL of solvent) were placed into autoclave reactors. The air inside of the reactors was removed by an inert gas stream (nitrogen) and the reactors were quickly heated to the desired temperature and kept at this temperature for 2 hours Samples were taken from the top of the reactor with a dip pipe at 20, 40, 60 and 120 minutes after the temperature of reactors reached the set point.

At the end of the experiment, the reactors were cooled rapidly to ambient conditions. Then solid particles and liquid products were separated by a filter. Separated liquid products were analyzed by HPLC and TOC devices.

2.4 Sample analysis

After the reaction, the liquid solution was directly analyzed by an HPLC (Agilent 1200A) device with a refractive index detector and an Aminex HPX-87H column. Acetic acid, formic acid, levulinic acid, and 5-HMF were analyzed according to Method 1, while sugars were analyzed by applying Method 2. Technical features and operating conditions of HPLC for Method I and Method II were given in Table 2.3. The concentration of total organic carbon in liquid phase samples was analyzed by the TOC analyzer (Shimadzu total organic carbon analyzer- Model: TOC-VCPH).

Table 2.3. *HPLC specifications and operating conditions for methods I and II.*

	Method I	**Method II**
Device	HPLC-RI (Agilent 1200A)	HPLC-RI (Agilent 1200A)
Column	HPX-87H column	HPX-87H column
Mobile Phase	5 mM H_2SO_4	5 mM H_3PO_4
Flowrate	0.6 mL/min	0.6 mL/min
Detector	Refractive Index	Refractive Index
Column Temperature	30°C	30°C

Detector Temperature	30°C	40°C
Injected Volume	20 µL	20 µL
Analysis Time	50 min	25 min

3. Results and Discussion

Hydrothermal catalytic conversion of Jerusalem artichoke as a real biomass feedstock and fructose as a model compound with Brönsted acid as H_2SO_4 to platform chemicals carried out in a batch reactor system. The effect of temperature (140-180 °C), biomass loading (1g-2g), pH of Brönsted acid (0.5-1.5), and reaction time (between 20 min and 120 min) on the production of valuable chemicals by the catalytic hydrothermal decomposition of biomass were studied. The results of the TOC and HPLC analysis of the samples taken from the reaction medium during the experimental studies are shown in Figure 3.1 to Figure 3.8.

3.1 Effect of Biomass/Solvent Ratio on aqueous product yields

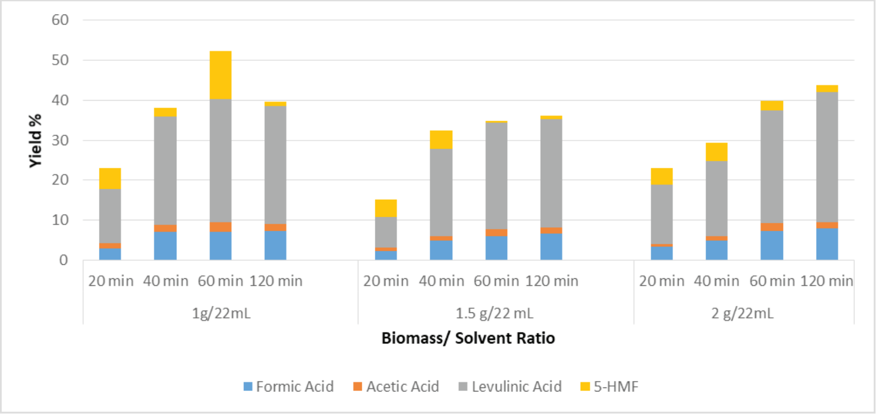


Figure 3.1. *Variation of organic acid yields due to the hydrothermal decomposition of Jerusalem artichoke in the presence of* H_2SO_4 *catalyst at 180 °C, 0.5 pH, and different biomass/solvent ratios.*

