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Yalçın İŞLER Yakup KUTLU

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Preface

3rd International Conference on Artificial Inteligence towards Industry 4.0, ICAII4' 2020, is organized by Izmir Ktip Celebi University and Iskenderun Technical University with international participation on November 12-14, 2020 in Izmir / Turkey. All presentations were online because of the pandemic.

ICAII conference series bring together the students, users, manufacturers, researchers, and public representatives from the sector. This conference holds all the theorical subjects and applications related to both artificial intelligence and industry 4.0 including but not limited to the list given below:

- Advanced Diagnostics, Prognostics and Asset Health Management
- Advanced Techniques and Technologies for Energy Saving
- AI-optimized Hardware
- Big Data
- Biometrics
- Cloud Computing
- Cybersecurity
- Embedded Systems
- Evolutionary Computations
- Fractional Differential Approach on Machine Learning
- Graph-based Data Analysis
- Grid Computing
- Internet of Things
- Knowledge Representation and Reasoning
- Machine Learning
- Machine-To-Machine Communication Standards for Smart Manufacturing
- Manufacturing Intelligence and Manufacturing Informatics

- Mathematical Modelling in Artificial Intelligence
- Mathematical Modelling and Optimization in Engineering Applications
- Multi-task Learning
- Radio Communications Technologies
- Remote Access and Control
- Remote Maintenance
- Robotic Process Automation
- Sequential Data Processing
- Signal and Image Processing
- Smart Applications
- Smart Grid
- Smart Manufacturing
- Smart Security and Data Applications
- Smart Systems
- Speech Recognition
- Survey Papers, Reports, Case Studies Work in Progress, and Applications
- Trends and Challenges
- Virtual Machines
- Wearable Technologies
- Wireless Sensor Network
- Other Topics

All submitted papers were reviewed by at least 2 referees from the Scientific Committee members who are experts in the related field. All accepted papers were appeared in the Conference Abstract Book with ISBN and full-length versions of these papers were published in supporting journals. Main conference language is English.

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- Zerrin ALADAĞ - Kocaeli University

Part I

Invited Talks

Replica Exchange using an Augmented Molecular Dynamics Method

ICAII4'2020

Nov 12-14, 2020

Izmir

Invited Talk

Oral presentation

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Hiqmet Kamberaj is Full Professor at International Balkan University. He was an Acting Dean ofthe Faculty of Engineering from January 2017 to September 2019. Hiqmet completed his Ph.D. (in Computational Physics) in 2005 from Manchester Metropolitan University and Post-Doctoral studies from the University of Minnesota, Arizona State University, and National Institute of Nanotechnology at University of Edmonton. He received his Bachelor of Science (in Physics) in 1996 from the University of Tirana and his Master of Science (in Physics) from the University of Siegen in 2000. Hiqmet has published more than 20 articles and book chapters in reputed journals and has been serving as editor-in-chief, editorial board member, and ad-hoc reviewer of repute. Very recently, Hiqmet Kamberaj has published a book at Springer publisher in Scientific Computation Series. His articles focus on understanding the structure, dynamics, and thermodynamics of macromolecular systems using the laws of physics and biochemistry, and applied mathematics. Please email `hkamberaj@ibu.edu.mk` *to contact Hiqmet or by visiting his professional profiles to learn more about how Hiqmet's research articles could contribute your research and teaching activities.*

Abstract: Molecular dynamics (MD) simulations are often used to provide detailed insights into the dynamics of macromolecular systems, such as proteins, DNA/RNA, membranes, and their complexes. These dynamics involve transitions between various conformational states due to atomic motions. The main problem of standard MD simulation is the time and size scale limitations of the technique in studying slow conformational motions of macromolecular systems. Therefore, the considerable time and size scale physicaland chemical phenomena will indeed require new statistical and computational approaches to be studied efficiently. In this talk, I will discuss different approaches suggested for enhancing the conformational search and sampling efficiency of MD simulations. In particular, I will focus on using the so-called augmented replica exchange approaches to improve conformational sampling in computer simulations of peptide/protein folding and transition path sampling.

Keywords: molecular dynamics; macromolecular systems; simulation; protein folding.

Selected Studies on Control Theory and Artificial Intelligence

ICAII4'2020

Nov 12-14, 2020

Izmir

Invited Talk

Oral presentation

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Cüneyt Güzeliş, is Professor of Electrical Engineering and Director of the Graduate School of Natural and Applied Sciences at Yaşar University in İzmir, Turkey. His expertise is in nonlinear circuits and systems, machine learning, and systems biology. He has published 50 SCI-indexed journal papers with more than 900 SCI citations, 6 peer-reviewed book chapters, and more than 80 peer-reviewed conference papers. He has supervised 17 M.S. students and 14 Ph.D. students. He has served as Professor at Istanbul Technical University, as Dean of the Faculty of Engineering at Dokuz Eylül University, and as Director of the Graduate School of Natural and Applied Sciences at İzmir University of Economics. He has held visiting research and/or teaching positions at the University of California Berkeley, Aachen Applied Sciences, Paris-Est and Paris-Nord Universities. He has participated in over 20 scientific research projects funded by the national and international institutions, such as the British Council, the French National Council for Scientific Research and the Turkish Scientific and Technological Research Council.

Abstract: The talk is on importance of control concept in systems biology and some current/emerging machine learning applications in intelligent control field. Control mechanisms are vital means for living things. From the single cell bacteria E. Coli, which has a hysteretic bi-stable switch for on/off control of sugar metabolism, to p53 gene network of human being, which is responsible to control the cell's repair and the cell's cycle arrest under Double Strand Break damages by means of an underlying relaxation oscillator. Analysis of these biological control mechanisms are helpful to understand biological systems in a deeper way. Such analyses give also the possibility of developing new control tools within the synthetic biology framework such as biological toggle switch and within the research of drug and therapy development for cancer. Control as an engineering branch makes, in a general sense, the life safe, easy, comfortable and regulated together with the satisfaction of performance requirements for almost all fields of daily life, including health domain. The well- established methods of control theory, which are mainly based on frequency-domain and time-domain state-space approaches, constitutes a very solid mathematical background for the analysis and design of control systems. Exploiting artificial intelligence in control field has been always an active research. The shift from the rule-based approach towards data-based, more precisely learning by data, approach has changed not only the artificial intelligence but also the intelligent control field, drastically. Machine learning models, in particular, artificial neural networks are used as controller as well as plant models. The talk presents several works on the application of machine learning in control done by the research teams, in which the speaker takes a part of them as one of the researchers. In these works, both of the system identification and controller design problems are formulated as supervised learning problems. In this framework, online/offline learning algorithms are used for

minimizing some regularized epsilon-insensitive error functions under Schur stability constraints to provide closed-loop stability, adaptiveness, and robustness against noise and disturbances. The talk concludes with some remarks related to emerging topics in intelligent control, more precisely the usage of deep learning methods in robotics and control.
Keywords: artificial intelligence; control applications; gene regulatory networks; modeling.

Eye-Tracking: What You See is What Science Gets

ICAII4'2020

Nov 12-14, 2020

Izmir

Invited Talk

Oral presentation

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Dr.Yüce was born in Çanakkale. His father was a fisherman, his mother was fisherman's friend. He was planning to become a lawyer when he was six since his only hero, at that time, was his father. As he grew up, he realized true pioneers of a society are engineers and decided to become one. He graduated Eastern Mediterranean University (EMU) and had his BSc. in computer engineering in 2000. He worked as a research assistant in EMU, Department of Computer Engineering between 2000-2003 during which he also completed his first MSc. under advisory of Prof.Dr. Alexander Kostin in Distributed Systems in Computer Engineering. He achieved his second MSc. degree in Medical Informatics in Akdeniz University in 2006. His passion on studying in Medicine dates back to 90s when his mother passed away due to a chronic disease. Henceforth, he continued to study Medical Informatics and gained his PhD in Medical Informatics in 2014 under Assoc.Prof.Dr. Kemal Hakan Gülkesen. Since then, he tries to do research on electronic Health (e-Health), mobile Health (m-Health), and their usability while he tries to develop systems in these areas. Currently, he works in Alanya Alaaddin Keykubat University (ALKU) as an Asst. Prof. (yes, there is such a title) in Department of Computer Engineering.

Abstract: Eye tracking can be considered as an old field. It dates back to 1870s. Basically, it aims to detect and measure activities of eye; e.g. detect where a subject is looking, thereby, it actually deals with monitoring what people do with their eyes in any setting or context, under different circumstances since our eyes can provide valuable information regarding how we perceive our surroundings (e.g. they can tell what we genuinely are interested). Hence, eye tracking can tell what one's brain chooses to look at, however, it cannot tell why. Despite it limits, eye tracking is a great tool that is applied in many fields. It helps discovering the patterns in using our eyes in many different settings. In Human-Computer Interaction, currently, it is used to develop interfaces that allows people to use computers by only moving their eyes. In Medicine, it enables alternative diagnostic approaches, e.g. in psychiatry, in addition to opening new gates to train physicians in fields such as Radiology. However, in the near future, we may start to use eye tracking in daily life for decision-support. It may come together with artificial intelligence approaches to better or ease our daily lives. Furthermore, It is possible for eye tracking to pave the way for intelligent machines using our vision and eye behaviors as input to perform jobs. Eye tracking, in essence, is a core technology that will open many gates to future.

Keywords: eye tracking; eye movement; smart glasses.

Part II

Regular Talks (Abstract Papers)

The Evaluation of European Airports using Clustering Methods

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Nov 12-14, 2020

Izmir

Talk

Oral presentation

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Abstract: This paper aims to provide perception into the roles of the distinctive feature of Airports using the K-means clustering algorithm. In this study, dataset based on the European airports including Turkey's airports is used. It contains pieces of information from 23 different features to 560 rows of 40 countries. In the clustering application to the whole data set, results are produced and illustrated in detail using the Euclidean and Cosine distance based methods. The investigation also focuses on a critical aspect of the process, which chooses the optimal number of clusters. To determine the optimum number of clusters, 30 different metrics provided by NbClust function found in R library, and Sweep Clustering Module and Elbow graphics method, as well as Python and R programming languages on Azure ML Studio and Kaggle platforms, are employed. The algorithm is simulated by the Azure ML Studio Platform and the clustered results show that similar airports have an obvious hierarchy.
Keywords: clustering; k-means; sweep clustering; NbClust; European airports.

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Talk

Oral presentation

Mini Review on Dental Imaging Devices and Use of Artificial Intelligence in Dentistry

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Abstract: In 1895, Wilhelm Conrad Roentgen accidentally discovered a different type of rays which can penetrate the human body and inform about the structures inside it. These rays named as X-Rays and are one type of ionizing radiation. They can be used in medicine to monitor the internal structures without invasion. For this procedure first X-Rays are sent to the body, then the rays pass through the body, some of their energy is absorbed by the tissues and the remaining attenuated rays captured with a film to form an image. Discovery of X-Rays is the beginning point of the medical imaging which developed and diversified in years. Since early days of X-Ray discovery they are used in also for imaging of teeth, in 1896, Dr. Otto Walkhoff imaged his mouth with X-Ray exposure. X-Rays helped the dentists to diagnose tooth decays and bone loss, examine dental structures and identify abnormalities of these structures. Today developments in technology resulted in different imaging techniques, X-Rays are used for Projectional Radiography and Computed Tomography, besides there are Nuclear Imaging, Magnetic Resonance Imaging and Ultrasound Imaging that widely used. In this review, imaging techniques for dental applications with the extension of artificial intelligence is examined to provide a brief information.

Keywords: dental imaging; medical imaging techniques; artificial intelligence.

Machine Learning Based Electric Energy Consumption Prediction of a Large-Scaled Production Plant with Small-Scaled Data

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Nov 12-14, 2020

Izmir

Talk

Oral presentation

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Abstract: Competition in the market is increasing day by day for manufacturing companies, and it is of great importance to reduce production costs in order to get ahead in this race. The important factors in production costs come from energy, material, labor, and logistics. In order to be more competitive in the market, manufacturing companies make long efforts to accurately budget the energy, material, labor, and logistics figures they need throughout the year to reach the financial targets that the company defines. The greatest importance of budgeting studies carried out is to interpret the complex data collected in a short time and to create an explainable scenario for the targeted numbers. At this point, the right solution is hidden behind data science. Data science is a multidisciplinary term for a whole set of tools and techniques of data inference, mathematical modeling and algorithm development to overcome complex analytical problems. The strength of the data-driven approach is to identify hidden patterns in energy, material, labor, and logistics historical data to help a business to enhance and expand their profits
Automotive and tire industries include many different production processes and areas. For these industries, it is important to accurately estimate the energy to be consumed in the budget period, and then take measures by determining the parameters that deviate from the budget target in the realization period. In order to achieve this improvement, it is necessary to carry out and follow this system with a limited number of parameters that can be targeted in the budget period.
This report covers the statistical approach to predict consumed energy for a tire production plant. The reasons behind this study are also to optimize the energy consumption budget and to follow the production area wised KPIs which is also vital for ISO 50001 Energy management system standard. In order to make it happen, writers clarify the main problem, then start to gather historical data pool and apply the steps of the machine learning for prepared data. The most important point of this study was that although the historical data is small-scaled (past 6 years, monthly), the parameters have a higher dimension according to input examples. Hence, the data to be used as input could be explained with simple variables to be used in the budget period. The study introduces data preparation steps based on the production area, grid search for best regression algorithm, comparison of models, and one-year KPI following results.

Keywords: machine learning; regression; small scaled data analytics; energy saving; energy consumption prediction; ISO 50001; analytics.

Augmented Reality (AR) Assisted Smart Glasses Case Study for Remote Support Between Two Distant Production Plants

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Talk

Oral presentation

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Abstract: Rapid developments in technology enable us to reach smart glasses and AR technology with a wide range of products and competitive prices. Hence, increase in smart glasses industrial use give an opportunity to whom work distant such as making it possible to see from each other's eyes, which increases the operational efficiency of the companies; since it is costly to make experienced staff traveled to another plant in aspects of travel cost, accommodation cost and the lack of the experienced person in his/her the main responsibility area in factories with different experiences in remote locations. This study is conducted about the application of smart glasses on one of the biggest tire manufacturing company since 2018.
End to end journey of the smart glasses' remote support applications, starting with how the devices are selected and ending with an evaluation of advantages / disadvantages of the smart glasses' technology, is explained in this paper. Moreover, the study covers details and observations of staff training, new product development, and inspections, first-run test on machinery, maintenance, and audits.
Keywords: smart glasses; augmented reality; remote support; IoT; on the job training; maintenance; new product development; inspection; audit; tire; tire industry.

Classifying Stable and Unstable Videos with Deep Convolutional Networks

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Talk

Oral presentation

Abstract: Since the invention of cameras, video shooting has become a passion for human. However, the quality of videos recorded with devices such as handheld cameras, head cameras, and vehicle cameras may be low due to shaking, jittering and unwanted periodic movements. Although the issue of video stabilization has been studied for decades, there is no consensus on how to measure the performance of a video stabilization method. In many studies in the literature, different metrics have been used for comparison of different methods. In this study, deep convolutional neural networks are used as a decision maker for video stabilization. VGG networks with different number of layers are used to determine the stability status of the videos. It was observed that VGG networks showed a classification performance up to 96.54% using only two consecutive scenes. These results show that deep learning networks can be utilized as a metric for video stabilization.
Keywords: video stabilization; deep learning; convolutional neural networks.

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Talk

Oral presentation

Effects of Industry 4.0 on Maritime Sector: A Review of Literature

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Abstract: The concept called as Industry 4.0 has become a part of our lives in recent years and this concept is structure that includes many modern automation systems, data exchange and production technologies. Industry 4.0 aims to integrate all operational processes in an efficient and cost-effective way by connecting them with integrated operation systems. Industry 4.0 technology that has affected almost all sectors in the world has affected maritime sector as well which plays an active role in transporting most of the world's cargo. Accordingly, the aim of this study is to evaluate the effects of Industry 4.0 on the maritime sector in terms of components such as internet of things, big data analytics, block-chain, autonomous robots and additive manufacturing by conducting a systematic literature review. In this paper, the studies exist in google scholar academic database examine the effects of the Industry 4.0 on the maritime sector were, collected and frequency analysis was made according to the related component. In the light of such information, gaps in the effects of these components had been identified in the literature and recommendations for further studies had been given.

Keywords: maritime; marine; industry 4.0; frequency analysis.

