Turkish Journal of Electromechanics and Energy
ISSN: 2547-975X
Vol:6, No:2, Page 53-57 (2021)
https://www.scienceliterature.com

A computer vision system for chain link sorting application

F. Akkoyun, M. N. Baş, S. Şimşek, D. E. Uysal, S. Güçlüer, A. Özçelik*

Department of Mechanical Engineering, Aydın Adnan Menderes University, Aydın 09010, Turkey

ARTICLE INFO

***Article Type*:**
Research Article

Article History:
Received: 15 May 2021
Revised: 13 July 2021
Accepted: 22 July 2021
Published: 25 September 2021

Editor of the Article:
M. E. Şahin

Keywords:
Chain link sorting
Real-time image processing
Conveyor line
Machine vision system

ABSTRACT

Sorting is a necessary process in industrial mass production applications. Considering the increasing population and demand for consumer products, simpler means to perform image detection and analysis through machine vision applications are crucial. This study demonstrates an effective machine vision application by analysing the correct faces of chain links. In the chain fabrication process, the high throughput production line requires proper alignment of each chain link due to the tolerance difference of each linked face due to the machining procedure. The manual labour currently applied in correcting the face orientation of the chain links in the production flow line increases the fabrication cost and human error. Through a simple machine vision application and an industrial-grade global shutter camera, detection of continuously flowing chain links is achieved by using a marker. The procedure works by detecting the marker on the related face of the chain links through image thresholding and analysis. The study is offering 100% accuracy for sorting single and multi-line chain links in real-time applications. The demonstrated application can be coupled by a sorting mechanism adapted to various quality control and sorting requirements in industrial manufacturing.

Cite this article: F. Akkoyun, M. N. Baş, S. Şimşek, D. E. Uysal, S. Güçlüer, A. Özçelik, "A computer vision system for chain link sorting application," *Turkish Journal of Electromechanics & Energy*, 6(2), pp.53-57, 2021.

1. INTRODUCTION

Machine vision and process automation have become indispensable tools for rapid, sensitive, and low-cost product detection and characterization [1-3]. In industrial real-time machine vision applications, the image obtaining procedure can be accomplished using a charge-coupled device (CCD) or complementary metal-oxide-semiconductor (CMOS) sensor-based cameras [4, 5]. Both sensor type provides practical solutions for real-time machine vision applications. Various parameters affect the accuracy of an imaging system, such as resolution, frame per second (FPS), and shutter type of the imaging device [6, 7]. An industrial camera integrated with an image processing solution leads to an increase in the accuracy level of automated applications in the manufacturing area. These solutions are used in many applications such as production monitoring, fault detection, and quality control [8-10]. In the industrial application of chain link fabrication and chain assembly, geometry-based constraints require determining the front and back sides of an individual link. A standard method in the chain production line is to manually rotate all the back-facing chain links flowing through the manufacturing line [11]. This manual labour limits production speed and accuracy due to human error [12]. Therefore, a low-cost and straightforward machine vision-based chain orientation detection approach is needed in the chain manufacturing industry.

Machine vision and image processing techniques have been adapted in numerous applications, including fruit harvesting, spectral analysis, industrial fabrication, and welding [9, 10, 13 – 16]. In the food sector, manual labour, which historically constituted the high cost of production, is being replaced by the advanced industrial applications of machine vision for the inspection and sorting of food products [4]. Image processing is an essential component of machine vision-based industrial automation. Continuous detection and sorting applications have become more common by developing real-time image acquisition and processing methods [17, 18]. In one example, rapid detection and analysis of images captured by a consumer-grade commercial camera were demonstrated. In this application, an individual element spectrum was analysed using a correlation-dependent matching algorithm. To overcome the imperfections in the experimental conditions, such as scattered and uneven lighting, the detection of the individual elements was considered a multi-label grouping task. Even though the proposed system yielded acceptable results of detection and analysis, the process is relatively complex and was not shown to be suitable in an industrial setting [5]. In a different application, crumbled aggregates were analysed by image processing for grading in a conveyor band. The authors of this work characterized various images taken from crushed samples considering the changes from pixel to pixel and the resolution scale. By this work, an image-dependent approach was adapted