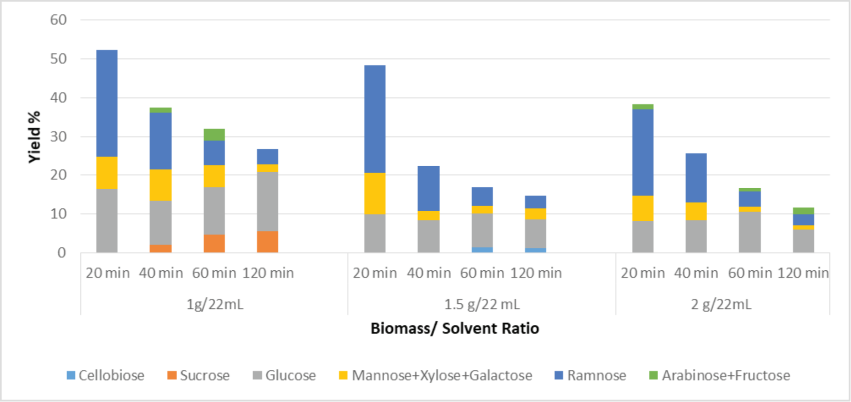


Figure 3.2. *Variation of sugar yields due to the hydrothermal decomposition of Jerusalem artichoke in the presence of H_2SO_4 catalyst at 180 °C, 0.5 pH, and different biomass/solvent ratios.*

The reaction temperature and pH of H_2SO_4 were kept constant at 180 °C and 0.5 in this set of experiments. The biomass/solvent ratio was changed from 1 g/22ml to 2g/22 ml. 3 repeated experiments were carried out in the same experimental conditions. The results were obtained by taking averages of these experiments.

Both total organic acids yield and total sugars yield increased with decreasing biomass/solvent ratio as shown in Figure 3.1 and Figure 3.2. For the total sugars formed as a result of the hydrolysis of lignocellulosic biomass, the maximum yield value was highest at 20 minutes for all biomass/solvent ratios and it tended to decrease over time. In contrast to sugars, organic acids show a tendency to increase over time.

When the ratio was 1g/22ml, total organic acids reached their highest value at % 52.3 after 60 minutes and the maximum total sugars yield was obtained as % 52.4 after 20 minutes.

According to these results, the study was continued by choosing 1 gram of Jerusalem artichoke/ 22 ml H_2SO_4 as the best proper biomass/solvent ratio. As the next step after determining the most suitable biomass/solvent ratio, the studies were carried out in constant biomass/solvent ratio.

3.2 Effect of pH on aqueous product yields

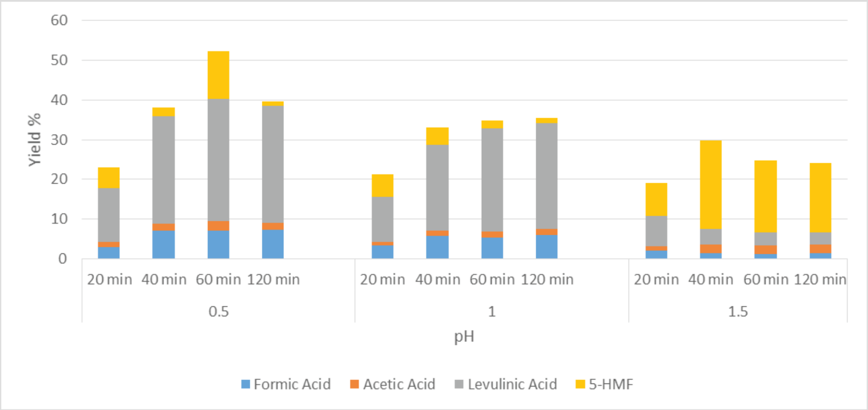


Figure 3.3. *Variation organic acid yields due to the hydrothermal decomposition of Jerusalem artichoke at 1g/22 ml biomass/solvent ratio and 180 °C in the presence of* H_2SO_4 *catalyst and different pH values*

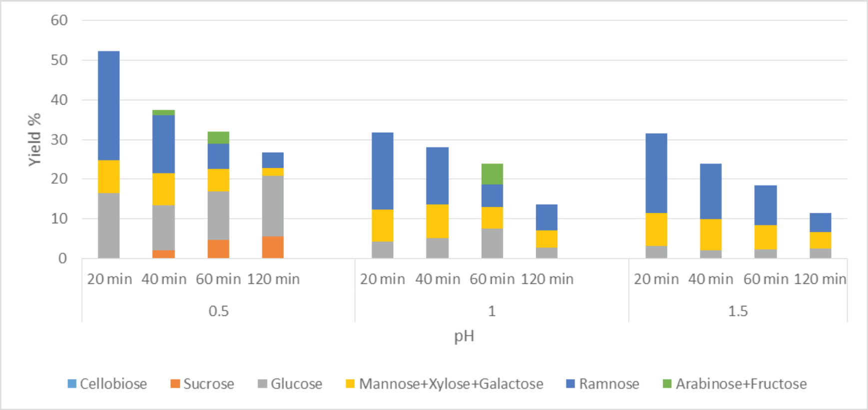


Figure 3.4. *Variation of sugar yields due to the hydrothermal decomposition of Jerusalem artichoke at 1g/22 ml biomass/solvent ratio and 180 °C in the presence of* H_2SO_4 *catalyst and different pH values*