User Localization in an Indoor Environment by Combining Different Algorithms through Plurality Rule

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Talk

Oral presentation

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Abstract: User localization in an indoor environment has a wide application area including production and service systems such as factories, smart homes, hospitals, nursing homes etc. User localization based on Wi-Fi signals has been widely studied using various classification algorithms. In this type of problem, several Wi-Fi routers placed in an indoor environment provide signals with different strengths depending on the location/room of the user. Most classification algorithms successfully make the localization with a high accuracy rate. However, in the current literature there is no widely accepted "best" algorithm for solving this problem. This study proposes the use of plurality rule to combine several classification algorithms and obtain a single result. Plurality voting rule is an electoral system where the candidate that polls the most vote wins the election. We apply plurality rule to indoor localization problem and generate the Majority algorithm. The Majority algorithm takes the "votes" of five different classification algorithms and provides a single result through plurality rule. Results show that the mean accuracy rate of Majority algorithm is higher than the classification algorithms it combines. In addition, we show that proving a single accuracy rate is not sufficient for declaring that an algorithm is better than the other. Classification algorithms select the training and test data randomly and different divisions result in different accuracy rates. In this study we show that comparing the classification algorithms through confidence intervals provides a more accurate information.

Keywords: indoor localization; classification algorithms; plurality rule.

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Talk

Oral presentation

RGB-D Object Recognition with Hierarchical Capsule Networks

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Abstract: Many computer vision and robotics applications require object recognition from RGB-D images that provide additional depth information. Although Convolutional Neural Networks (CNNs) perform very well in recognizing objects from RGB-D images, they have some limitations. The pooling layer of CNNs causes information loss during the feature extraction phase. In addition, CNNs are very sensitive to changes in environmental factors such as rotation and light intensity. Capsule networks have been proposed by Hinton to overcome these limitations. A capsule is a set of neurons with activity vector that contains the information about an object. The length of the activity vector of a capsule represents the probability of the object's existence while the direction of the vector represents the instantiation parameters such as pose, velocity, and albedo, etc.

In this study, a two-layered hierarchical structure using capsule networks as classifiers is designed for the recognition of objects from RGB-D images. The performance of the hierarchical capsule networks is evaluated on the Washington RGB-D dataset that includes masked RGB and grayscale depth images of 51 different object classes and 300 distinct instances. First, the capsule network is trained with colored depth images of all classes. According to the classification results of the test set, classes with classification accuracy less than 90% are grouped together. This group is classified with the second capsule network that is trained with RGB images. One of the compelling aspects of the study is that the dataset has high intraclass and interclass variations, which negatively affects the generalization ability of the network for object recognition. The performance of the proposed structure is compared with the performance of the capsule networks that are trained with RGB and depth images.

Keywords: capsule network; hierarchical classification; rgb-d image; object recognition.

Predictive Maintenance Studies Applied to an Industrial Press Machine Using Machine Learning

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Izmir

Talk

Oral presentation

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Abstract: The main purpose of Industry 4.0 applications is to provide maximum uptime, reduce production costs and increase productivity throughout the production chain. Predictive Maintenance studies have gained speed thanks to Big Data, Internet of Things and Machine Learning (ML), which are among Industry 4.0 technologies. Applying Predictive Maintenance in the industry reduces the number of breakdowns with long maintenance and repair times and minimizes production losses and costs. With the use of machine learning, equipment malfunctions and maintenance needs can be predicted for unknown reasons. A large amount of data is needed to train the machine learning algorithm, as well as adequate analytical method selection suitable for the problem. The important thing is to obtain the valuable signal by cleaning the data from noise with data processing. In order to create prediction models with machine learning, it is necessary to collect accurate information and to use many data from different systems. The existence of a large amount of data about predictive maintenance and the need to monitor this data in real time, delays in data collection, network and server problems are major difficulties in this process. Another important issue concerns the use of artificial intelligence. For example, obtaining training data, dealing with variable environmental conditions, choosing the ML algorithm better suited to a specific scenario, necessity of information sensitive to operational conditions and production environment are of great importance for analysis. In this study, predictive maintenance works for the transfer press machine used in the automotive industry, which can predict the maintenance time and give warning messages to the relevant people when abnormal situations approach, will be mentioned. Various sensors have been placed in the machine to detect past malfunctions and the data to be collected from these sensors are determined. Machine learning algorithms were created to detect anomalies and model past failures with the collected data. The application was made in a factory producing automotive parts.

Keywords: predictive maintenance; machine learning; anomaly detection; industry 4.0; automotive industry.

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Talk

Oral presentation

Investigation of Elastic Tensile Behavior of Thermoplastic Discs Reinforced with Steel Wires

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Abstract: In this study, the stresses occurring in a thermoplastic composite disk were examined by numerical analysis. Assuming that the modulus of elasticity does not change with temperature, temperature distributions of 20 ^{o}C, 40 ^{o}C, 60 ^{o}C, 80 ^{o}C, and 100 ^{o}C were referenced in the study. Composite materials are formed by combining the best properties of two or more materials together or by creating a new property. Thermoplastic composites, on the other hand, are bendable and ductile. It is vital to know the thermal behavior of these materials, which are preferred in many parts of the technology.At the end of the study, it was observed that radial and tangential stress values at high temperature were greater than at low temperatures, tangential stresses were greater than radial stresses. It has been concluded that the increase in the value of the uniform temperature acting on the thermoplastic disk affects the distribution and values of both thermal stresses and residual stresses.

Keywords: composites; thermoplastic composite disc; thermal stress; parabolic temperature distribution.

Modeling of ECG and SCG Signals Using Predefined Signature and Envelope Sets

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Talk

Oral presentation

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Abstract: SCG (seismocardiogram) is a low-cost monitoring method to collect precordial vibrations of sternum due to heartbeats and evaluate cardiac activity. It is mostly used as an auxiliary measurement to the other monitoring methods; however, it carries significant patterns reflecting current cardiovascular health status of subjects. Thus, if it is properly collected within a non-clinical environment, it might be able to present preliminary data to physicians before clinic. In SCG, the amount of data obtained from clinic stage monitoring is excessive to archive as in other monitoring techniques. Besides, the huge problem is the noisy morphology of SCG signals due to acquiring the data. Consequently, by removing redundant data and compressing these signals effectively without losing significant information corresponding to heartbeat complexes is important. Previously, the method called compressed sensing (CS) had been applied to weed up the redundant information by taking the advantage of sparsity feature in a study. This compressed sensing is based on storing significant signals below the Nyquist rate. Thus, it had been feasible to compress SCG signals with 3:1 compression rate at least while maintaining accurate signal reconstruction. Nevertheless, higher compression rates lead to form artifacts on reconstructed signals. This limits a more aggressive compression to reduce the amount of data. The requirement of a different approach which will allow higher compression rate and lower loss of information arises. The purpose of this study is to obtain more competent results by using a relatively novel method called predefined signature and envelope vector sets (PSEVS) which had been satisfyingly applied by Gürkan, Güz and Yarman (2007) to ECG and speech signals. In the study, simultaneously recorded ECG and SCG signals were modeled with the method called PSEVS. And then, reconstructed signals were compared to original signals so as to investigate the efficacy of signature-based modeling methods in constructing medically remarkable biosignals for clinical use. After examining the components of reconstructed signals named frame-scaling coefficient, signature and envelope vectors, it had been seen that the error function values of envelope vectors differ from expected values. And we concluded that reconstructed SCG signals were not adequate for medical diagnosis.

Keywords: electrocardiogram; seismocardiogram; pre-defined signature and envelope sets.

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Nov 12-14, 2020

Izmir

Talk

Oral presentation

Effect of Different Batch Size Parameters on Predicting of COVID19 Cases

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Abstract: The new coronavirus 2019, also known as COVID19, is a very serious epidemic that has killed thousands or even millions of people since December 2019. It was defined as a pandemic by the world health organization in March 2020. It is stated that this virus is usually transmitted by droplets caused by sneezing or coughing, or by touching infected surfaces. The presence of the virus is detected by real-time reverse transcriptase polymerase chain reaction (rRT-PCR) tests with the help of a swab taken from the nose or throat. In addition, X-ray and CT imaging methods are also used to support this method. Since it is known that the accuracy sensitivity in rRT-PCR test is low, auxiliary diagnostic methods have a very important place. Computer-aided diagnosis and detection systems are developed especially with the help of X-ray and CT images. Studies on the detection of COVID19 in the literature are increasing day by day. In this study, the effect of different batch size (BH=3, 10, 20, 30, 40, and 50) parameter values on their performance in detecting COVID19 and other classes was investigated using data belonging to 4 different (Viral Pneumonia, COVID-19, Normal, Bacterial Pneumonia) classes. The study was carried out using a pre-trained ResNet50 convolutional neural network. According to the obtained results, they performed closely on the training and test data. However, it was observed that the steady state in the test data was delayed as the batch size value increased. The highest COVID19 detection was 95.17% for BH = 3, while the overall accuracy value was 97.97% with BH = 20. According to the findings, it can be said that the batch size value does not affect the overall performance significantly, but the increase in the batch size value delays obtaining stable results.

Keywords: COVID19; ResNet50; batch size; pre-trained CNN model.

Performance Comparison of Balanced and Unbalanced Cancer Data Sets using Pre-Trained Convolutional Neural Network

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Talk

Oral presentation

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Abstract: Cancer disease is one of the leading causes of death all over the world. Breast cancer, which is a common cancer disease especially in women, is quite common. The most important tool used for early detection of this cancer type, which requires a long process to establish a definitive diagnosis, is histopathological images taken by biopsy. These obtained images are examined by pathologists and a definitive diagnosis is made. It is quite common to detect this process with the help of a computer. Detection of benign or malignant tumors, especially by using data with different magnification rates, takes place in the literature. In this study, two different balanced and unbalanced study groups have been formed by using the histopathological data in the BreakHis data set. We have examined how the performances of balanced and unbalanced data sets change in detecting tumor type. In conclusion, in the study performed using the InceptionV3 convolution neural network model, 93.55% accuracy, 99.19% recall and 87.10% specificity values have been obtained for balanced data, while 89.75% accuracy, 82.89% recall and 91.51% specificity values have been obtained for unbalanced data. According to the results obtained in two different studies, the balance of the data increases the overall performance as well as the detection performance of both benign and malignant tumors. It can be said that the model trained with the help of data sets created in a balanced way will give pathology specialists higher and accurate results.

Keywords: breast cancer; histopathological images; pre-trained CNN model; Inception V3.

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Talk

Oral presentation

Patient Survival Prediction with Machine Learning Algorithms

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Abstract: In this study, the intensive care unit patient survival is predicted by different machine learning algorithms according to the examinations performed in the first 24 hours. The data of intensive care patients were collected from approximately two hundred hospitals over a period of one year. Algorithms are run in Python environment. Machine learning models were compared with the Cross-Validation method, and the random forest algorithm is used. The model made the prediction with 92.53% accuracy rate.

Keywords: machine learning; intensive care unit; patient survival prediction.

Classification of Phonocardiography Signals Using Imbalanced Machine Learning Algorithms

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Izmir

Talk

Oral presentation

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Abstract: Cardiovascular diseases, which involve heart and blood vessel dysfunctions, cause a higher number of deaths than any other disease in the world. Throughout history, many approaches have been developed to analyze cardiovascular health by diagnosing such conditions. One of the methodologies is recording and analyzing heart sounds to distinguish normal and abnormal functioning of the heart, which is called Phonocardiography. With the emergence of machine learning applications in healthcare, this process can be automated via the extraction of various features from phonocardiography signals and performing classification with several machine learning algorithms. Many studies have been conducted to extract time and frequency domain features from the phonocardiography signals by segmenting them first into individual heart cycles, and then by classifying them using different machine learning and deep learning approaches. In this study, various time and frequency domain features have been extracted using the complete signal rather than just segments of it. Random Forest algorithm was found to be the most successful algorithm in terms of accuracy as well as recall and precision.

Keywords: phonocardiography; ECG; machine learning; imbalanced learning.

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Talk

Oral presentation

Virtual Reality Applications in Nursing

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Abstract: The progress in technological and scientific fields in the 20th century has transformed and shaped the lives of people remarkably. In healthcare, technology can be described as the application of the methods, systems, medicines, devices, vaccines and organized information to improve the quality of life by providing solutions for the needs of both professionals and patients. Besides its potential of reducing fragmentation and costs while increasing the safety, utilization of technology can be considered as the key to achieving a safe, sustainable, and person-centered healthcare environment. Virtual Reality (VR) is a computer-generated three-dimensional interactive environment that stimulates multiple sensory methods. Considering the fact that VR is one of the crucial technological trends of this century, it has the potential of affecting the health industry until 2025 extremely. It is a real-time graphic simulation that includes visual, auditory, and tactile experiences. In the field of health, VR is used for multiple purposes as training of medical students for critical surgeries, education of nursing candidates, and treatment of some diseases. As essential members of the healthcare team, nurses should be a strict follower of the rapidly evolving technology to provide efficient and quality care. The utilization of VR in nursing education has the advantage of decreasing faulty interventions, which enhances patient safety as well as the quality of the healthcare services in the future.

Keywords: virtual reality; nursing; nursing education; health.

Electromagnetic Weaponed Based Anti Terrorism Robot

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Izmir

Talk

Oral presentation

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Abstract: This study proposes the integration of electromagnetic weapons on a land robot, design and construction of an electromagnetic armed robot, autonomous targeting of possible targets with the electromagnetic weapon, and the features a electromagnetic armed safety robot should have. Unlike traditional user-targeted field security land robot approaches, the robot mentioned in this study detects potential threats in the task area with image processing and artificial intelligence techniques, so the user can accurately identify and autonomously target targets without the need for controlled targeting. Unlike today's armed land robots, an electromagnetic armed robot, which will be a new literature study, has been developed to create a reference path. An electromagnetic weapon that can be carried by a robot is produced and integrated into the land robot and a new armed robot approach with electromagnetic weapon is introduced. Various methods are proposed considering the range restriction of electromagnetic weapons and possible targeting errors of the robot user. A control algorithm has been developed to have the most appropriate targeting under the dynamic constraints of the robot and user for target tracking. Prototyping and experiments show the ability of an autonomous security robot with an autonomous targeting system to troubleshoot user problems and targeting problems. In addition, various methods and recommendations are provided for the features that a electromagnetic armed security robot working in the field should have.

Keywords: unmanned vehicle; electromagnetic weapon; autonomous targeting; military robot; defence systems.

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Talk

Oral presentation

Electromagnetic Weaponed Air Robot

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Abstract: This article is about the integration of mini electromagnetic weapons into an air robot, autonomous targeting of possible targets with electromagnetic weapon and suggest the features that an electromagnetic armed air robot should have. Autonomous aiming with an electromagnetic weapon integrated into the air robot to create a reference path mechanism has been developed. Range limitation of electromagnetic weapons and various methods and algorithms considering targeting errors of the robot user is recommended. Situations such as strong recoil, sound and smoke formation seen in conventional gunpowder weapons can be prevented by choosing an electromagnetic weapon. In this way, an aerial vehicle can be created that will operate more successfully, quietly and effectively in the field. Prototyping and experiments show that an autonomous electromagnetic-armed air robot can aim more accurately, operate more effectively and silently than today's firearm air robots.

Keywords: unmanned air vehicle; electromagnetic weapon; autonomous targeting; military robot; defence systems.

Effect of Deep Learning Feature Extract Techniques on Respiratory Sounds

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Izmir

Talk

Oral presentation

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Abstract: Analysis of respiratory sounds increases its importance every day. Many different methods are available in the analysis, and new techniques are continuing to be developed to further improve these methods. Features are extracted from audio signals and trained using different machine learning techniques. The use of deep learning, which is a different method and has increased in recent years, also shows its influence in this area. Deep learning techniques applied to the image of audio signals give good results and continue to be developed. In this study, image filters were applied to the values obtained from audio signals and the results of the features formed from this were examined in machine learning and deep learning techniques. Their results were compared with the results of methods that had previously achieved good results.

Keywords: respiratory sounds; machine learning; deep learning; feature extraction.

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Talk

Oral presentation

Use of Artificial Intelligence in Production of Desired Quality Steel in Ladle Furnaces in Iron and Steel Industry

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Abstract: Iron production in the iron and steel industry is a process that begins with the melting of scrap in electric arc furnaces or iron ore in basic oxygen furnaces. The proportions of the alloys in the liquid steel obtained from the liquid steel obtained by melting scrap are of great importance in order to produce the desired quality iron. In steel production, it is necessary to reduce the carbon rate to the desired level, to reduce the proportions of manganese, silicon and other chemicals to the values prescribed in the prescription, and to remove sulfur from liquid steel as much as possible. The liquid steel transferred to the ladle furnace is analyzed at certain intervals and the addition of chemical alloys continues until the required ratios are obtained. Chemical alloys added to liquid steel should not be less or more than they should be, in terms of both material and quality standards. Because the mentioned alloys are serious cost items when purchased in dollars and spread over a long term. For this reason, the rates should be adjusted very accurately. All these metallurgical processes are complex, multivariate systems. Looking at the examinations made, it is seen that while the alloys (FeSiMnPOTP, AltelPOTP, GrnKrbnPOTP, FeMnOrtCPOTP, KirecPOTP, FeSiPOTP, AlPOTP, FlşptPOTP vb.) to be added to the liquid steel in the ladle furnace are rehearsed for an average of 4 times in a casting, this process is repeated at least 2 and at most 6 times. Taking samples from the liquid steel in the ladle furnace, sending the sample for chemical analysis, obtaining the result of chemical analysis and repeating these processes if the desired quality standards are not obtained, the average time is 45 minutes. These periods cause serious waste of time. For this reason, the time of the next casting has to be started later than the planned time. This causes delay in the subsequent processes (pouring liquid steel into molds in continuous casting, forming in the rolling mill, passing through quality tests, etc.). Today, with the advancement of technology, the use of artificial intelligence in the iron and steel industry will be a mandatory approach to minimize the number of proofs and minimize the loss of material and temporal labor.