*Corresponding author e-mail: aozcelik@adu.edu.tr

for aggregate grading, and a supervised categorisation was demonstrated by applying wavelet entropy-related features [19]. Similar to the examples mentioned above, there are several other machine vision applications in quality control and product sorting [20-22]. However, most of these applications are proof of concept demonstrations that utilise complex algorithms and processes, usually not appropriate for industrial applications. For example, in the chain-link assembly process, rapid identification of link orientation is required for continuously sorting the links in the right orientation.

In the present study, a simple and cost-effective solution is presented for machine vision and image processing-based detection and characterization of chain-link front and backside orientations in a flow-through configuration for high throughput industrial manufacturing. For this, chain links marked based on their face orientation are rapidly detected using a high frame rate industrial camera.

2. EXPERIMENTAL

It is crucial to determine the pressing face of the chain links in chain production lines to eliminate the failures in chain assembly stages. The main objective of this study is to classify chain links concerning a circular mark on the links using machine vision technology. The links are prepared with a circular mark on the pressing face at the beginning of the production stage. Determining the right side of the links is conducted using image processing procedures by evaluating the marks. The open-source computer vision library (OpenCV) and C++ programming language was used in the image processing stage. It is an open-source library that provides many machine learning and image processing algorithms. It supports C++ and many more programming languages, and it is a platform-independent library. The detection and classification experiments are implemented on an industrial roller conveyor mechanism in real-time. A Cross-illuminating technique was used with light emitting diode (LED) light sources which are mounted on the roller conveyor mechanism. An industrial CCD camera was integrated with an industrial personal computer (IPC) using computer vision software for detecting and determining the marked faces of chain links on a production line. The structure of machine vision system (MVS) is given in Figure 1.

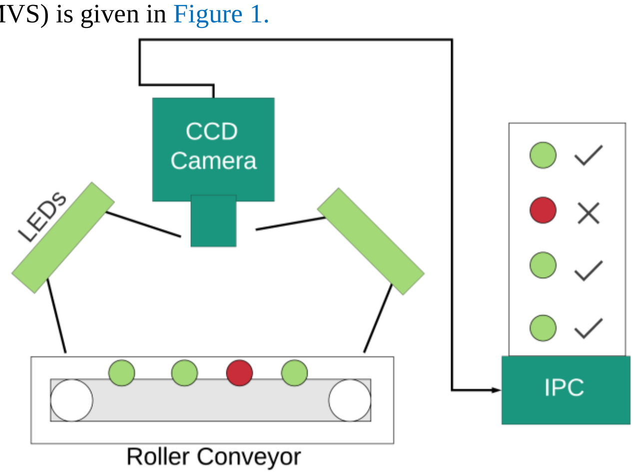


Fig. 1. The structure of the system.

An isolated illumination environment based on the cross-lighting technique was prepared for illuminating the chain links. To minimize the background's reflecting effect, opaque black material was used on the roller conveyor line. The speed of the conveyor line was adjusted using a stepper motor and driver together. The input frequency for adjusting the speed was generated via a microcontroller unit (MCU) connected to an IPC over USB. The OpenCV library was used for processing images in real-time. The developed algorithm was implemented using the OpenCV library and C++ programming language. The flow chart of the software is shown in Figure 2.