To observe the effect of pH on biomass conversion, three different pH values (0.5, 1, and 1.5) were investigated. The reaction temperature and biomass/solvent ratio were held constant at 180 °C and 1 g/22ml, respectively. The concentration of total sugars reached its highest value after 20 minutes for all pH values. After that moment, it declined gradually. By contrast to sugars, total organic acids concentration was lowest at the first moments and rose considerably over time from the first 20 minutes to the end of 1 hour (see Figure 3.3).

Percentages of total sugar yield after 20 min of reaction time in the presence of an H_2SO_4 catalyst with pH values of 0.5, 1, and 1.5 were 52.4, 31.7, and 31.6, respectively. The result demonstrated that plant cell wall degradation and sugar production were higher at the lower pH value.

It is stated in the literature that low pH values are more effective in the production of platform chemicals from lignocellulosic biomass. Fang et al have performed a study on sorghum kernel's conversion to LA. The study has shown that LA yield increases with decreasing sorghum kernel loading, increasing temperature, and H_2SO_4 concentration. Maximum LA yield was reached with 33% at 200 °C, 8% H_2SO_4 concentration, and 10% biomass feed (Fang et al., 2002).

According to Figure 5.3 from 1.5 pH to 0.5 pH, there was a sharp increase in total organic acids yield in the liquid product with H_2SO_4 catalyst after 60 minutes of reaction time from %24.9%52.3.

For all that reasons, the optimum pH value was identified on biomass conversion to platform chemicals with H_2SO_4 catalyst as 0.5 and it kept constant at the next experiments.

3.3 Effect of temperature on aqueous product yields

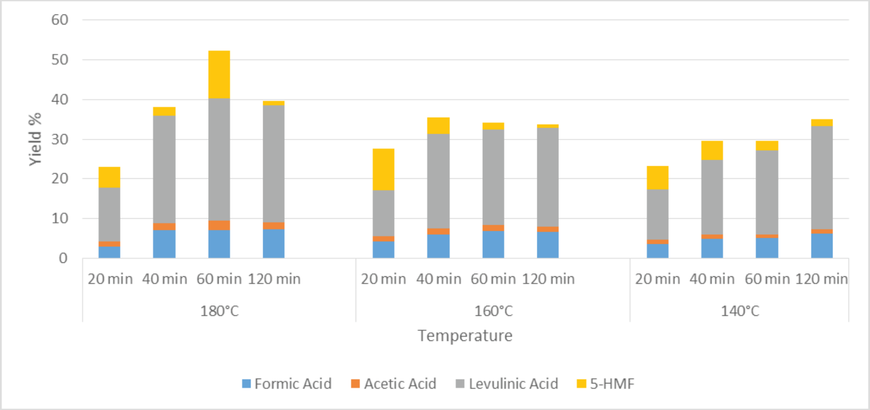


Figure 3.5. *Variation of organic acid yields due to the hydrothermal decomposition of Jerusalem artichoke at 1g/22 ml biomass/solvent ratio, 0.5 pH, in the presence of H_2SO_4 catalyst and different temperatures*

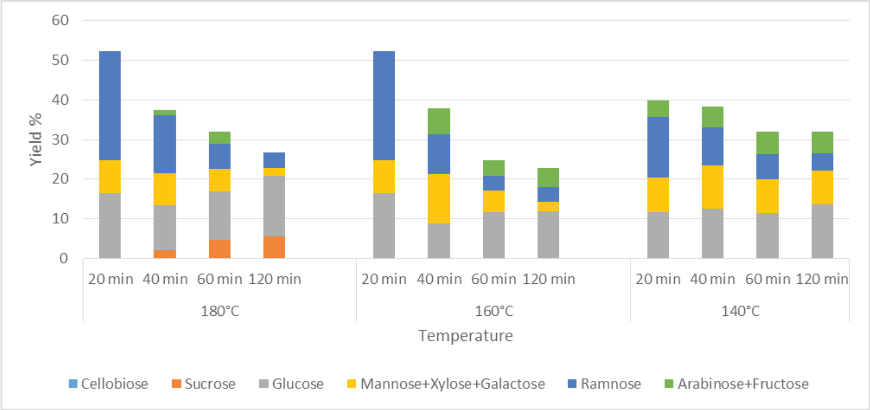


Figure 3.6. *Variation of sugar yields due to the hydrothermal decomposition of Jerusalem artichoke at 1g/22 ml biomass/solvent ratio, 0.5 pH, in the presence of H_2SO_4 catalyst and different temperatures*