Keywords: crucible furnace; liquid steel; artificial intelligence.

Usage of Machine Learning Methods on Precision Agriculture Applications

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Izmir

Talk

Oral presentation

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Abstract: Agricultural monitoring and analysis of data to be used in management decisions to increase the quality, profitability, sufficiency, continuity and efficiency of agricultural production is called Precision Agriculture.1 Precision Agriculture technologies aim to help the farmers with the decision making process by providing them information and control over their land, crop status and environment using remote sensing systems. Remote sensing systems use multispectral cameras to gather information, which filter different wavelengths of light in separate bands. Vegetation indices derived from the spectral bands of the remote sensing systems carry useful information about crop characteristics such as nitrogen content, chlorophyll content and water stress which supports the farmers to plan irrigation and pesticide spraying processes without the need of manual examination, providing a cost and time-efficient solution.

This study aims to explore three specific Precision Agriculture applications, such as crop segmentation, illness detection and yield prediction on olive trees in Manisa, Turkey by using machine learning algorithms. Using the spectral band information gathered from an Orange-Cyan-NIR (OCN) camera embedded UAV system, NDVI (NIR/ORANGE) was calculated and the data was preprocessed by segmentating the tree pixels from background based on those values using MiniBatchKMeans algorithm. NDVI, NNI (ORANGE/CYAN), NDWI (NIR/CYAN) and tree pixel sizes were selected as optimal features based on accuracy comparison for yield and disease predictions. A Decision Tree Regressor (DTR) model was trained for yield prediction while a Random Forest Classifier (RFC) model was trained for disease prediction.

The results showed that crop segmentation had an accuracy rate of 0.85-0.95, while DTR and RFC models had an R2 score of 0.99 and accuracy rate of 0.98 respectively, which displayed the importance and usefulness of vegetation indices.

Keywords: machine learning; artificial intelligence; precision agriculture; yield prediction; disease prediction; crop segmentation.

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Talk

Oral presentation

The Use of Turkish NLP-capable Humanoid Robot in Education of Autistic Children

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Abstract: Studies on using robots in education of individuals with autism have shown that they can develop their social, joint attention, eye contact and communication skills through applications. In this study, the NaO humanoid robot was used to increase the communication skills of individuals with autism. A question and answer platform was created with Turkish rule-based natural language processing techniques. The application, which has not yet been tested on individuals with autism, has been tested on normal individuals, and can provide simple answers to simple questions in conversation form. The questions and answers used in the study are completely in Turkish. A new interface is designed for the Nao humanoid robot. This interface is designed to easily be used by educators. This platform was designed to be improvable and specially prepared for the education of individuals with autism and will serve as a basis for future studies.

Keywords: natural language processing; autism; Nao robot; human-computer interaction.

Part III

Regular Talks (Full Papers)

Genetic-algorithm-tuned Fuzzy-Hammerstein controller design by means of human operator modeling

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***Abstract*—This study involves obtaining a genetic-algorithm-tuned Fuzzy-Hammerstein model that learns from human operator so that the resulting model can be used as controller. For the sake of completeness, experimental setup and data collecting steps are explained. The Fuzzy-Hammerstein model is simple yet very effective for online identification and implementation. Linear parametric, neuro-fuzzy, and fuzzy models have also been obtained and compared with Fuzzy-Hammerstein model numerically. Obtained models have been placed into the system as controllers to replace the human operator in the closed loop. Performances of approaches have been compared with human operators. Methods resulted with about 80% fit of estimated human control action with actual data, which was found to be quite successful based on infinite step predictions.**

Keywords— Human operator control actions modeling, linear parametric modeling, neuro-fuzzy modeling, fuzzy modeling, and control.

I. INTRODUCTION

Human-machine interaction is one of the most attractive areas for researchers to achieve different goals. Control actions of human operators have been intensively studied since 1940s to compare pilot ratings, develop new control methods based on human response, improve vehicle handling quantities, etc. Aims of this study have been determined as obtaining effective, simple, flexible, easy to analyze and generalized models that effectively represent control actions of human operators and replacing human operators with models obtained.

Recent studies like [1] presents an overview of learning approaches for the acquisition of controllers and movement skills in humanoid robots. [2] surveys the main approaches developed to date to endow robots with the ability to learn from human guidance. The field is best known as robot programming by demonstration, robot learning from/by demonstration, apprenticeship learning and imitation learning. [3] presents a comprehensive survey of robot Learning from Demonstration (LfD), and introduce the LfD design choices in terms of demonstrator, problem space, policy derivation and performance, and contribute the foundations for a structure in which to categorize LfD research.

This study involves building an experimental setup suitable for modeling the human operator control actions and constructing models which can be used as controllers replacing human operators obtained from data collected by this setup. The block diagram of the experimental setup which is considered as a man-machine system is illustrated in Figure 1. Man-machine systems can be classified into four groups according to the visual display type ([4], [5], [6]): Compensatory, pursuit, preview, and precognitive systems. In a compensatory system, the operator sees only the error and tries to compensate it. In a pursuit system operator sees both the reference and the actual output of the system simultaneously. In a preview system, the future values of the reference signal are also shown to the operator. In a precognitive system, augmented display types are used to help the operator controlling higher order systems and/or systems having large time delays. The experimental setup used in this study has the characteristics of both a compensatory system and a pursuit system.

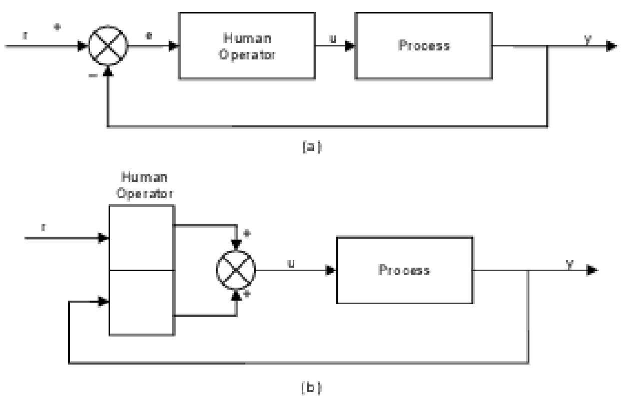

Figure 1. Man-machine systems; (a) Compensatory system, (b) Pursuit system

Five essential approaches to obtain the mathematical model of a human operator control actions found in literature can be outlined as follows:

i. The Quasi-Linear Model: The quasi linear model is composed of a linear constant coefficient differential equation and a random noise or remnant shown in Figure 5 ([4], [5], [6]).

ii. Optimal Control Models: In optimal control models, it is assumed that the human operator tries to minimize a complex cost function that might be tracking error, error rate, etc. ([6]).

iii. Linear Parametric Models: Development of parametric models using system identification methods allows obtaining human operator models such as ARX, ARMAX, etc. ([7], [8], [9], [10]).

iv. Nonlinear and/or Adaptive Models: The adaptive and nonlinear nature of the human operator control actions force researchers to develop adaptive and/or nonlinear models ([11], [12], [13]). There is also a study about reducing the model uncertainty, but [14] showed that the improvement noted was limited.

v. Intelligent Models: Since both fuzzy logic systems and artificial neural networks are inspired from human beings, adequate models can be developed using these methods ([8], [9], [10], [15], [16], [17], [18], [19], [20], [21], [22], [23]).

In this study, besides linear parametric and neuro-fuzzy models, genetic-algorithm tuned Fuzzy-Hammerstein model has been identified and used as a closed-loop controller.

II. Motivation

The fascinating idea of creating controllers which learn directly from human is the main motivation of this study. Due to uncertainties and ever-changing characteristics, it is difficult to capture skills of human operators. The candidate models are either too complicated i.e., having many parameters for on-line identification and implementation or too simple to control a nonlinear dynamic system effectively. So far, different linear and intelligent models and combinations of both have been designed and tested to predict the one-step ahead, five-step ahead and infinite-step ahead predictions of human operators ([8], [9] and [10]). [10] has also been achieved to use these models as a controller. Nonetheless, performance of controllers was neither evaluated nor compared numerically. A new approach, Genetic-Algorithm-Tuned Fuzzy-Hammerstein Model has been trained and its performance as controller has been tested and compared against previously suggested different controllers numerically in this study.

The Fuzzy-Hammerstein (FH) Model suggested by [24] which consists of a linear part and a nonlinear part is considered very suitable for this task. Since the FH model has only few parameters, these parameters must be tuned with high accuracy. Genetic Algorithm (GA) which is very suitable for this type of tuning is selected as an optimization algorithm for identifying the optimum FH model parameters. The resulting FH model is compared with different candidate models and the real human operator actions.

Fuzzy-ARX (F-ARX) model studied by [10] is briefly mentioned and The reader should refer [10] for more details. Since the experimental setup has been modified, in addition to the FH model, ANFIS, F-ARX and Hard-Switching Local linear ARX model (HSLARX), presented in previous publications have been identified in this study again for a fair comparison. The zero-order and the first-order Takagi-Sugeno models are also identified using GA in this study. Then, six different models were put in the closed loop as controllers.

Another important difference from previous publications is the signal being compared. The comparison was made between the output of identified models to the human operator actions (the control action u in Figure 1) showing how well models represented human operator in [10]. But in this study, the identified models put in the closed loop as controllers and y, the output of the controlled system and e, the tracking error as seen in Figure 1, are also compared numerically. The FH model yielded the best performance when used as controller. The rest of the text explains major steps of the research by giving graphical and numerical results.

III. Experimental Setup

To obtain data from human operators for the identification process, an experimental setup has been used. There are two critical points considered during the design of the experimental setup:

i. The limitations of the human operator must be considered.

ii. A nonlinear system which is relatively difficult to control has been chosen because the aim is the modeling of the control actions of the human operator during a control task which can bring out as much skills as possible.

Therefore, the control task is established as the tip position control of a single flexible arm. The similar setup was used by [10]. For the sake of completeness, the hardware and the software have been described here, and further improvements specific for this study are also explained below.

A. Hardware

The hardware consists of a flexible arm, a DC motor with gearbox, a DC motor driver circuit, a data acquisition card, a joystick, a camera, and a PC.

The flexible arm has been selected as a plexiglass rod whose dimensions are 3 cm × 50 cm × 2 mm. After some trial and error, adding a small amount of tip weight have resulted oscillations with satisfactory amplitude and damping. The term satisfactory means, when the operator applies a perfunctory control, high amplitude oscillations occur at the tip and these oscillations cannot been damped very quickly. In addition, a dry friction element is placed at the base to stabilize the tip position. A white circle with a diameter of 1.5 cm is located on the tip of the flexible arm to extract the tip position by an image processing algorithm. An electric motor with gearhead is mounted on the base of the flexible arm. The mechanical construction is shown in Figure 2. The data acquisition card has been used to generate pulse-width-modulation (PWM) signal according to the data acquired from the joystick. The duty cycle of the PWM signal is directly proportional to the displacement of the joystick on horizontal axis. Therefore, it is (approximately) directly proportional to the base rotational speed of the flexible arm.

The human operator uses a joystick to rotate the base end of the flexible arm. If the operator moves the joystick along the positive direction of x-axis, the flexible arm rotates in the clockwise direction with an angular speed, which is directly proportional with the displacement of the stick. If the operator moves the stick along the negative direction of x-axis, the flexible arm rotates in the counterclockwise direction.

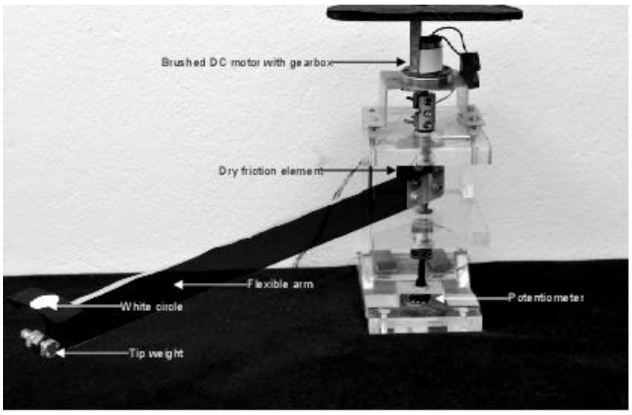

Figure 2. Mechanical construction

A camera has been placed about two meters above the flexible arm to capture the video of the flexible arm for image processing. Operator does not observe the flexible arm directly; instead, he observes the tip position of the arm from the video captured by the camera. A monochrome, FireWire type camera has been used. Although there is a study about estimating the position from the data collected from an accelerometer placed at the tip, it is stated that this technique does not work very well ([25]). For this reason, the position has been measured from captured video, instead of estimation. A PC has been used to acquire, process, and generate signals.

B. Software

One of the most important challenges modeling in the human operator is maintaining the data flow with certain rate. Data acquisition and recording, image processing algorithms cause high computational load. A software program has been used for this work to overcome this problem. The software interface to provide the interaction of human operator with the experimental setup is shown in Figure 3. The center of rotation of the flexible arm has been marked with a plus-sign (+). The orbit of the tip of the flexible arm has been marked with a semi-circle. Reference position has been denoted with two lines having five degrees of angular distance between them. Instead of giving a simple line as a reference, a range has been given because human operators are more successful tracking a reference range according to Fitt's Law and information theory. Human operators over-force themselves for the case of single reference line and this can lead to higher position error due to over-sensitivity ([4], [5], [6]). Another software program has been used for post-processing data.

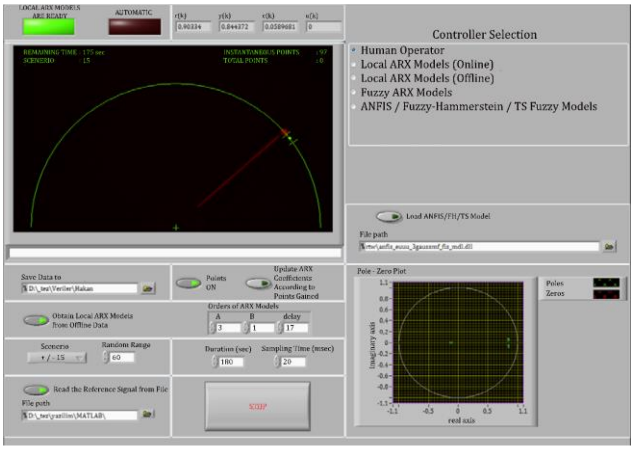

Figure 3. Software interface for human operator

The operator has been told to track the tip reference trajectory as fast as possible without oscillating the tip within 180° of workspace. Although the flexible arm system having a tip weight may be considered like a crane system, this system is faster and exhibits higher amplitude and frequency oscillations.

To emphasize the importance of the control task, a scoring system has been developed. A positive integer has been initialized related with the last and current reference as an instantaneous score at each instant of reference change. Then, instantly the score counts down until the operator reaches the reference. In addition to speed, accuracy (e.g., oscillations with less amplitude) is also important. Therefore, the score stops counting down after the tip does not go outside the reference lines for a certain period. Instantaneous scores have been summed to obtain total score after each change of the reference. Higher scores indicate better controls. Experiments showed that the scoring system has motivated the operator. Scores have not been used as input data during modeling processes. The schematic diagram of the whole system is shown in Figure 4. All signals have been recorded with a sampling frequency of 50 Hz.

The experimental setup has many nonlinear effects. Three of the most important ones are dead zone of the motor, backlash of the gearbox and different responses of the motor to control signals with the same magnitude but with opposite sign. These nonlinearities have been left as they are because human operators control plants having such effects in real world and they are important from the perspective that they induce nonlinear control actions.

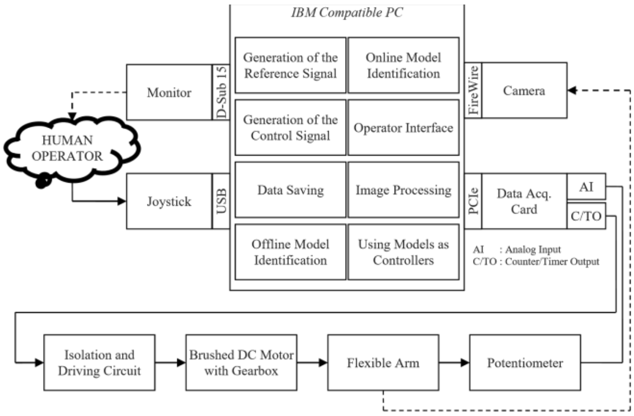

Figure 4. Schematic diagram of the whole system with human operator

C. *Improvements in Hardware and Software*

In this study, higher video resolution and sampling rate values have been achieved compared with [10] by the help of improvements in the computer technology. Camera resolution used in this study is 1024 x 768 pixels which was 493 x 300 pixels. Moreover, sampling rate has been increased from 20 Hz to 50 Hz. Both spatial and time resolution enhancements have positive effects on capturing details in human operator control actions accurately.