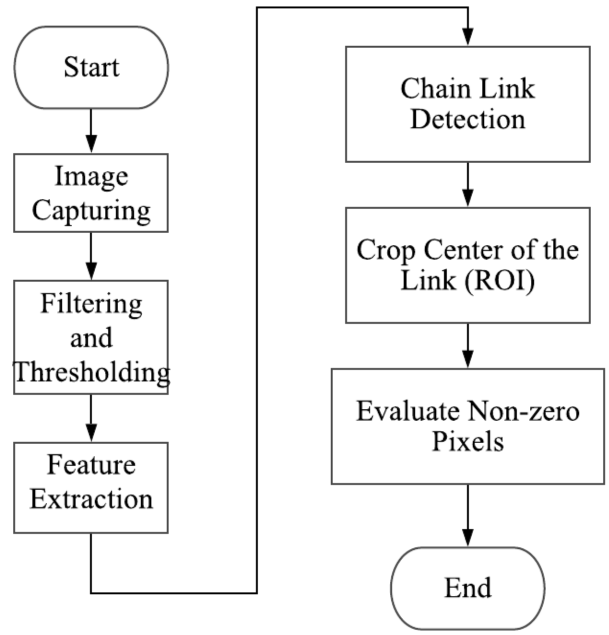


Fig. 2. The flowchart of the method.

The image capturing and processing steps for determining the face of chain links was implemented on the roller conveyor line in real-time. The capturing and processing stage automatically initiates when a chain link enters the measurement area. The face of links evaluated according to marking sign existence for sorting the links with the right side. An output signal was generated for each reversed link and transferred from IPC to MCU via universal serial bus (USB) using serial communication. These processes are accomplished by selecting chain links concerning press machining face and eliminating face downlinks. In Figure 3, chain links samples are given for marked and non-marked links.

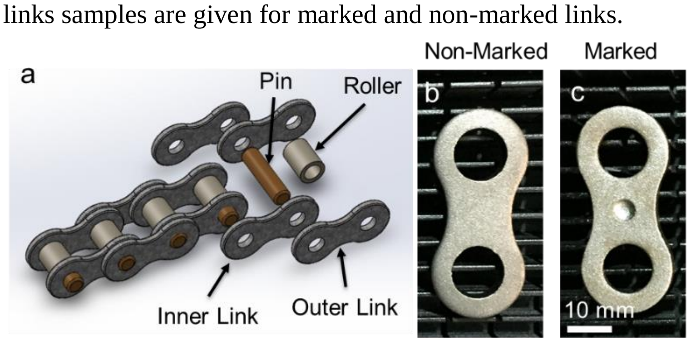


Fig. 3. The chain and parts, (a) pin, roller, inner and outer links on a chain assemble, (b) non-marked link, (c) marked link.

In the experimental stage, thirty-four samples were used to evaluate the accuracy of the system. The image capturing and processing steps were accomplished while chain links moving on the roller conveyor line in real-time. The image processing stage was triggered with a continuous object detection procedure. The objected detection and feature extraction processes are accomplished to determine the face of a link. Image processing stages to determine marked and non-marked chain links initiate while an object enters in measurement area as indicated in Figure 4. (a) between green line and red line. The output signal is produced and transferred to MCU while the centre of the chain-link passes through a decision line (Figure 4. (a) magenta line). A detected marked chain link in Figure 4. (a) with cropped centre image and thresholded image are shown in Figure 4 (b, c), respectively. A detected non-marked chain-link in Figure 4. (d) with cropped centre image and thresholded image are shown in Figure 4 (e, f), respectively.