As the optimum pH of the H_2SO_4 catalyst (0.5) and biomass/solvent ratio (1g/22ml) was identified before, they were kept constant to determine the optimum temperature for the maximum yield of organic acids. The bar graphs above compare the yields of total organic acids and total sugars between a temperature range from 140 to 180 C° over time.

The conversion efficiency of biomass to organic acids demonstrated an increasing trend from 140 °C to 180 °C reaching %52.3, whereas total sugar yield increased between 140 and 160 °C but remained constant from 160 to 180 °C (See Figure 3.5 and Figure 3.6). Thus, the reaction temperature of 180°C was selected for further investigation.

According to the results obtained from this set of the study, the best experimental conditions determined to produce platform chemicals from Jerusalem artichoke by catalytic hydrothermal conversion towards sulfuric acid as 1 gram of Jerusalem artichoke, 0.5 pH of H_2SO_4 and 180 °C reaction temperature. The total organic acid yield obtained under these conditions was determined as 52.3% 60 minutes for reaction time.

3.4 Total Organic Carbon (TOC) Results

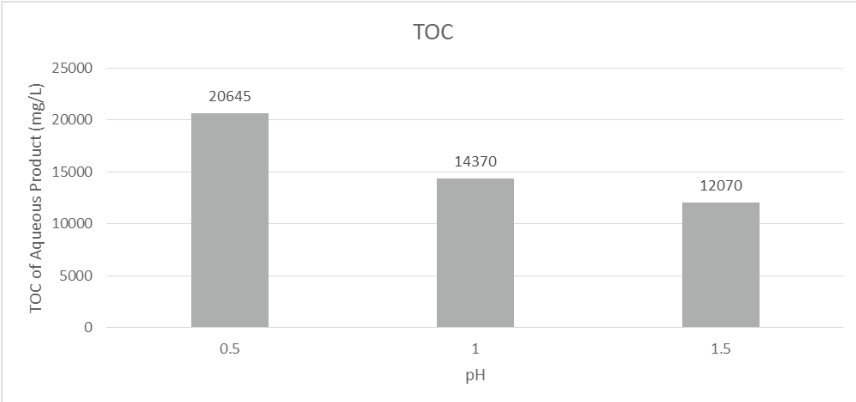


Figure 3.7. *Variation of TOC of aqueous products at 1g/22 ml biomass/solvent ratio and 180 °C in the presence of H_2SO_4 catalyst and different pH values***.**

The bar chart above gives information about the total organic carbon content of liquid products at 180°C, 60 minutes of reaction time, 1g Jerusalem Artichoke/22ml $H_2SO_{4\ loading}$ with a range of pH values from 0.5 to 1.5. The total organic carbon (TOC) of aqueous products shows a decreasing trend with increasing pH values of H_2SO_4. TOC (mg/L) contents for hydrothermal catalytic conversion of Jerusalem artichoke were found to be 20645 at 0.5 pH, 14370 at 1 pH, and 12070 at 1.5 pH.

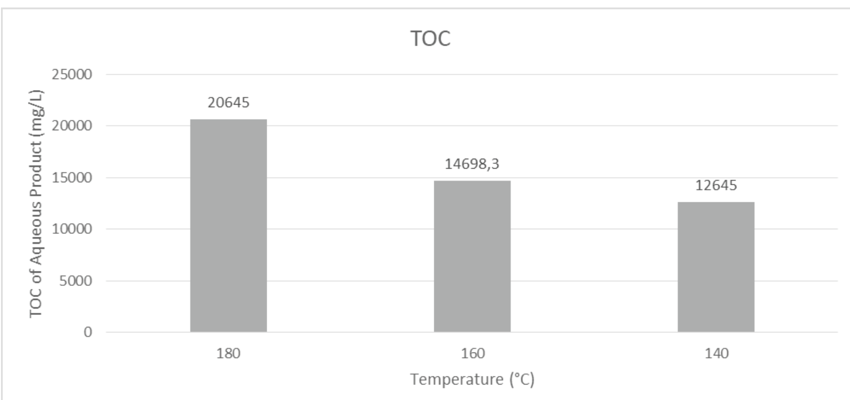


Figure 3.8. *Variation of TOC of aqueous products at 1g/22 ml biomass/solvent ratio and 0.5 pH in the presence of H_2SO_4 catalyst and different temperatures*