IV. LINEAR PARAMETRIC IDENTIFICATION

Although control actions of a human operator are nonlinear, they have been thought to be described as a combination of a linear part and a noise term or remnant, which cannot be eliminated and related to the internal dynamics of the human. In literature, it is called as quasi-linear human operator model and shown in Figure 5 ([4], [5], [6]). The quasi linear model of the human operator can be written as follows:

$$U(s)=Y_H(s)E(s)+\text{remnant} \quad (1)$$

where E(s) and U(s) are Laplace transforms of the error signal e(t) and the output signal u(t) of the human operator model, respectively. The transfer function of the human operator $Y_H(s)$ can be written as follows:

$$Y_H(s)=\frac{Ke^{-\tau_d s}(T_L s+1)}{(T_N s+1)(T_I s+1)} \quad (2)$$

where K is the gain adjusted between 1 and 100 by the operator, τ_d is the reaction time delay between 0.12 second and 0.2 second, and T_N is the time constant of a first order lag in the neuro-muscular system that is about 0.2 second. T_L and T_I are the lead and lag coefficients adjustable by the gain K to ensure satisfaction of a certain performance criterion.

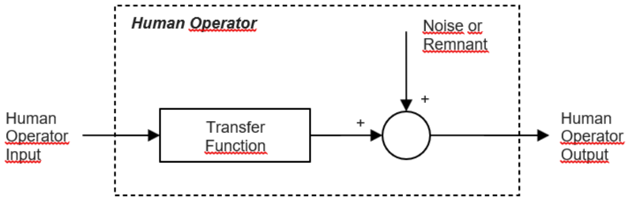

Figure 5. Quasi-linear model of human operator

Since quasi-linear models are also linear approximations to human operator modeling, linear system identification methods might be used if appropriate data can be collected. Nevertheless, one of the most difficult challenges is obtaining a single generalized model of the human operator by system identification methods ([7]).

A. *Input signal selection and persistent excitation*

The order of the persistent excitation of the input signal of the collected data to estimate the model determines and restricts the number of parameters that can be estimated ([26], [27]). It is given in the literature that Pseudo Random Binary Signal (PRBS) is persistently exciting of all orders and therefore, it is the most suitable input signal for system identification ([26], [27]).

The input signal for models obtained in this study is defined as the error between the reference and the output signals (angular tip position of the flexible arm) which is notated by e(t), and therefore, it is more meaningful to test this signal rather than PRBS reference signal r(t) for the persistent excitation because of the model structure used in this study. The output signal is defined as the voltage applied to the DC motor which is notated by u(t). A 3-minute-long ±15° PRBS signal has been used as the reference signal to collect data for analyses in this section.

A signal is said to be persistently exciting of order n, if the covariance matrix of order n is positive definite ([26], [27]). Covariance matrix $R_e(n)$ can be calculated by using autocorrelation function as follows:

$$R_e(n)=\begin{bmatrix} r_e(0) & r_e(1) & \cdots & r_e(n-1) \\ r_e(-1) & r_e(0) & & \vdots \\ \vdots & & \ddots & \vdots \\ r_e(1-n) & \cdots & \cdots & r_e(0) \end{bmatrix} \quad (3)$$

where autocorrelation function of the error signal $r_e(\tau)$ is defined as follows:

$$r_e(\tau)=\lim_{N\to\infty}\frac{1}{N}\sum_{t=1}^{N} e(t+\tau)e^T(t) \qquad (4)$$

The persistently excitation order of the error signal has been calculated and found to be at least order of 10. Therefore, it is possible to estimate models with order of up to 10.

B. Coherence analysis

Since one of the main objectives of this study is obtaining a linear model of a human operator, it is required to analyze the linearity of the control actions of the operator. Coherence analysis is used to analyze the linearity of the input - output relationship of a single input - single output system ([28]). The analysis takes place by estimating the coherence function for different frequency values. Magnitude squared coherence function $\gamma_{eu}^2(f)$ is defined as follows:

$$\gamma_{eu}^2(f)=\frac{|G_{eu}(f)|^2}{G_{ee}(f)G_{uu}(f)}=\frac{|S_{eu}(f)|^2}{S_{ee}(f)S_{uu}(f)} \qquad (5)$$

where $S_{ee}(f)$ and $S_{uu}(f)$ are auto spectral density function defined in $(-\infty,+\infty)$, $S_{eu}(f)$ is cross spectral density function defined in the same range. $G_{ee}(f)$, $G_{uu}(f)$ and $G_{eu}(f)$ are the counterparts of the functions above defined in $[0,+\infty)$. The range of the magnitude squared coherence function $\gamma_{eu}^2(f)$ is defined as follows:

$$0\leq\gamma_{eu}^2(f)\leq 1 \qquad (6)$$

for all frequency values. The coherence function takes the value of 1 when the relationship between the input and the output is purely linear. There are three different reasons for the values different than 1; (i) the presence of noise in data, (ii) the relationship between input and output is nonlinear and/or (iii) the output u(t) is dependent the input(s) other than the input e(t).

It is stated in the literature that the human operator can track the references up to 2 Hz ([4], [5], [6]). In this study, the coherence function takes the value of 0.6 at 0.5 Hz and goes above 0.6 at lower frequencies for the input and output data collected from the human operator. Thus, it has been inferred from the analysis that the relationship between the input and the output is almost linear between 0.2 Hz and 0.5 Hz as shown in Figure 6. Therefore, the PRBS reference signal used in this study has been generated up to 0.5 Hz frequency.

C. Determination of the structure of the linear parametric model

There are various model structures for system identification such as ARX, ARMAX, BJ, OE, etc. ([26], [27]). Among these structures, ARX model has the property of being the discrete counterpart of the quasi-linear model. Less number of parameters to be estimated makes the ARX model a good candidate for online implementation. Besides, it was shown in earlier studies that ARX models performed around 20% better than ARMAX models on the average in terms of prediction success ([7], [9], [14], [29], [30]). Thereby, in this study, ARX model structure has been selected for the parametric models.

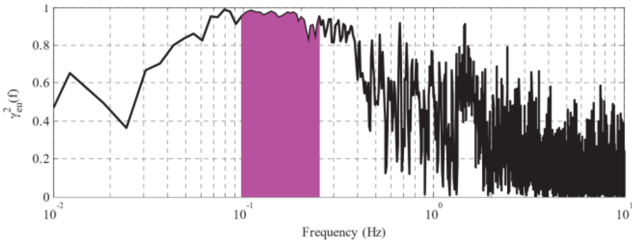

Figure 6. Plot of the coherence function of the error signal

The output of the ARX model consists of the previous outputs with the previous and current inputs of the model and an error term. The structure of the discrete ARX model can be defined as follows:

$$A(q)u(t)=B(q)e(t-nk)+d(t) \qquad (7)$$

where t is the sampling instant as an integer (e.g., t=5 means 5th sampling instant), nk is the order of delay between the output and the input as an integer multiple of the sampling period, q is the shifting operator, u(t) is the output, e(t-nk) is the input nk samples before the sampling instant and d(t) is the modeling error. A(q) and B(q) are polynomials in terms of q defined as follows:

$$A(q)=1+a_1q^{-1}+a_2q^{-2}+\cdots+a_{na}q^{-na} \qquad (8)$$

$$B(q)=b_1+b_2q^{-1}+\cdots+b_{nb}q^{-nb+1} \qquad (9)$$

where na is the most delayed output and nb is the most delayed input. The sum of na and nb gives the total number of parameters to be estimated. Therefore, (7) can be rewritten explicitly as follows:

$$u(t)+a_1u(t-1)+a_2u(t-2)+\cdots+a_{na}u(t-na)$$

$$=b_1e(t-nk)+b_2e(t-nk-1)+b_{nb}e(t-nk-nb+1)+d(t) \qquad (10)$$

Prediction errors versus increasing model orders shown in Figure 7 have been examined and the model order has been selected as the smallest number of parameters for which the prediction error relatively decreased compared to the one with fewer parameters. A model with 4 parameters, which corresponds to na=3, nb=1 and a delay of nk=17, which means 340 milliseconds of delay also found very similar in [10] has been selected as the candidate model and named as ARX3117 in short. In [4], [5] and [6] experiments showed that the human operator has a delay between visual sensing and acting with his hand/foot and this is about 200-300 milliseconds, which is similar to the value found in this study. Therefore, the difference equation for the selected ARX model structure has been given as follows:

$$u(t)+a_1u(t-1)+a_2u(t-2)+a_3u(t-3)=b_1e(t-17)+d(t) \quad (11)$$

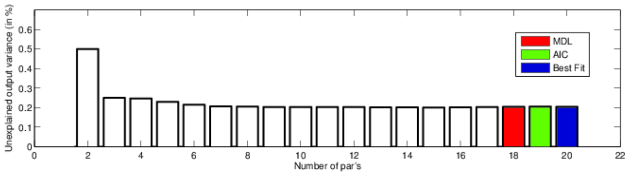

Figure 7. ARX model selection

Although obtaining a single generalized model for the human operator is the preferred case for modeling, local models have represented the control actions of the human operator better than a generalized model. The data acquisition and modeling sessions have been labeled as 15°, 30°, 45° and 60° which means that the amplitude of the generated PRBS input signal gets only the values of ±15°, ±30°, ±45° and ±60° away from the centerline, respectively. An ARX model has been estimated for each session which takes 3 minutes. Validation of estimated models has been realized by replacing the human operator with the obtained models and comparing the control actions of the human operator with the output of the model according to the following performance criterion ([27]):

$$\%fit(y)=100\left[1-\frac{\|y_m-y_{ho}\|}{\|y_{ho}-\bar{y}_{ho}\|}\right] \quad (12)$$

where y_m is the tip position of the flexible arm when the model is used as the controller, y_{ho} is the tip position of the flexible arm while the human operator controlling it, and $\bar{y}_{ho}$ is the arithmetical mean of the tip position of the flexible arm while the human operator is in action. The same formula has been adapted to be used for the output signal of the controller u:

$$\%fit(u)=100\left[1-\frac{\|u_m-u_{ho}\|}{\|u_{ho}-\bar{u}_{ho}\|}\right] \quad (13)$$

where u_m is the output of the model when used as the controller, u_{ho} is the output of the human operator while the he is controlling the flexible arm, and $\bar{u}_{ho}$ is the arithmetical mean of the human operator while he is in action.

Before using the models as controllers, a stability analysis has been carried out. It has been seen that all poles of all models stay inside the unit circle. Therefore, models obtained here are said to be stable. For validation, a reference signal taking a random value within the range of ±60° has been used.

D. Online estimation of ARX models

Least squares algorithm is one of the most powerful and used method for estimation of the parameters of ARX models ([27]). The recursive format of least square algorithm which is defined as:

$$\hat{\theta}(t)=\hat{\theta}(t-1)+L(t)\left[u(t)-\varphi^T(t)\hat{\theta}(t-1)\right] \quad (14)$$

where $\hat{\theta}(t)$ and $\hat{\theta}(t-1)$ are parameter vectors estimated at time instant t and (t-1), respectively, u(t) is the output of the model, φ(t) is the regression vector at time t and L(t) is the pre-filter for prediction errors and defined as:

$$L(t)=\frac{P(t-1)\varphi(t)}{\lambda(t)+\varphi^T(t)P(t-1)\varphi(t)} \quad (15)$$

where λ is the forgetting factor defined in the range $0\leq\lambda(t)\leq 1$ and P(t) is the asymptotic covariance matrix defined as:

$$P(t)=\left[P(t-1)-\frac{P(t-1)\varphi^T(t)\varphi(t)P(t-1)}{\lambda(t)+\varphi^T(t)P(t-1)\varphi(t)}\right]/\lambda(t) \quad (16)$$

The forgetting factor has been selected as λ(t)=0.95 and orders of the ARX models have been selected as the same as the previous case where na=3, nb=1 and nk=17.

One local linear ARX model has been identified for each scenario; 15°, 30°, 45° and 60° as given below:

IF $0^\circ\leq|e(t)|<30^\circ$ THEN $ARX3117_{15}$
IF $30^\circ\leq|e(t)|<60^\circ$ THEN $ARX3117_{30}$
IF $60^\circ\leq|e(t)|<90^\circ$ THEN $ARX3117_{45}$
IF $90^\circ\leq|e(t)|\leq120^\circ$ THEN $ARX3117_{60}$

After model identification processes have been finished, these models used together as a single controller and called "Hard-Switching Local ARX (HSL-ARX)". It has been tested for the random scenario whose reference signal takes value within the range of ±60°. The tip position of the flexible arm, the error and control signals have been shown in Figure 8. Models achieved fitness value of 77.9% according to (12).

V. Fuzzy And Neuro-Fuzzy Identification

It has been shown that HSL-ARX model showed considerable performance, but the inherent noise and nonlinearities of the human operator could not be completely captured by these linear models. Therefore, intelligent modeling methods should be considered. Both neural networks and fuzzy logic systems are classified as intelligent systems. Although neural networks have learning and generalization capabilities by training; they have many parameters to be determined. Moreover, they are black-box models, which cannot be easily debugged to analyze. Since the neuro-fuzzy systems are inspired from decision making processes of humans, they may better represent control actions of a human operator. Fuzzy logic systems are constructed with IF-THEN-ELSE statements and have many design parameters that must be selected by the designer as well. Therefore, it takes a long time to design, tune and debug a fuzzy logic system ([18], [19]).

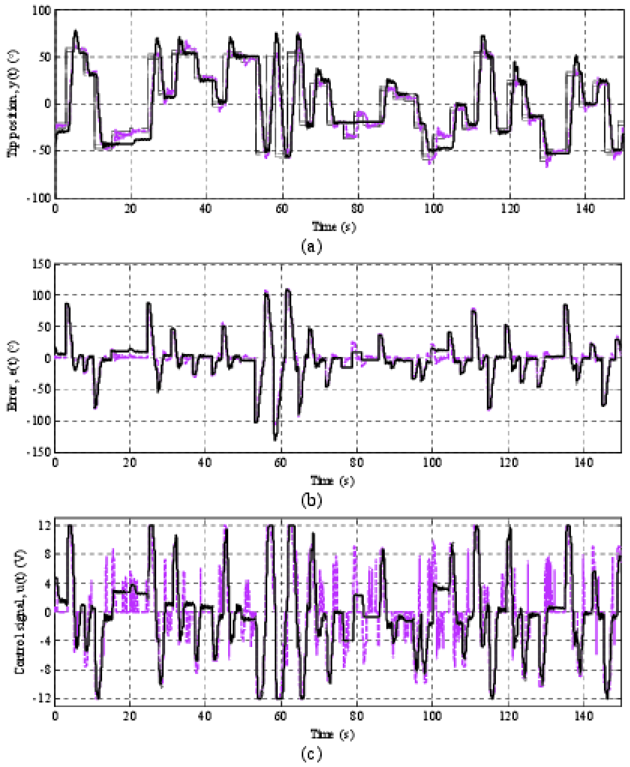

Figure 8. (a) Tip position, (b) Error signal and (c) Control signal when HSL-ARX model has been implemented as the controller. Reference signal *dashed line*, human operator *solid line*, HSL-ARX model *thicker solid line*

A. Identification of Parameters of the Fuzzy-ARX Model

Fuzzy-ARX (F-ARX) model is a nonlinear ARX (NARX) model proposed by [10] can be thought as a combination of infinitely many ARX models connected each other with a fuzzy inference mechanism. The fuzzy inference mechanism provides smooth transition between local ARX models.

The human operator is likely to be control the system according to the absolute instantaneous value of the error. Therefore, the absolute value of the tip position error e(t) has been used as the input of the fuzzy inference system (this should not be confused with the input of the ARX model which is the error). Input membership functions of the fuzzy system are defined as four local scenarios, output membership functions are the coefficients of the local ARX models obtained in each scenario. F-ARX model used in this study is shown in Figure 9.

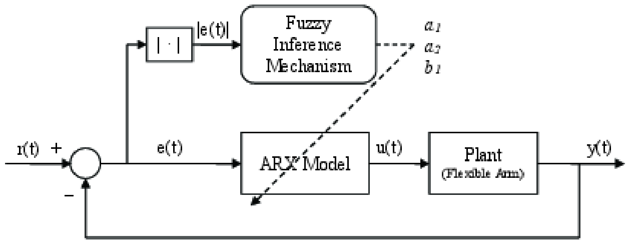

Figure 9. F-ARX model structure

The rule-base of the fuzzy inference mechanism is constructed by matching each scenario to the parameters of the corresponding local ARX model:

IF $|e(t)|$ is A_i THEN $f_1(\cdot)=a_{1,i}$ $i=1,\ldots,4.$
IF $|e(t)|$ is B_i THEN $f_2(\cdot)=a_{2,i}$ $i=1,\ldots,4.$
IF $|e(t)|$ is C_i THEN $f_3(\cdot)=b_i$ $i=1,\ldots,4.$

where A_i, B_i and C_i are the input membership functions shown in Figure 10. The tip position of the flexible arm, error, and control signals when F-ARX model was implemented as the controller are shown in Figure 11. The fit performance of the F-ARX model has been calculated as 77.1% according to the (12).