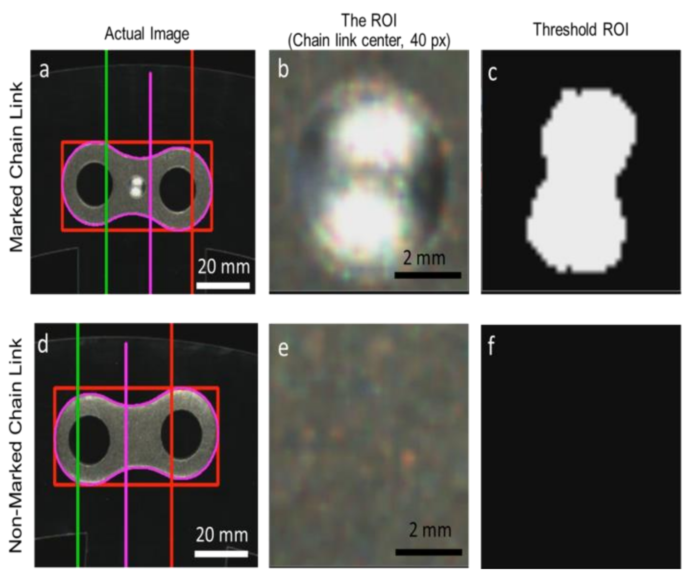


Fig. 4. Image processing procedure for detecting marked (a, b, c) and non-marked chain links (d, e, f).

The chain face detecting experiments was implemented on the conveyor line with various speed from low to high. The rate of a conveyor line depends on the perimeter (P) of the conveyor drum that can be calculated using diameter (D) (Equation 1). The round per second (RPS) for a conveyor is a turn in a second refers to the frequency (Equation 2) that can be controlled using a motor with a driving frequency. The speed of the conveyor (V) can be calculated concerning the RPS and the P values together (Equation 3). The multiplication of RPS with perimeter of the drum gives the speed of conveyor line which can be assumed as the speed of an object moving on the conveyor line.

$$P = \pi \times D(m) \quad (1)$$

$$RPS = \frac{Drivefreq}{Stepfreq} \quad (2)$$

$$V\ (m/s) = P \times RPS \quad (3)$$

3. RESULTS

In the experiments, thirty-four samples were examined. The accuracy of MVS was evaluated by increasing the speed of the roller conveyor line. To detect and classify objects using an industrial camera on a conveyor line concerning a high accuracy, the speed of the conveyor belt depending on the drive frequency must be adjusted under the operation. The relationship between drive frequency and conveyor line speed is given in Figure 5. According to the experiments, there is a linear correlation between these two parameters.

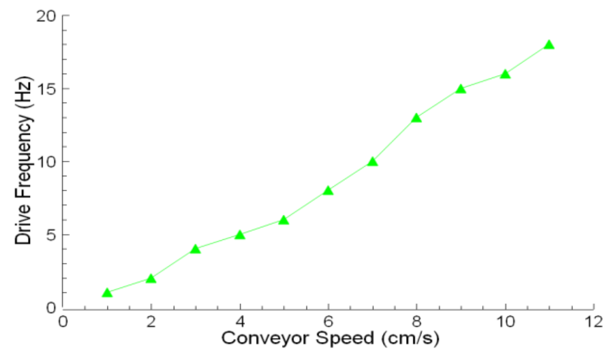


Fig. 5. The relationship between drive frequency and conveyor line speed.

In Figure 6, the accuracy of MVS concerning conveyor line speed is demonstrated. The accuracy is constant, and there is no error up to 0.15 m/s. Above this threshold, accuracy is distinctively decreasing due to the limited response time of MVS that depends on hardware features. For this reason, the MVS performance is suitable for selecting up to five chain links in real-time. It is important to note that this is a limitation of the hardware in general. Nevertheless, the sorted link count with the current setup and camera arrangement applies to industrial production line speeds, which can reduce the error in counting and increase the overall efficiency.

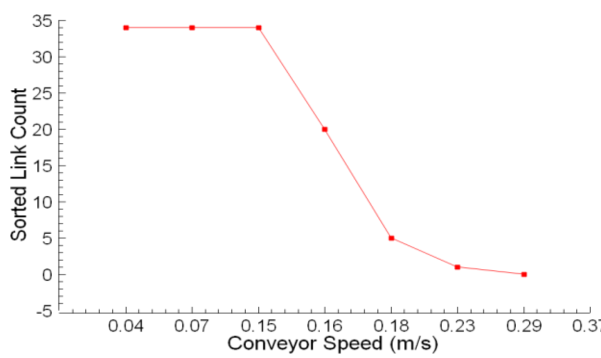


Fig. 6. The accuracy of MVS concerning conveyor line speed.