Figure 3.8 shows the TOC result for the aqueous product at constant H_2SO_4 pH of 0.5, biomass/solvent ratio as 1g/22ml, 60 minutes of reaction time, and different temperatures between 180°C and 140°C. The TOC values decreased with decreasing temperature from 180°C to 140°C (20645 and 12070 mg/L, respectively).

4. Conclusion

The effects of biomass loading (1g-2g), pH of Brönsted acid (0.5-1.5), temperature (140-180°C), and reaction time (between 20 min and 120 min) were investigated on the yield of hydrothermal catalytic conversion of Jerusalem artichoke as a real biomass feedstock with H_2SO_4 to platform chemicals such as Levulinic acid and 5-HMF.

Both total sugars and total organic acids yield increased with decreasing biomass/solvent ratio from 1g/22ml to 2g/22ml in the presence of H_2SO_4. When the temperature increases from 140 to 180°C, the total organic acids amount showed an increasing trend. The total sugar amount increased to 160°C, but it remained constant from 160 to 180°C. Based on this result, it can be understood that 160 °C reaction temperature was sufficient for the hydrolysis of lignocellulosic biomass to sugars and their isomerization reactions of them. However, this temperature is not sufficient for the conversion of sugars to platform chemicals. Furthermore, organic acid yields considerably decreased with increasing the pH value from 0.5 to 1.5. The data demonstrated that plant cell wall degradation and sugar production were higher at the lower pH value. All the results obtained from the experimental study show that the highest product yields for platform chemicals and sugars were achieved at 180°C, 0.5 pH, 1g/22ml biomass/solvent ratio, and after 60 minutes of reaction time.

REFERENCES

Bui, L., Luo, H., Gunther, W.R. and Román-Leshkov, Y., 2013, Domino reaction catalyzed by zeolites with Brønsted and Lewis acid sites for the production of γ-Valerolactone from furfural, Angew. Chem., 125, pp. 8180-8183

Choudhary, V., Mushrif, S. H., Ho, C., Anderko, A., Nikolakis, V., Markinkovic, N.S., Frenkel, A. I., Sandler, S.I. and Vlachos, D.G., 2013, Insights into the interplay of Lewis and Brønsted acid catalysts in glucose and fructose conversion to 5-(hydroxymethyl) furfural and levulinic acid in aqueous media, Journal of the American Chemical Society, 135(10), pp. 3997-4006

Fang Q. and Hanna M.A., 2002, Experimental studies for levulinic acid production from whole kernel grain sorghum., Bioresource Technology, 81, pp. 187–192.

Girisuta, B., Janssen, L.P.B.M. and Heeres. H.J., 2007, Kinetic Study on the Acid-Catalyzed Hydrolysis of Cellulose to Levulinic Acid, Industrial and Engineering Chemistry Research, 46(6), pp. 1696–1708

Meyer, D. and Blaauwhoed, P., 2009, Handbook of Hydrocolloids (Second edition), Woodhead Publishing Ltd., Cambridge, pp 829-848

Morone, A., Apte, M., and Pandey, R.A., 2015, Levulinic acid production from renewable waste resources: Bottlenecks, potential remedies, advancements and applications, Renewable and Sustainable Energy Reviews, 51, pp. 548-565

Peng, L., Lin, L., Zhang, J., Zhuang, J., Zhang, B. and Gong, Y., 2010, Catalytic Conversion of Cellulose to Levulinic Acid by Metal Chlorides, Molecules, 15, pp. 5258–5272.

Rowell, R.M., Pettersen, R. and Tshabalala, A. M., 2012, Handbook of Wood Chemistry and Wood Composites

Trivedi, J., Bhonsle, A. K. and Atray, N., 2020, Processing food waste for the production of platform chemicals, Refining Biomass Residues for Sustainable Energy and Bioproducts, pp. 427-448

Yan, L., Yang, N., Pang, H. and Liao, B., 2008, Production of Levulinic Acid from Bagasse and Paddy Straw by Liquefaction in the Presence of Hydrochloride Acid, Clean, 36(2), pp. 158-163