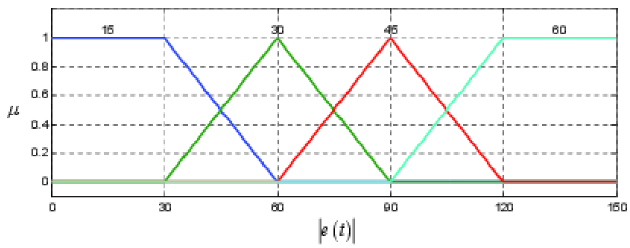

Figure 10. Input membership functions of the F-ARX model

B. Identification of Parameters of the Takagi-Sugeno Fuzzy Model by Adaptive Neuro-Fuzzy Inference System

Facts mentioned above have been overcome with the Adaptive Neuro-Fuzzy Inference System (ANFIS). ANFIS is a process to create and fine-tune the Takagi-Sugeno (TS) fuzzy inference system using radial basis function networks. It has characteristics of both fuzzy inference systems and neural networks. In addition, it requires relatively fewer parameters to be determined providing faster training without loss of generalization power ([15], [16], [17]). It is shown in the literature that ANFIS has the power of matching any nonlinear function arbitrarily well ([31]). In literature, modeling control actions of human operators by using ANFIS had been studied by [8], [9], [29] and [30].

Fuzzy rules for a first order Takagi-Sugeno fuzzy logic system with two inputs, two membership functions for each input and one output can be represented as follows:

$$\text{IF } x \text{ is } A_i \text{ and } y \text{ is } B_i \text{ THEN } f=k_{1i}x+k_{2i}y+k_{3i}, i=1,2. \quad (17)$$

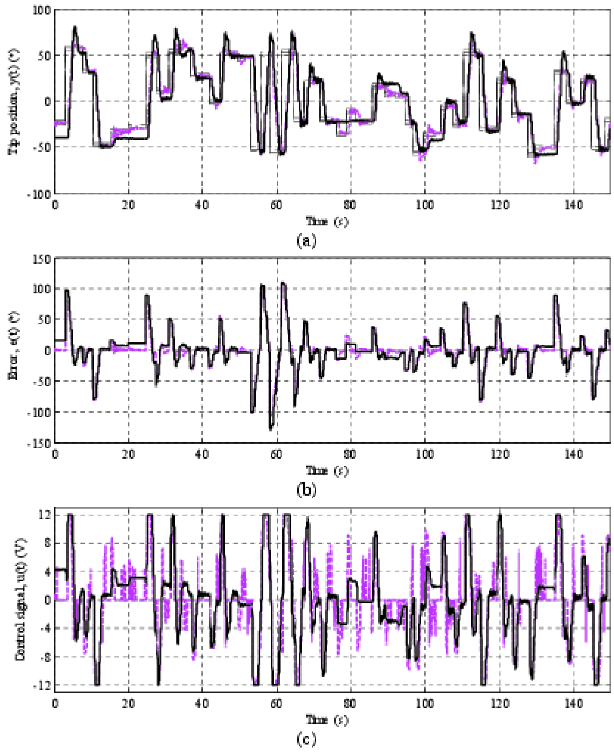

Figure 11. (a) Tip position, (b) Error signal and (c) Control signal when F-ARX model has been implemented as the controller. Reference signal *solid line, in (a)*, human operator *thicker dashed line*, neuro-fuzzy model *thicker solid line*

where x and y are inputs, A_i and B_i are fuzzy membership functions for inputs x and y respectively, k_1, k_2 and k_3 are constants to be determined by tuning, and f is the output. The structure for this type of configuration is shown in Figure 12.

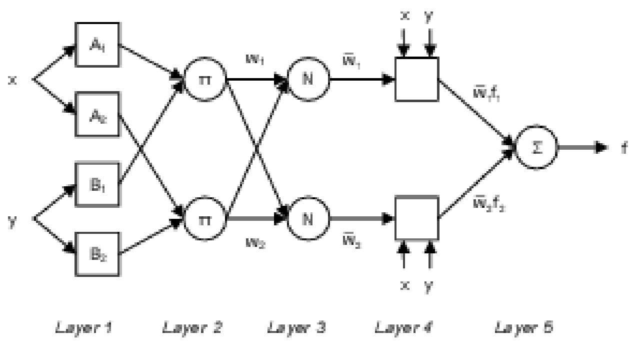

Figure 12. ANFIS structure example

Theoretical studies show that complex input-output mappings are possible by ANFIS, however, they do not give the information about the configuration (e.g., number of inputs, number of membership functions for each input, type of the membership functions). Especially, the number of inputs and the number of membership functions for each input determine the number of rules to be trained (e.g., n inputs and m membership functions for each input requires m^n rules to be trained). Although more membership functions often give better results, training time takes longer with increasing number of membership functions.

The training data of the neuro-fuzzy model has been formed from one long session which has been composed of one of the each 15°, 30°, 45° and 60° sessions. The data collected from the random session has been used for the validation. After some trial and error, it has been concluded that using more than three membership functions does not improve the performance noticeably; using two or three membership functions is suitable for each input. Besides, Gaussian, and triangular shaped membership functions have showed better results than the other types, such as generalized bell, pi, sigmoid, etc. for this study. An exhaustive search algorithm has been developed to determine the inputs of the neuro-fuzzy model for this work. Each configuration has two, three or four inputs, which are combinations of all past inputs up to 20, and all past outputs up to 10 sampling intervals. Three-input configuration has less validation error than the two-input configuration. A part of results sorted in the ascending order of the error of the verification data only for three-inputs has been shown in Table I. The best configuration has been coincided with the ARX model structure which has been estimated in the previous section. Inputs of the model have been selected as u(t-1), u(t-2), u(t-3) and e(t-17) with only 2 Gaussian shaped membership functions for each. As a result, the rule base of the intelligent model has become as follows:

IF u(t-1) is A_i and u(t-2) is B_i and u(t-3) is C_i and e(t-1) is D_i

$$\text{THEN } f=k_1u(t-1)+k_2u(t-2)+k_3u(t-3)+k_4e(t-17)+k_5;\ i=1,2. \quad (18)$$

	Input Number			Error Value	
Model No	**1**	**2**	**3**	**Train.**	**Valid.**
3456	e(t-14)	u(t-1)	u(t-2)	0.0987	0.0911
3949	u(t-1)	u(t-3)	u(t-4)	0.1053	0.0912
3896	e(t-20)	u(t-1)	u(t-2)	0.1039	0.0916
3336	e(t-13)	u(t-1)	u(t-2)	0.0992	0.0919
⋮	⋮	⋮	⋮	⋮	⋮

Table I. Comparison of training and validation errors of ANFIS structures with all possible 3 input combinations for 1 to 20 delays

The tip position of the flexible arm, error, and control signals when neuro-fuzzy model was implemented as the controller are shown in Figure 13. The fit performance of the neuro-fuzzy model has been calculated as 79.5% according to the (12).

C. *Identification of Parameters of the Takagi-Sugeno Fuzzy Model by Genetic Algorithm*

Parameters of a first order TS fuzzy model can be identified by ANFIS, as well as Genetic Algorithm (GA), which is an optimization method for both constrained and unconstrained optimization problems inspired from natural selection seen in biological variation and development processes of living organisms ([32]).

Inputs of the TS fuzzy model have been selected as u(t-1), u(t-2) and e(t-14) have been found in the previous section. All the signals are scaled between ±1 to have better control on them. One Z-shaped and one S-shaped membership functions have been defined for each input. Since there are 2^3=8 combinations for this configuration, 8 zero-order and first order output functions are defined resulting 8 rules for each (there is no rule-sharing defined). Proposed structure for the TS fuzzy controller to be tuned can be seen in Figure 14.

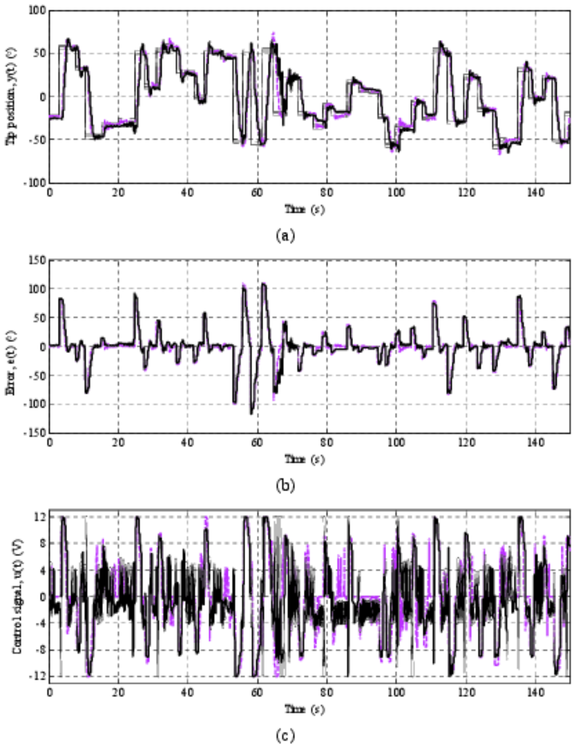

Figure 13. (a) Tip position, (b) Error signal and (c) Control signal when neuro-fuzzy model has been implemented as the controller. Reference signal *solid line, in (a)*, human operator *thicker dashed line*, neuro-fuzzy model *thicker solid line*.

A population consists of 300 individuals has been decided to be appropriate for this work. Equation (12) has been selected as the fitness function. Models have been obtained after 200 cross-over iterations for zero- and first-order TS fuzzy models used as controllers in the closed loop system whose results can be seen in Figure 15 and Figure 16, respectively.

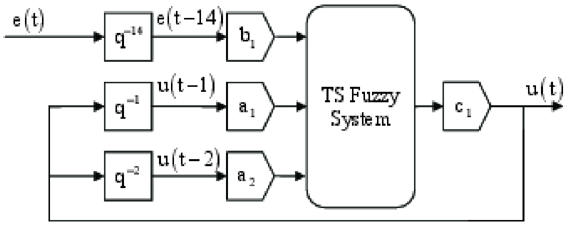

Figure 14. Structure of TS type fuzzy controllers

D. *Identification of Parameters of the Fuzzy-Hammerstein Model by Genetic Algorithm*

A Fuzzy-Hammerstein (FH) model consist of a linear block in series with a static nonlinear block. This type of models is much simpler than nonlinear-ARX models. Hammerstein models which are series combinations of a memoryless nonlinear structure and a dynamical linear structure are special types of NAARX models. There are many applications of Hammerstein models in the industry where nonlinear effects such as chemical, electromechanical, etc. are present. Moreover, if there is pre-information about the process, Hammerstein models can be used as gray-box modeling ([24]).

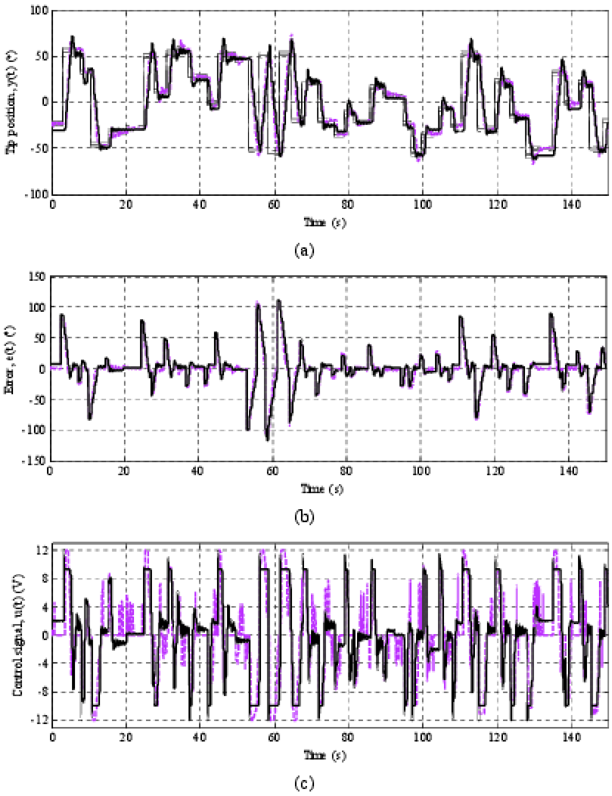

Figure 15. (a) Tip position, (b) Error signal and (c) Control signal when zero-order TS model whose parameters have been found by using GA has been implemented as the controller. Reference signal *solid line, in (a)*, human operator *thicker dashed line*, Zero-order TS model *thicker solid line*

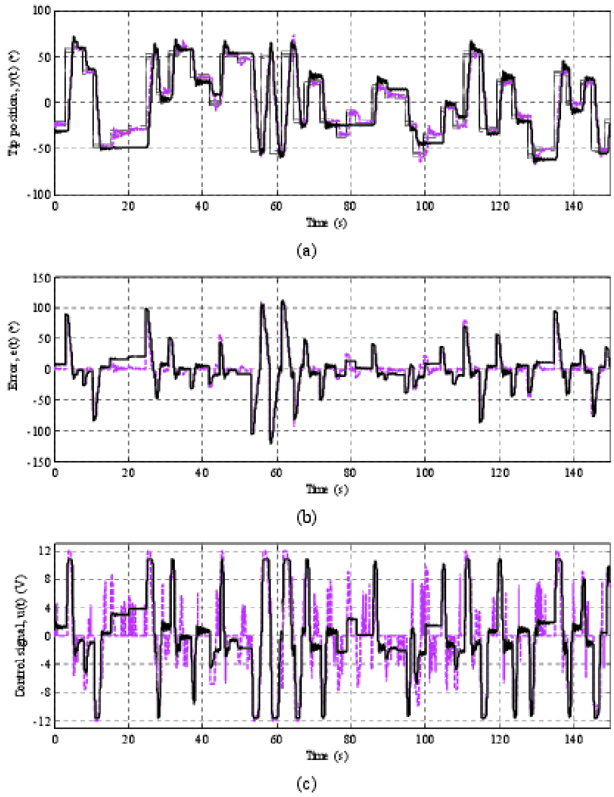

Figure 16. (a) Tip position, (b) Error signal and (c) Control signal when first-order TS model whose parameters have been found by using GA has been implemented as the controller. Reference signal *solid line, in (a)*, human operator *thicker dashed line*, First-order TS model *thicker solid line*.

A simple generalized structure of a FH model can be seen in Figure 17 where nu and ne are the number of outputs and inputs, respectively, $e=[e\_1,\dots e_{ne}]$ is the input vector and $v=[v\_1,\dots v_{ne}]$ is the transformed input vector, v=f(e) is the nonlinear function representing the nonlinear structure and G is the linear function of the linear structure.

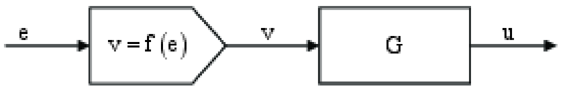

Figure 17. General structure of a FH model

If the static nonlinear structure is parametrized separately, $f(\cdot)$ can be defined as a function set of $v_h=f_h(e)$ for h=1,…,ne. Moreover, $f_h(\cdot)$ functions can be defined in a zero-order TS fuzzy model represented by the following rule set:

$$R_j^h\text{:IF } e_1 \text{ is } A_{1,j} \dots \text{ and } e_{ne} \text{ is } A_{ne,j} \text{ THEN } v_h=p_j^h \quad (19)$$

Therefore, the output of the fuzzy model can be found by weighted sums as follows:

$$v_h=\frac{\sum_{j=1}^{Nr}\beta_j(u)p_j^h}{\sum_{j=1}^{Nr}\beta_j(u)} \quad (20)$$

Since a multivariable linear dynamical ARX is followed by a multivariable static nonlinear structure, a multiple input - multiple output Hammerstein model in NAARX can be described in the following form:

$$u(t)=\sum_{i=1}^{na}A_i u(t-1)+\sum_{i=1}^{nb}B_i f\big(e(k-i-ng)\big) \quad (21)$$

where u(t), … ,u(t-na+1) and e(t-ng), … , e(k-nb-ng+1) are delayed inputs and outputs of the linear dynamical system, $A_1,\dots,A_{na}$ and $B_1,\dots,B_{nb}$ are matrices with dimensions of nu×nu and ne×ne, respectively.

There are no criteria for defining inputs and outputs, types and number of input and output membership functions for FH models in the literature as well, like ANFIS. Inputs of the FH model has been selected as u(t-1), u(t-2) and e(t-14) which are the same inputs of ARX and ANFIS models previously found in this work. The FH model used as a controller can be seen in Figure 18.