The experiments were repeated three times for given conveyor line speeds in Figure 6, and the falling edge for the accuracy of the real-time detection process is shown in Figure 7 (a, b) from high to low, respectively. The accuracy of the chain link face detection process was found 100% (Figure 7 (a)). The speed limit of the MVS due to the falling edge (from 0.15 to 0.16 m/s) caused by hardware limitation is shown in Figure 7 (b). Considering the experiments, the chain link face determining process can be achieved and automated with the help of the image processing technology and computerized systems. The experiments also refer that there is a speed limit due to the image capturing frequency of the camera which refers frame per second (FPS). Beside this limitation, the use of more advanced hardware solutions offers faster processes for selecting and sorting applications.

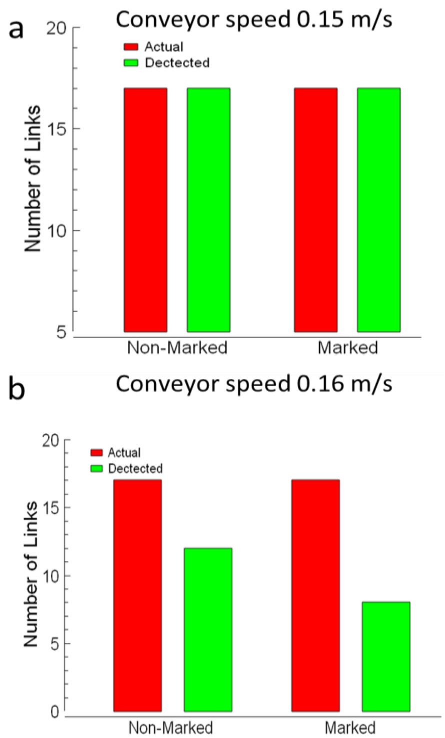


Fig. 7. The falling edges for the accuracy of the real-time detection process from high (a) to low (b) concerning conveyor line speed.

The experiments are conducted for single and multi-flow lines, and the same results are obtained. Due to the high processing speed of the central processing units (CPUs), the developed solution is proper for single multi-line flow applications with the same accuracy results. The experiments show that the limits for multi-flow applications depend on the mechanical limitations of the sorting mechanism. In the light of the experiments, these solutions can sort chain links concerning the link face for both single and multi-line flow applications with quietly high accuracy.

4. CONCLUSION

This study demonstrated an industrial machine vision approach for determining the true face of chain links before the chain assembling stage. It is contributed to the decrease in the number of defective chain links in the production line, increases production efficiency, decreases machine downtime. Additionally, the ability to monitor and product tracking process could be accomplished in the classification process. The proposed method continuously detects and determines chain link faces by evaluating the appropriate face of the chain links in a conditioned measurement area on a conveyor line in real-time. The method is quite accurate, and the study shows that it is possible to eliminate manufacturing faults by investigating parts with a machine vision system before assembling stages for chain links. It offers to sort more products in a shorter time than traditional methods by reducing product sorting time. Overall, a cost-effective and straightforward way is demonstrated to achieve industrial chain link detection application. With this achievement, more complex and functional systems can be adopted and applied in applications, including product characterisation and sorting. Considering the critical role of product sorting in manufacturing and mass production, the simple detection and analysis approach, which is demonstrated herein, is an invaluable capability for industrial applications.

Acknowledgement

This work was funded by the Scientific and Technological Research Council of Turkey (TUBİTAK), through grant number 120M134.

References

[1] M. H. Ali, S. Kurokawa, and K. Uesugi, "Application of machine vision in improving safety and reliability for gear profile measurement," *Mach. Vis. Appl.*, 25(6), pp. 1549–1559, 2014.

[2] N. Herakovic, M. Simic, F. Trdic, and J. Skvarc, "A machine-vision system for automated quality control of welded rings," *Mach. Vis. Appl.*, 22(6), pp. 967–981, 2011.