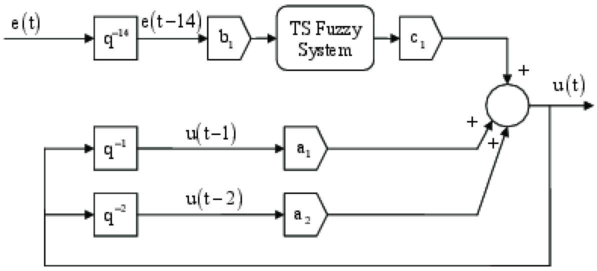

Figure 18. Structure of the FH controller

Describing function of the Figure 18 can be written as follows:

$$u(t)=a_1u(t-1)+a_2u(t-2)+c_1\sum_{j=1}^{Nr}b_1p_j\beta_j e(t-14) \quad (22)$$

where b_1 and c_1 are the input and the output scaling coefficients of the TS fuzzy system to scale inputs and the output into ±1 range. Five triangular and five linear membership functions have been selected for inputs and outputs, respectively. No rule sharing has been allowed. Therefore, one membership function for each possibility determines the number of membership functions as five.

Experimental results obtained from the FH model which has been trained from control actions of the human operator used as a controller is shown in Figure 19.

VI. Conclusion and Future Works

In this study, an experimental setup has been used to obtain data from a human operator to develop both linear and intelligent models. Then obtained models put into the closed loop replacing the human operator in the real time control system. Of course, limitations and performance of human operators have been considered to collect valuable data and obtain successful models.

Four different local linear ARX models are combined as a single HSL-ARX model. Even if the performance was poor compared to intelligent models, HSL-ARX also achieved to control the system.

Parameters of zero- and first-order TS fuzzy models have been obtained using GA. ANFIS has been trained as another intelligent model. Both zero- and first-order TS fuzzy models have been showed quite good performance. The number of parameters for TS fuzzy models is directly proportional with the order of the models. Therefore, selecting a zero-order TS fuzzy model which has shown nearly the same performance with the first-order TS model could be a good choice to maintain simplicity and reducing computational load for online-identification.

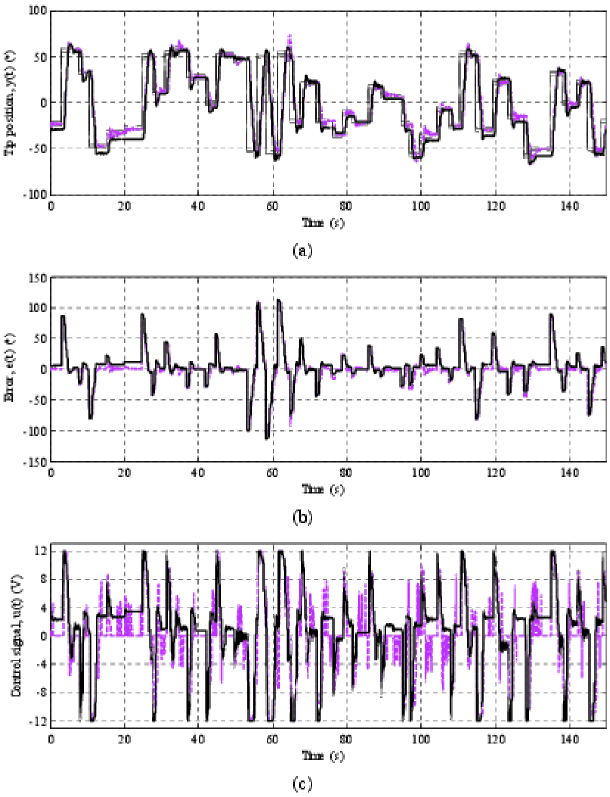

Figure 19. (a) Tip position, (b) Error signal and (c) Control signal when FH model has been implemented as the controller. Reference signal *solid line, in (a)*, human operator *thicker dashed line*, FH model *thicker solid line*.

FH model has been used for the modeling control actions of the human operator for the first time in the literature. The FH model has simpler structure than TS fuzzy models and thereof a smaller number of linear and nonlinear parameters needs to be identified. Such a structure is more suitable for both online and offline identification. Parameters of FH models have been identified by using GA as well in this study.

All identified models put in the closed loop as controllers to replace the human operator. All models achieved to control the system. The performance of models has been compared based on how well they controlled the system. The output of the controlled system, %fit(y) and SSE, sum of squared tracking errors is both good indicators of controller performance. The FH model has shown the highest performance as controller as seen in the Table II. The performance criterion %fit(u) indicates how well the model imitates the human operator. But that does not necessarily an indication of how well the model controls the system.

On the other hand, some of ANFIS models used as controllers have shown poor performance and tip point oscillations with very high amplitudes. The main reason for oscillations is the non-linearity of the system to be controlled. Therefore, each adequate model has been tested by online trails to guarantee the performance satisfaction when they have been used as controllers.

This study can be extended to build a database of control actions of experienced human operators to train inexperienced operators. Training time and cost can be reduced by this way.

Models in this study are identified offline such that the modeling process takes place after collecting data. One step ahead from this point is the online training of models. Because human operator control actions change with time and/or the human operator learns and trains himself as he/she controls the system. Hence, depending on the application, online parameter update would be necessary and add a good enhancement to this study.

Model	**% fit(u)**	**% fit(y)**	**SSE**	**Number of Parameters**		**Training Time**
				Linear	**Non-linear**	
HSL-ARX	47.1	77.9	0.319	12	0	Very short
F-ARX	48.1	77.1	0.315	12	17	Very short
ANFIS	33.1	79.5	0.279	112	18	Short
Zero order TS	45.0	75.3	0.286	8	12	Long
First order TS	51.9	79.2	0.328	32	12	Long
FH	44.1	80.2	0.262	12	5	Medium

Table II. Performance of the models used as controllers (SSE: Sum of Squared Error)

One of the other extensions of this study is the predicting the control actions of the human operator, and the output of the system. Many systems that humans use can be mathematically modeled and can be simulated. If a valid model for the control action of the human operator can be estimated, the model can be used to predict the response of the human operator, and the system which accommodate closed-loop simulations for different purposes (e.g. developing early warning systems).

ACKNOWLEDGEMENTS

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Artificial Intelligence - Human Health-Genetic Algorithm And Diet

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Abstract— The recommended diet for human health has become a very important concept today. A literature review of nutrition and diet found that some studies were insufficient. It is known that every day in our country and around the world they apply to dietitians to receive services from human nutrition and diet outpatient clinics. However, it is obvious that these studies need to be replicated quickly. Artificial intelligence has entered our lives in recent days with the increase of epidemics, especially Covid-19. A healthy diet can be called an adequate and balanced diet. In order for our body's cells to function regularly, we need to provide adequate amounts of fats, carbohydrates, proteins, vitamins and minerals, which are food sources. Minerals should be taken in our body at sufficient levels, and excessive amounts of them lead to obesity and an unhealthy life. Controlling this condition is very important in terms of healthy life. The history of the" artificial intelligence" concept is as old as modern computer science. II. Computer science and artificial intelligence concepts emerged thanks to electromechanical devices produced with crypto analysis requirements during World War II. Artificial intelligence artificial intelligence, a popular topic of discussion in recent periods, has also begun to attract interest and curiosity in Turkey. The main goal of artificial intelligence is the ability to act like the human brain. Bringing technology and science together, its development is enthusiastically followed by a large number of people. In this study, it is believed that nutrition and diet can be further facilitated by artificial intelligence, more realistic and timely data can be reached. Obesity is very important for our human lives. Excessive fat accumulation negatively affects human health in such a way as to risk human health. It will demonstrate the importance of contribution to science by creating adequate vitamins, adequate nutritional supplements and an optimal diet list, where new coding can be made through artificial intelligence. For a healthy community life, it is believed that different studies should be done on balanced nutrition, vitamin intake and environmental factors, and it may be appropriate to do this with artificial intelligence.

Keywords — Artificial intelligence, genetic algorithm, human health, diet, diet list

I. INTRODUCTION

With the Covid-19 virus, which has been occupying humanity in recent days, we hear more often the name of artificial intelligence and robots. It may not be wrong to say that artificial intelligence has entered human life. Today, the use of artificial intelligence in all applications of especially science, social and health sciences has increased. Scientists have accelerated their studies for digital models and solutions on computers. The usability of artificial intelligence in the health sector is discussed. Artificial intelligence is very important for using artificial intelligence models to classify medical diagnoses, especially various types of cancer. New ideas, models and coding can be produced with artificial intelligence.

A healthy diet is to take the nutrients (carbohydrate, protein, fat, vitamins, minerals and water) required for the proper and regular functioning of the cells that make up our body in sufficient and balanced amounts. Even though the individual thinks that he / she is fed adequately, he / she cannot make enough use of the nutrients he / she receives in cases where he / she cannot make an appropriate selection or applies the wrong cooking method. Nutrition for us begins in the womb and continues throughout infancy, childhood, adulthood, pregnancy and old age. We can make it a little more reliable to feed with some small details that we will rule ourselves in our lives. Never starts the day without breakfast, a well-made breakfast will allow us to have more control over other meals during the day. We can choose to eat less and frequently during the day by determining snacks and main meals for yourself after breakfast.

We can keep our food consumption record. No food you eat will make us feel full for days, so we need to care about the quality of what you eat. In addition, never neglect your fluid intake; we must take care to drink at least 8-10 glasses of water a day. This is very important in evaluating the results of a healthy diet we do. It is very important to be able to control these results with artificial intelligence. When the literature scan is done, it has been seen that there are very few studies in the field of nutrition optimization. For this reason, studies are needed in the field of nutrition and diet, which is an essential condition for human health. With this study, it has been tried to integrate artificial intelligence and diet. On the other hand, the accuracy and reliability of the information obtained from the Internet and other information sources is important in order to demonstrate healthy eating behavior. To find out whether there is a significant relationship with the cyberchondria state that may occur as a result of online health research.

II. ARTİFİCİAL INTELLİGENCE

Before defining artificial intelligence, it is necessary to know the concept of intelligence. Intelligence can be explained simply as the ability to understand and comprehend any situation, to understand a phenomenon, to provide a concept. With the introduction of computers into our lives, the desire of human beings to automate the work that started in the ages before Christ has led to the introduction of the concept of artificial intelligence. With the use of computer technology in tape production processes in the industry, the concept of robot has been used. Artificial intelligence briefly; is the art of a computer or a robot under computer control to perform various activities similar to intelligent creatures. The word AI, which is the acronym of the concept of artificial intelligence in English, is also frequently used in informatics [1].

A. *HİSTORY OF ARTİFİCİAL INTELLİGENCE*

Innovations known as artificial intelligence technology affect humanity intensely. Artificial Intelligence applications have attracted great attention in the industry and have brought solutions to many problems with their use in various fields. McCulloch and Pitts come to mind when it comes to artificial intelligence. These researchers have revealed methods of computational models. Artificial intelligence and artificial neural networks have accelerated the studies in the world and in our country, especially with robots that look like humans. Today, the use of artificial intelligence in every field is very important in health and nutrition.

Although studies on artificial intelligence have been on the agenda since the 1960s, artificial intelligence applications have prevented the rapid progress of research due to the need for powerful computers. However, thanks to the cheap and powerful computers provided by the developments in computer technology today, it has become possible to conduct large-scale research in the field of artificial intelligence from an economical perspective. As a result, significant developments have already been achieved in expert systems, which are a sub-field of artificial intelligence, and it is observed that the business world significantly benefits from expert systems in the decision-making process [2].

B. *SUB-BRANCHES OF ARTIFICIAL INTELLIGENCE*

Learning skill is included in the logic of artificial intelligence. Because just as a person cannot do a job without learning, artificial intelligence must first learn that job. The biggest contribution of artificial intelligence is to apply the most accurate way they learn very quickly. Artificial intelligence is divided into different sub-branches according to its usage areas. The sub-branches of artificial intelligence are given in Table 1.

Number	Sub-branches of Artificial Intelligence
1	Artificial Neural Networks (ANN: Artificial Neural Networks,
2	Robotics and mixed systems
3	Chaotic Modeling
4	Simulated Annealing
5	Expert Systems
6	Computer Vision
7	Speech Recognition
8	Fuzzy Logic
9	Genetic Algorithms (Genetic Algorithms)

Table 1. Sub-branches of Artificial Intelligence

III. ARTIFICIAL INTELLIGENCE AND DIET

There are personalized medicines and treatments for the emergence of technologies developed with the support of artificial intelligence in the field of health. Artificial intelligence applications provide great convenience in finding new drugs based on previous data and medical knowledge in recent years. Determining the best treatment plans according to patient data brings along customized solutions for patients. Artificial intelligence and its sub-branches have started to be used especially in all fields of engineering and law. In addition, some countries use artificial intelligence effectively in the fight against Covid-19, which threatens the world and our country. Artificial intelligence examples are very common in the field of engineering. In a study, the lateral buckling behavior of hybrid composites was estimated with artificial neural networks and shared with the literature with graphics and tables [3]. The use of artificial intelligence in early diagnosis of human brain functions and neurological detection has been investigated [4], [5]. It is seen that the studies in the field of nutrition, which is the main source of human health, are quite insufficient. Some of these are briefly: When the studies in other fields are examined; When the literature is scanned, the amount of personnel demand for food for enterprises has been estimated by using artificial neural networks. In general, a model has been developed that estimates the amount of food produced or the demand for personnel using artificial neural networks. At the end of the study, it was concluded that the error rate of the model was low, its performance was high and the use of artificial neural networks for demand prediction was positive [6].

Figure 1. Artificial Intelligence and diet

In another study, the nutrition chart of the individual was calculated with the help of an algorithm [7]. In another study, a model was developed that allows for the prediction of chloramine demand in drinking water sources, allowing us to distinguish a cleaner water by estimating the amount of chloramine in drinking water for water treatment operators [8], In different studies; The usability of the genetic algorithm, which is a sub-branch of artificial intelligence in diet problems, and the optimization of diet problems have been investigated In a different study [9], [10], [11]. Genetic Algorithm was used in Nutrition Problem. Linear programming model has been revealed by using real data in the study. With this model, the findings obtained by analyzing using linear programming and genetic algorithm have been shared with the literature. In a different study, diet planning was made using an expert system. In the study; For a normal person or a specific diet patient, an expert system method is recommended to generate the amount of each ingredient food [12]. In a different study, the optimization of the costly diet problem was investigated using fuzzy logic [13], [14]. Correct and timely nutrition constitutes the basis of creating a conscious society by increasing the quality of life of people. It is thought that benefiting from the genetic algorithm can provide more effective solutions in order to benefit from artificial intelligence in nutrition and dietary needs. In addition, Microbiota, whose name we have heard frequently recently, consists of individual microorganism groups consisting of bacteria, fungi, viruses and archae bacteria in the human body. As a result of not being digested correctly, probiotic bacteria can become harmful by changing the intestines.In this context, it is thought that studies on probiotic bacteria can be carried out using genetic algorithm and artificial intelligence. A large part of this community known as microbiota constitutes the intestinal microbiota. Changes occur in the microbiota with the effect of external factors such as diet, social life, stress, smoking and alcohol use. We can develop safer probiotics that can treat patients who cannot naturally digest the chemicals in the nutrients taken into our body. With models that can be developed using artificial intelligence and sub-branches, the estimation of the nutrient needs in individuals; It is thought that with adequate vitamins, nutrients and optimum nutrition, individual nutrition systems can be easily predicted and researched.

A.GENETİC ALGORITHM, THE SUB-BRANCH OF ARTİFICIAL INTELLIGENCE

The genetic algorithm is an artificial intelligence component. Genetic algorithms are an ideal approach to constantly improving solutions based on the rule that the best in nature lives. Genetic algorithm is a method that uses random and deterministic search techniques. Its working principle can be explained as an intuitive search technique based on parameter coding. When the history of the genetic algorithm was examined, John Holland made the first studies at the University of Michigan. John Holland (1975) made use of natural evolution and this process in excitement to work on machine learning. In addition, with his work on the control of pipelines, Goldberg demonstrated the possibility of practical use of genetic algorithms [15]. Genetic algorithm is a model of evolutionary processes in nature. It can be referred to as computer-based problem solving techniques. Classification and multidimensional optimization problems, which are difficult to solve with traditional programming techniques, provide solutions more easily and quickly with their help. Genetic algorithms are algorithms that can be created by natural selection and natural mechanism. Generally, a simple genetic algorithm consists of three different genetic processes. These can be called selection, crossover, and mutation. Parents are hybridized to give birth to children, and in the mutation process, the offspring can be changed according to the mutation rules, and the recurrence of the agorithm is called generations [16], [17], [18]. After making the definition of the genetic algorithm, it is useful to know what the gene and chromosome are. Gen briefly; it can be named as the smallest genetic unit carrying genetic information. The best individuals are determined. Genetic algorithm chart is given in Figure 2.

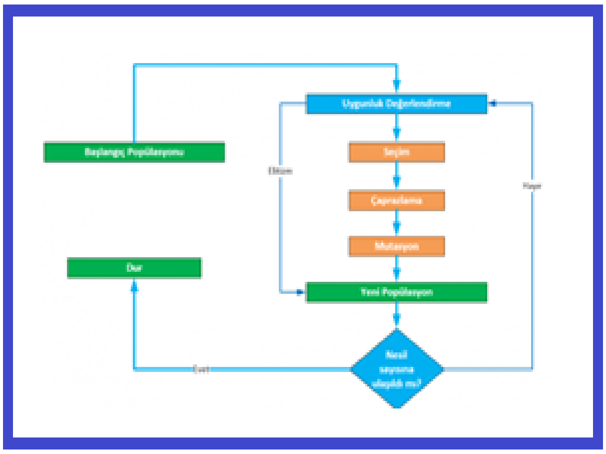

Figure 2 Genetic algorithm scheme [19].

Number	Uses of Genetic Algorithm
1	Optimization
2	Automatic Programming and Information Systems problems
3	Mechanical Learning processes
4	Financial transactions
5	Marketing operations
6	Scheduling Problem and its solutions
7	Assembly Line Balancing Problems and Solutions
8	Facility Layout Problem and its solutions
9	System Reliability Problem and solutions
10	Traveling Salesman Problem and its solutions

Table 2. Uses of Genetic Algorithm

General usage areas of the genetic algorithm are given in Table 2 and it includes the usage areas of the genetic algorithm. According to this table, it is known that optimizations can be used in the field of nutrition and diet. Genetic algorithms do not produce a single solution to problems, but create a solution set consisting of different solutions, ultimately reaching a holistic solution. Chromosome is briefly; It consists of one or more genes coming together. The chromosome may be the people around us, they can offer the best solution to problems. Genetic algorithm working principle, solution group is created for possible coding to be solved. Good chromosome is found with fitness function. New population groups are created by matching. Chromosome compatibility is determined by replacing old chromosomes with new ones. In a different study, DietPal: A Web-Based Dietary Menu-Generating and Management System was investigated. In their work; Create and manage a diet menu for patients with simple smart abilities to design and create appropriate diet plans and menus according to the patient's energy needs and compare this system with other similar Web-based systems - for example, Menu Planner by the National Institute of Health, Lung and Blood They declared that it was used. Interface of the program used by dietitians and an example of the menu / diet plan developed by Noah et al. for 600 kcal / day . A section of the program is given below [20].

in their study, presented a program that planned daily menus for dietitians and prepared using a genetic algorithm [21].Chromosome coding and the presence of genetic factors are also reflected in this program. The formulas that determine the genetic operators and the parameters of the algorithm are given below. The function f determines if the quantitative requirements are met and is calculated using the formula:

$$F(X)=\frac{\sum_{i=0}^{dr-1} f(v_i,w_i)+\sum_{a=0}^{j-1}\sum_{b=0}^{mr_a-1} f(v_b,w_b)}{dr+\sum_{a=0}^{j-1} mr_a} \qquad (1)$$

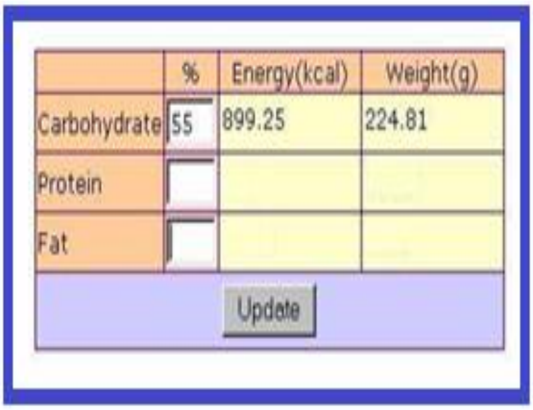

Figure 3. Food distrubiton [20]

Figure 4. Diet menu program created with genetic algorithm [20]

Figure 5 shows an example of a study combining genetic algorithm and diet.

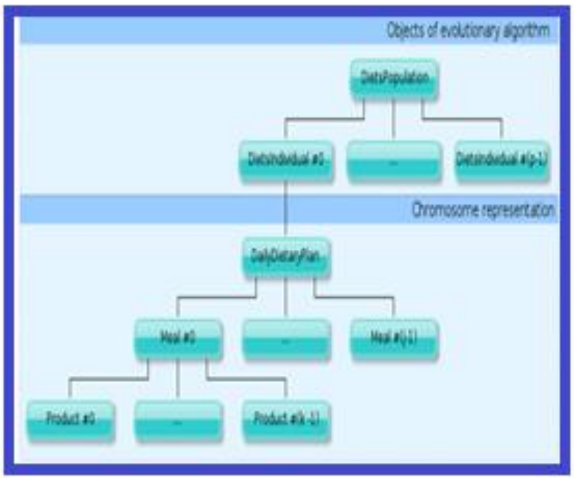

Figure 5. Genetic Algorithm and Diet Relations Example [21]

A system has been put forward for the production of daily meals that can reflect different nutritional standards. The system consists of algorithms. [22], conducted a study on Development of a Genetic Algorithms Optimization Algorithm for a Nutritional Guidance Application. It was concluded that the genetic algorithm can be applied to nutrition. [23], used Diet Generator Using Genetic Algorithms in their study. They shared their results with the literature. [24], conducted a study on coding with a genetic algorithm. [25], investigated Dietary Menu Planning Using an Evolutionary Method in his study. They shared their results with the literature. They investigated the relationship between artificial intelligence and nutrition in their study, and shared their findings with the literature by researching the usability and sub-branches of artificial intelligence in the field of nutrition.

RESULTS AND DISCUSSION

In this study, the usability of our artificial intelligence-human health, genetic algorithm and diet habits has been investigated. It is thought that the usability of the genetic algorithm, which is the sub-branch of artificial intelligence, in the field of nutrition and diet, can be determined by reference to some characteristics of individuals, and individual daily, weekly or monthly ideal nutrition schedules.

It has been concluded that using genetic coding, which is considered as a sub-branch of artificial intelligence, in solving problems requiring DNA, RNA and genetic coding may be appropriate with the literature review.

It is thought that artificial intelligence can be used in healthy bowel structure, analysis of microbiota, cancer treatment methods.

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Identification of a Nonlinear DC Motor Model with Particle Swarm Optimization

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***Abstract*— Direct Current (DC) motors are well-known electromechanical elements that are extensively used as actuating components in many applications such as robotics, automotive, etc. They are low cost, rugged, and easily controllable components. A comprehensive mathematical model including nonlinear friction terms of a DC motor is requested for the accurate dynamic response analysis. Moreover, the mathematical model can be used for design, control, optimization, and fault detection purposes. Several studies have been reported in the area of modeling with the aim of better understanding the dynamic model of DC motors. Most of these models utilize a second-order linear model of a DC motor and ignore possible existing nonlinearities in the model. However, there are some nonlinear terms such as nonlinear friction torque in the real model of a DC motor. Nonlinear system identification of this component has a vital role in robust control and performance evaluation. This work utilizes a Particle Swarm Optimization (PSO) algorithm for nonlinear system identification of a DC motor. The proposed method is used for estimating the parameters of both linear and nonlinear parts of the mathematical model simultaneously. The linear model of the DC motor includes both electrical and mechanical circuits. The parameters of the electrical circuit are inductance of the armature, the resistance of the armature, and voltage constant. The parameters of the mechanical circuit are the moment of inertia of the rotor and friction constant. The nonlinear friction parameters are Coulomb friction torque, static friction torque, and Steribeck speed. The results show that the suggested algorithm estimates all of the parameters of the model accurately. The suggested algorithm is developed and implemented in the MATLAB software package.**

Keywords—DC Motor, Particle Swarm Optimization; Nonlinear System Identification; Parameter Estimation.

I. INTRODUCTION

Direct Current (DC) motors are electromechanical actuators that are widely used in industrial applications such as robotics, automotive, etc. [1]-[4]. They have been the most preferred component due to their simple construction, low cost, reliability, and easily controllability characteristics [5]-[6]. A general mathematical model of a DC motor is requested for accurate dynamic response analysis. Several studies have been reported in the area of mathematical modeling with the aim of better understanding the dynamic model of DC motors. Most of these models are utilizing a second-order linear model of a DC motor while ignoring the possible existing nonlinearities in the real model [7]-[10]. However, there are some nonlinear terms such as nonlinear friction torque in the real model of a DC motor. Nonlinear system identification of this component has a vital role in robust control and performance evaluation. The identified nonlinear model that is fully describing the underlying physical system of the DC motor can be utilized for design, control, optimization, and fault detection purposes.

There are different parameter estimation techniques for the linear model of a DC motor. Usman et al. utilized an adaptive estimator for parameters estimation of a typical DC motor [11]. They utilized a method that applies an adaptive stabilizer for parameter estimation. They estimated the parameters of the permanent magnet DC motor using input voltage and output speed. Lavanya and Devendra utilized several estimation techniques for identifying the parameters of a brushless DC motor [12]. They used the least squares approximation, Gradient search, and Marquardt methods. The estimated parameters of the brushless DC motor are motor resistance, motor inductance, and motor inertia. They showed that the least squares approximation method has more accurate results compared to other estimation methods. Chaves et al. developed a trust region algorithm for parameter identification of a permanent magnet DC motor model [13]. They utilized different input signals such as square waves as excitation signals. Saab and Kaed-Bey employed discrete measurements of a dynamometer to determine the parameters of a DC motor [14]. They used the least squares estimation method for identifying the parameters of the electrical circuit and mechanical circuit of the DC motor.

The linear model gives a satisfactory result as far as the DC motor runs at high speed. However, identifying nonlinear terms such as nonlinear friction that happens at low speeds of the DC motor has a vital role in dynamic analysis and robust control. In the literature, there are a few research papers that are investigating the nonlinear model of the DC motors. Kara and Eker suggested a nonlinear model for a DC motor [15]. They investigated existing dynamic friction and the dead-band in the nonlinear model. They utilized the Hammerstein nonlinear model for nonlinear system identification of the DC motor. Cong et al. utilized a combination of the Genetic Algorithms (GA) optimization and the simplex methods for parameter identification of the nonlinear model of a DC motor [16]. They used nonlinear friction torque in the DC motor model. They showed that the utilization of the nonlinear model for modeling of the DC motor decreases the estimation error significantly. Zhang et al. suggested a compound estimation algorithm for nonlinear parameter estimation of a brushless DC motor [17]. They combined an Extended Kalman Filter (EKF) and a Smooth Variable Structure Filter (SVSF) estimation method.

In this research, we will utilize a Particle Swarm Optimization (PSO) algorithm to identify the parameters of the nonlinear DC motor model. The proposed algorithm is used for determining the parameters of both linear and nonlinear parts of the model simultaneously. The linear model of the DC motor includes both electrical and mechanical circuits. The parameters of the electrical circuit are inductance of the armature, the resistance of the armature, and voltage constant. The parameters of the mechanical circuit are the moment of inertia of the rotor and friction constant. The nonlinear friction parameters are Coulomb friction torque, static friction torque, and Steribeck speed. The validation of the estimated parameters is shown through the simulation results.

This research is arranged as follows: In Section 2, the mathematical model of the DC motor is presented. In section 3, the methodology describing a Particle Swarm Optimization (PSO) algorithm for parameter estimation of the nonlinear model of DC motor is described. The results of the parameter estimation procedure are discussed in section 4. Finally, the concluding remarks are given in section 5.

II. MATHEMATİCAL MODEL OF THE DC MOTOR

A DC motor is an electromechanical component that converts electrical energy into rotational mechanical energy [18]. The model of a DC motor model is represented in Figure 1.

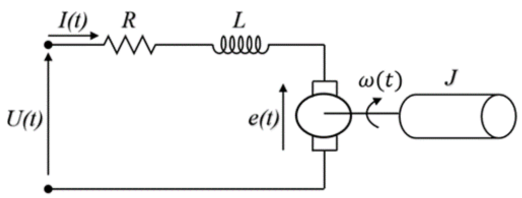


Figure 1. Representation of a DC motor model

The input of the model is the voltage source U(t) that is applied to the armature of the motor. The inductance (L) of the armature is in series connection with the resistance (R) of the armature and the induced voltage e(t) (Back Electro-Motive Force) of the motor. The direction of the induced voltage e(t) is in the opposite direction of the input voltage U(t). The output of the circuit is the angular velocity ω(t) of the rotor. The moment of inertia of the rotor is shown with J.

A. Electrical Circuit

The voltage law of Kirchhoff is used to represent the electrical circuit of the DC motor as equation 1 [18].

$$U(t) = R \cdot I(t) + L \cdot \frac{dI(t)}{dt} + e(t) \tag{1}$$

Where:

U(t): Input voltage of the armature (V)

I(t): Current of armature circuit (A)

L: Inductance of armature circuit (H)

R: Resistance of armature circuit (Ω)

e(t): Back Electro-Motive Force (V)

Back Electro-Motive Force (EMF) of the electrical circuit is shown as equation 2:

$$e(t) = K \cdot \omega(t) \tag{2}$$

Where:

K: Voltage constant of DC motor (V·s/rad)

ω(t): Angular velocity of the rotor (rad/s)

B. Mechanical Circuit

A DC motor is applying a torque that acts on the mechanical structure of the model. The torque is characterized by the moment inertia of the rotor J ($kg.m^2$) and the viscous friction coefficient B (N.m.s/rad). Newton's second law is used to represent the mechanical circuit of the DC motor as equation 3 [18].

$$K \cdot I(t) - B \cdot \omega(t) = J \cdot \frac{d\omega(t)}{dt} \tag{3}$$

By re-arranging the equation 3, the equation 4 is used to represent the current of the armature circuit as:

$$I(t) = \frac{J}{K} \cdot \frac{d\omega(t)}{dt} + \frac{B}{K} \cdot \omega(t) \tag{4}$$

By integrating from equation 4, the integral of the current of the armature is shown as equation 5:

$$\frac{dI(t)}{dt} = \frac{J}{K} \cdot \frac{d^2\omega(t)}{dt^2} + \frac{B}{K} \cdot \frac{d\omega(t)}{dt} \tag{5}$$

By replacing the equation 5 into the equation 1, the second-order linear model of DC motor will be obtained as equation 6:

$$\frac{d^2\omega(t)}{dt^2} = -\frac{JR+LB}{JL} \cdot \frac{d\omega(t)}{dt} - \frac{BR+K^2}{JL} \cdot \omega(t) + \frac{K}{JL} \cdot U(t) \quad (6)$$

By replacing $\omega(t)=y_1(t)$ and $d\omega(t)/dt=y_2(t)$, the linear first-order differential equation system will be obtained as equation 7 and equation 8. This linear model can be used for modeling and control of the DC motor when it runs at high speeds.

$$\dot{y_1}(t) = \frac{dw(t)}{dt} \quad (7)$$

$$\dot{y_2}(t) = \frac{d^2\omega(t)}{dt^2} = -\frac{JR+LB}{JL} \cdot \frac{d\omega(t)}{dt} - \frac{BR+K^2}{JL} \cdot \omega(t) + \frac{K}{JL} \cdot U(t) \quad (8)$$

C. Nonlinear Friction Model

The linear model can be utilized for mathematical modeling and control purposes only in the cases where the DC motor operates at high velocities. The existing nonlinearities such as nonlinear friction terms can be neglected for high velocities. However, the linear model is not accurate when the DC motor operates at low velocities. Since the nonlinear friction appears as a hard nonlinearity term in low-speed operation ranges, it should be considered in the model of the DC motor. A nonlinear friction model consists of Stiction fiction, Coulomb friction, and Steribeck effect terms [19]. Stiction friction occurs against the motion of the rotor when the velocity is equal to zero. Coulomb friction is related to the direction of the angular velocity of the rotor. A Steribeck effect is a friction effect that occurs when fluid lubrication is used for the contact surfaces of the rotor. The nonlinear model which represents the transition of the friction torque (T_f) from Steribeck friction (T_s) to the Coulomb friction (T_c) with the Steribeck effect is shown in Figure 2.

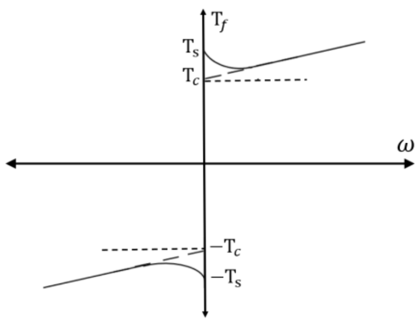


Figure 2. Representation of the nonlinear friction Model

The general form of the nonlinear friction (T_f) that includes the Stiction fiction, Coulomb friction, and Steribeck effect terms are formulated with equation 9 [19].

$$T_f = T_c \cdot sgn(\omega) + (T_s - T_c) \cdot e^{\left(\frac{|\omega|}{|\omega_s|}\right)} \cdot sgn(\omega) \quad (9)$$

Where:

T_s: The Stiction friction torque (N·m).