[3] B. Aksoy, O. Salman, İ. Sayin, and K. Özsoy, "11 Artificial intelligence applications for medical diagnosis and production with 3D printing technologies," in *Artificial Intelligence for Data-Driven Medical Diagnosis*, De Gruyter, 2021, pp. 225–244.

[4] P. Balkir, K. Kemahlıoğlu, and U. Yücel, "Machine vision system: Food industry applications and practices," *Turkish J. Agric. - Food Sci. Technol.*, 7(7), p. 989, 2019.

[5] E. Ukwatta, J. Samarabandu, and M. Hall, "Machine vision system for automated spectroscopy," *Mach. Vis. Appl.*, 23(1), pp. 111–121, 2012.

[6] P. K. Sinha, "Review of image parameters," in *Image Acquisition and Preprocessing for Machine Vision Systems*, 1000 20th Street, Bellingham, WA 98227-0010 USA: SPIE, pp. 601–638, 2012.

[7] K. Özsoy, B. Aksoy, and M. Yücel, "Design and manufacture of continuous automatic 3D printing device with conveyor system by image processing technology," *Erzincan University Journal of Science and Technology*, vol.13, p. 392-403, 2020.

[8]L. Pérez, Í. Rodríguez, N. Rodríguez, R. Usamentiaga, and D. García, "Robot Guidance Using Machine Vision Techniques in Industrial Environments: A Comparative Review," *Sensors*, 16(3), p. 335, 2016.

[9] F. Akkoyun *et al.*, "Measurement of micro burr and slot widths through image processing: comparison of manual and automated measurements in micro-milling," *Sensors*, 21(13), p. 4432, 2021.

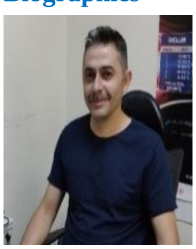
[10] F. Akkoyun and A. Ozcelik, "Rapid characterization of cell and bacteria counts using computer vision," *Turkish Journal of Nature and Science*, 10(1), pp.269-274, 2021.

[11] T. D. Bhoite, P. M. Pawar, and B. D. Gaikwad, "Fea based study of effect of radial variation of outer link in A typical roller chain link assembly," *Int. J. Mech. Ind. Eng.*, no. 2231, pp. 69–74, 2012.

[12] A. Güney, M. Temizkan, S. Tekin, D. C. Samuk, and O. Çakır, "Temperature control of an electric furnace with intuitive

control methods," *Turk. J. of Electromec. & Energy*, 5(1), pp. 3-8, 2020.
[13] M. N. Örnek and H. Hacıseferoğulları, " Design of real time image processing machine for carrot classification," Yüzüncü Yıl University Journal of Agricultural Sciences, 30(2), pp. 355–366, 2020.
[14] D. Martin, D. M. Guinea, M. C. García-Alegre, E. Villanueva, and D. Guinea, "Multi-modal defect detection of residual oxide scale on a cold stainless steel strip," *Mach. Vis. Appl.*, 21(5), pp. 653–666, 2010.
[15] A. R. Jiménez, R. Ceres, and J. L. Pons, "A vision system based on a laser range-finder applied to robotic fruit harvesting," *Mach. Vis. Appl.*, 11(6), pp. 321–329, 2000.
[16] Z. Ren, J. Liao, and L. Cai, "An algorithm to estimate the crown patterns of diamonds based on machine vision," *Mach. Vis. Appl.*, 23(2), pp. 197–215, 2012.
[17] M. F. Carlsohn, "Spectral image processing in real-time," *J. Real-Time Image Process.*, 1(1), pp. 25–32, 2006.
[18] A. Ozcelik, "Atomic Layer Deposition (ALD) of Vanadium Oxide thin films," *Turkish J. Electromechanics Energy*, 4(2), pp. 13–18, 2019.
[19] F. Murtagh *et al.*, "A machine vision approach to the grading of crushed aggregate," *Mach. Vis. Appl.*, 16(4), pp. 229–235, 2005.
[20] B. Büyükarıkan and E. Ülker, "Aydınlatma Özniteliği Kullanılarak Evrişimsel Sinir Ağı Modelleri ile Meyve Sınıflandırma," *Uludağ Univ. J. Fac. Eng.*, 25(1), pp. 81–100, 2020.
[21] O. Ağın and A. Taner, "Determination of weed intensity in wheat production using image processing techniques," *ANADOLU J. Agric. Sci.*, 30(2), p. 110, 2015.
[22] G. Cagıl and B. Yıldırım, "Detection of an assembly part with deep learning and image processing," *J. Intell. Syst. Theory Appl.*, 3(2), pp. 31–37, 2020.

Biographies



Fatih Akkoyun received the M.Sc. degree in electronic and computer education program from the Kocaeli University, Turkey, in 2011 and a PhD degree in mechanical engineering from the Adnan Menderes University, Turkey, in 2020. He currently works as a research assistant at the Faculty of Engineering, Mechanical Engineering Department, Adnan Menderes University. His current research interests include spectral imaging, machine and computer vision applications.
E-mail: fatih.akkoyun@adu.edu.tr

Merzun Niray Baş graduated from Aydın Adnan Menderes University Mechanical Engineering Department in 2021. In 2018, she was among the founding members of the Robotics and Automation (RAS) university community affiliated with IEEE. During her undergraduate education, she worked as a trainee researcher in the TÜBİTAK 1002 Trainee Researcher Program titled "Low-cost Design and Production of Broad-Band, Motorized Selectable Filter, Multispectral Imaging Device and Experimental Setup".
E-mail: m.niray.bas@gmail.com

Seher Şimşek received her the B.Sc. Degree from the Department of Mechanical Engineering, Aydın Adnan Menderes University, Aydın, Turkey, in 2021. She was among the founding members of the Robotics and Automation (RAS) community affiliated with IEEE in 2018. During her undergraduate education, she took part in the TUBITAK 2247-C Trainee Researcher Program (STAR) Project titled "Low-cost Design and Production of Broad-Band, Motorized Selectable Filter, Multispectral Imaging Device and Experimental Setup" project.
E-mail: sehersimsek2229@gmail.com

Duran Emre Uysal was born in Muğla, Turkey. He graduated from Aydın Adnan Menderes University Mechanical Engineering and Civil Engineering Department with a double major program in 2021. During his undergraduate education, he took part as a Trainee Researcher in the TUBITAK 2247-C Trainee Researcher Program project titled "Development of an acoustofluidic micromixer and micropump for on-chip laboratory applications".
E-mail: uysal.duranemre@gmail.com

Sinan Güçlüer received the M.Sc. degree in mechanical engineering from Mustafa Kemal University, Turkey, in 2007 and a PhD degree in mechanical engineering from Gazi University, Turkey, in 2017. He currently works as an assistant professor at the Faculty of Engineering, Mechanical Engineering Department, Aydin Adnan Menderes University. His current research interests include energy, heat transfer, fluid mechanics, CFD, microfluidics, nanofluidics.
E-mail: sgucluer@adu.edu.tr

Adem Özçelik received his B.Sc. degree in physics department at Karadeniz Technical University, Turkey, in 2007. Then he received his M.S. degree in Materials Science and Engineering in 2011 and a PhD degree in Engineering Science and Mechanics in 2016 from Penn State University, USA. He worked as a Postdoctoral Associate in Mechanical Engineering and Materials Science Department at Duke University, USA (2016-2017). Currently, he is an Asst. Prof. of Mechanical engineering at Aydın Adnan Menderes University. His research interest includes biomedical applications of micro/nanoelectromechanical systems (BioNEMS/BioMEMS), microfluidics, micro-total-analysis systems, acoustofluidics, and materials science.
E-mail: aozcelik@adu.edu.tr