T_c: The Coulomb friction torque (N·m).

ω_s: The Steribeck velocity (rad/s).

III. THE METHODOLOGY OF PARAMETER ESTİMATİON

In this research, the parameters of both linear and nonlinear terms of the DC motor model are determined by employing the Particle Swarm Optimization (PSO) algorithm.

A. Particle Swarm Optimization (PSO)

Particle Swarm Optimization (PSO) is an optimization approach that is inspired by animal swarming behavior [20]. The algorithm iteratively searches for the best result in the solution space. The three main steps for obtaining the best solution are the initialization of the particle, the update of the velocity of the particle, and the update of the position of the particle. The positions of the particle are initialized randomly within the lower and upper bounds of the variables. Then, the velocity (V_{id}) of the particle uses equation 10 to direct the movement of the particles within the solution space.

$$V_{id} = \chi[V_{id} + C_1(pBest - X_{id}) \times rand_1 + C_2(gBest - X_{id}) \times rand_2] \quad (10)$$

Where:

C_1: The self-confidence (positive constant).

C_2: Swarm confidence (positive constant).

pBest: Optimal particle solution.

gBest: Optimal global solution.

X_{id}: Position of the particle.

V_{id}: Velocity of the particle.

$rand_1$ and $rand_2$: Uniformly distributed random numbers between 0 and 1.

The inertia weight is shown with χ and can be expressed as equation 11. It provides a balance between particle and global exploration.

$$\chi = \chi_{max} - \frac{\chi_{max} - \chi_{min}}{Iter_{max}} \quad (11)$$

Where the χ_{max} and χ_{min} are the initial and final inertia weights. The maximum iteration is shown with $Iter_{max}$.

After the calculation of the new velocities of the particles, the position of the particle (X_{id}) is updated as shown in equation 12. The iterative steps are repeated until the best solution is found.

$$X_{id} = X_{id} + V_{id} \quad (12)$$

B. *Main Steps for Parameter Estimation*

In the first step, the simulation data is generated through a nonlinear mathematical model of the DC motor. The model is excited through a pseudo-random binary signal (PRBS). The PRBS has a random switching time between two input voltage values of -5 (V) and 5 (V). The spectrum of PRBS input excites all of the dynamics of the system which is a very important issue in nonlinear system identification. The output of the model is the angular velocity of the rotor of the DC motor. The input and output signals are shown in Figures 3 and 4, respectively.

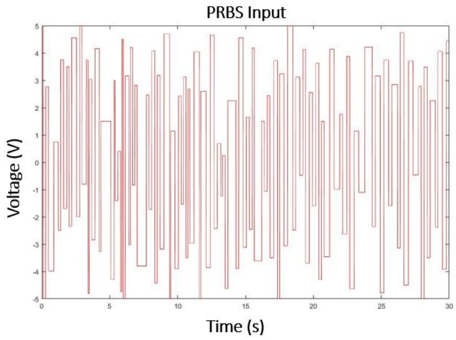


Figure 3. Input Signal

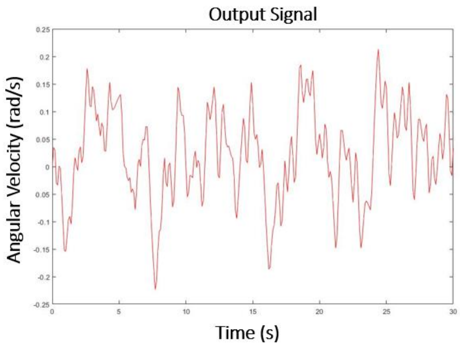


Figure 4. Output Signal

In the next step, the PSO algorithm is used to determine the parameters of the nonlinear model of the DC motor. The parameters that will be obtained through the implementation of the PSO algorithm are as follows: The parameters of the electrical circuit are inductance of the armature (L), the resistance of the armature (R), and voltage constant (K), and the parameters of the mechanical circuit are the moment of inertia of the rotor (J) and friction constant (B). The nonlinear friction parameters are Coulomb friction torque (T_c), Stiction friction torque (T_s), and Steribeck speed (ω_s). The parameter vector (x) that will be estimated through the PSO algorithm is represented as equation 13.

$$x = [L, R, K, J, B, T_c, T_s, \omega_s] \tag{13}$$

The parameters of the nonlinear model of DC motor will be determined such that the mean square error between the simulated model with original parameters and the model with estimated parameters is minimized. For this purpose, the mean square error is utilized as the objective function of the PSO algorithm. Equation 14 represents the objective function (J) of the PSO algorithm.

$$J = \frac{1}{2}\sum_{n=1}^{N} e^2 \tag{14}$$

Different parameters of the PSO algorithm and their values are shown in Table I.

Parameter	Value
Number of dimensions	8
Number of particles	40
Maximum iteration	350
C1 and C2	2
χ_{max}	0.9
X_{min}	0.4

Tablo I. Different parameters of the PSO algorithm and their values

Parameters of the nonlinear model of the DC motor are the dimensions of particles of the PSO algorithm and their bounds are given in Table II.

Dimension	Lower Bound	Upper Bound	Unit
L	0.2	0.8	H
R	0.0001	2	Ω
K	0.0001	0.02	V·s/rad
J	0.0001	0.02	$kg.m^2$
B	0.0001	0.2	N.m.s/rad
T_c	0.001	0.01	N.m
T_s	0.001	0.01	N.m
ω_s	0.01	0.09	rad/s

Tablo II. Bounds of dimensions of the PSO algorithm

I. Results and Discussion

The convergence plot of the objective function of the PSO algorithm is represented in Figure 5.

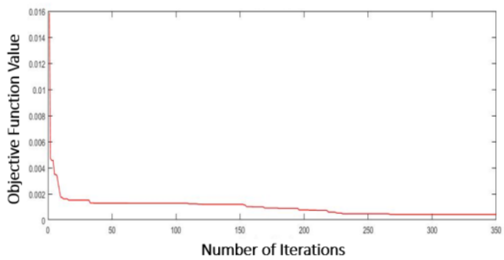


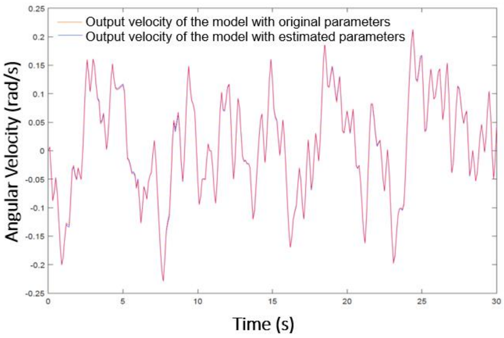
Figure 4. Output Signal

The estimated parameters through the PSO algorithm and original values of the parameters are given in Table III.

Dimension	Lower Bound	Upper Bound	Unit
L	0.2	0.8	H
R	0.0001	2	Ω
K	0.0001	0.02	V·s/rad
J	0.0001	0.02	$kg.m^2$
B	0.0001	0.2	N.m.s/rad
T_c	0.001	0.01	N.m
T_s	0.001	0.01	N.m
ω_s	0.01	0.09	rad/s

Tablo III. Estimated and original values of the parameters

The output velocities of the model with original parameters and the model with estimated parameters for PRBS voltage input are shown in Figure 6.



The results show that the parameters of the nonlinear model of the DC motor were estimated by the PSO algorithm accurately. A comparison of the model with estimated parameters and the model with original parameters shows that the estimated parameters are in close proximity with the original parameters. It shows that the PSO algorithm was able to predict all of the parameters of the model accurately. Moreover, it is shown that the PSO algorithm converges after 267 iterations. After this iteration, the mean-square-error which is described as the objective function of the PSO algorithm becomes 0.0005. It shows that the error between the model with estimated parameters and the model with original values is not significant.

II. CONCLUSİON

In this research, a Particle Swarm Optimization (PSO) algorithm was proposed for parameter estimation of the nonlinear model of a DC motor. In the first step, a general mathematical model that includes nonlinear friction terms were utilized for artificial data generation. For this aim, a Pseudo-Random Binary Signal (PRBS) which can excite all dynamics of the system, is utilized as an input signal. The angular velocity of the rotor of the DC motor was taken as the output signal. In the next step, the PSO algorithm was developed through the generated data and implemented for parameter estimation of the nonlinear model of the DC motor. The mean-square-error is utilized as the objective function of the PSO algorithm which guarantees the convergence of the identification algorithm. It was shown that the PSO algorithm can estimate the parameters of both linear and nonlinear terms of the model accurately. Eight parameters namely the inductance of the armature (L), the resistance of the armature (R), and voltage constant (K), the moment of inertia of the rotor (J), friction constant (B), Coulomb friction torque (T_c), Stiction friction torque (T_s), and Steribeck speed (ω_s), were estimated simultaneously. The accuracy of the estimated parameters was verified with the original parameters of the nonlinear model of the DC motor. The suggested algorithm was developed and implemented in the MATLAB software package.

In future work, it is planned to implement the suggested PSO algorithm to determine the parameters of the nonlinear model of a DC motor through experimental data. Moreover, the proposed algorithm will be utilized to estimate the model parameters of the other components such as solenoid actuators.

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Part IV

Appendices

Banner


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İZMİR KÂTİP ÇELEBİ UNIVERSITY
ICAII 4.0
The 3rd
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Abstract/Full Paper Submission Deadline 1 August 2020
Notification to Authors 1 September 2020
Early Registration 15 October 2020
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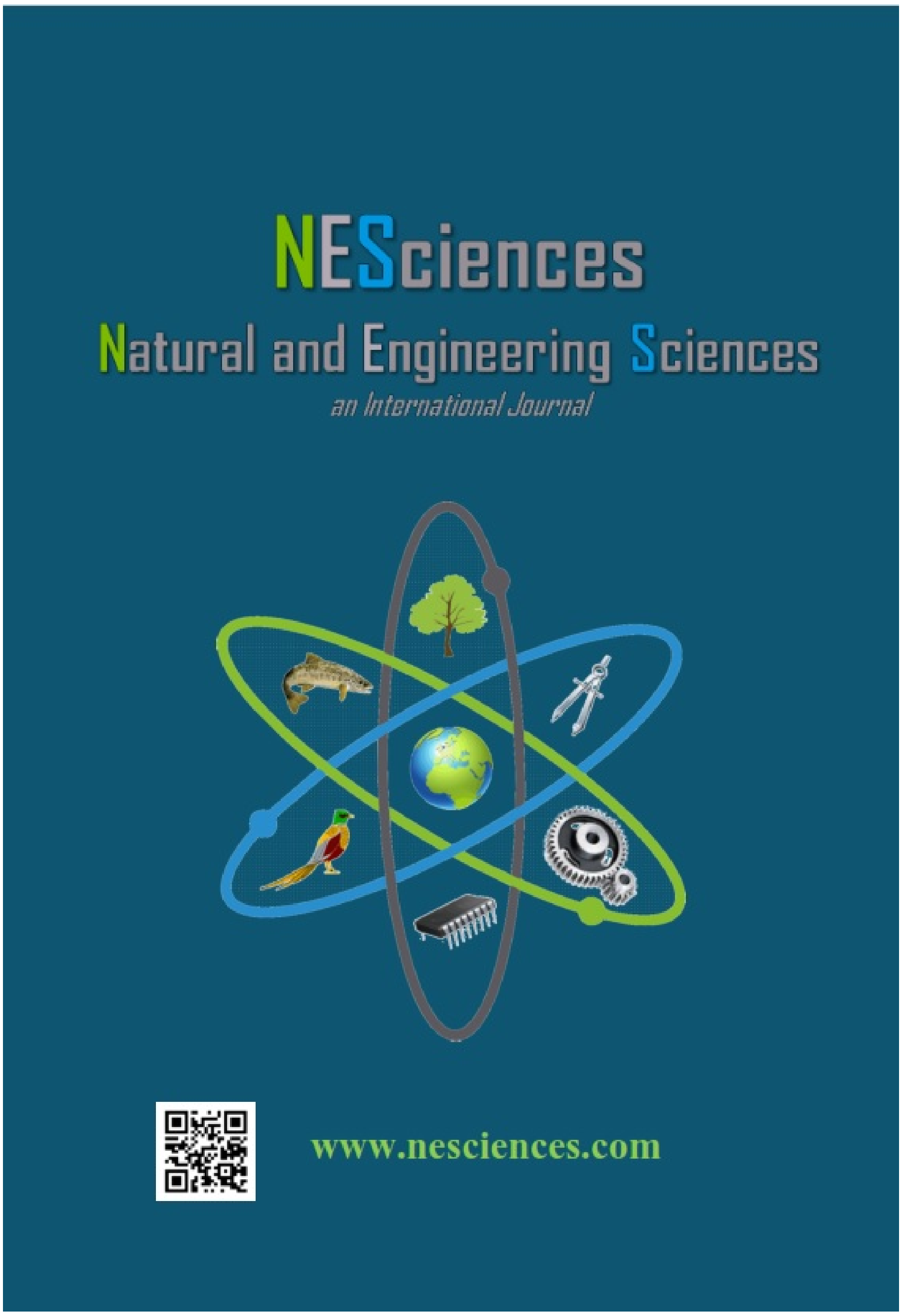
Supporting Journals

This conference is supported by two academic journals: (a) Journal of Intelligent Systems with Applications, and (b) Natural and Engineering Sciences.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3rd International Conference on Artificial Intelligence towards Industry 4.0 (ICAII4'2020)

Technical Program (November 12th, 2020 – THURSDAY)

10:30	**Opening Talk**
	Yalçın İşler, Yakup Kutlu
11:00	**Invited Talk: Selected Studies on Control Theory and Artificial Intelligence**
	Cüneyt Güzeliş
12:00	**Invited Talk: Replica Exchange Using an Augmented Molecular Dynamics Method**
	Hiqmet Kamberaj
13:00	**LUNCH BREAK**
14:00	**The Evaluation of European Airports using Clustering Methods**
	Ahmet Arif Çolakoğlu, Hüseyin Koçak
14:15	**Mini Review on Dental Imaging Devices and Use of Artificial Intelligence in Dentistry**
	Saadet Sena Egeli, Yalçın İşler
14:30	**Machine Learning Based Electric Energy Consumption Prediction of a Large-Scaled Production Plant with Small-Scaled Data**
	Anıl Çalışkan, Arif Yiğit, Volkan Özdemir
14:45	**Augmented Reality (AR) Assisted Smart Glasses Case Study for Remote Support Between Two Distant Production Plants**
	Anıl Çalışkan, Volkan Özdemir, Özgür Fırat
15:00	**Classifying Stable And Unstable Videos With Deep Convolutional Networks**
	Mehmet Sarıgül, Levent Karacan
15:15	**Effects of Industry 4.0 on Maritime Sector: A Review of Literature**
	Mahmut Mollaoğlu, Hakan Demirel, Abit Balın
15:30	**User Localization in an Indoor Environment by Combining Different Algorithms through Plurality Rule**
	Nilgün Fescioğlu Ünver, Muzaffer Cem Ataş, Osman Emre Gümüşoğlu, Aslınur Çolak
15:45	**RGB-D Object Recognition with Hierarchical Capsule Networks**
	Mert Şen, Hatice Doğan
16:00	**Predictive Maintenance Studies Applied to an Industrial Press Machine Using Machine Learning**
	Ahmet Erdem Öner, Erkut Yiğit, Mehmet Zeki Bilgin
16:15	**Investigation Of Elastic Tensile Behavior Of Thermoplastic Discs Reinforced With Steel Wires**
	Hüseyin Fırat Kayıran
16:30	**Modeling of ECG and SCG Signals Using Predefined Signature and Envelope Sets**
	Emir Hardal, İnci Zaim Gökbay
16:45	**Genetic-Algorithm-Tuned Fuzzy-Hammerstein Controller Design by Means of Human Operator Modeling**
	Şeniz Ertuğrul, Hakan Ertuğrul
17:00	**Effect of Different Batch Size Parameters on Predicting of COVID19 Cases**
	Ali Narin, Ziynet Pamuk
17:15	**Performance Comparison of Balanced and Unbalanced Cancer Data Sets using Pre-Trained Convolutional Neural Network**
	Ali Narin
17:30	**End of the First Day**

3rd International Conference on Artificial Intelligence towards Industry 4.0 (ICAII4'2020)

Technical Program (November 13th, 2020 – FRIDAY)

11:00	**Invited Talk: Eye-Tracking: What You See is What Science Gets**
	Yılmaz Kemal Yüce
12:00	**LUNCH BREAK**
14:00	**Patient Survival Prediction with Machine Learning Algorithms**
	Mustafa Berkant Selek, Saadet Sena Egeli, Yalçın İşler
14:15	**Classification of Phonocardiography Signals Using Imbalanced Machine Learning Algorithms**
	Mustafa Berkant Selek, Sude Pehlivan, Yalçın İşler
14:30	**Virtual Reality Applications in Nursing**
	Sude Pehlivan, Gizem Arslan, Yasemin Tokem, Yalçın İşler
14:45	**Electromagnetic Weaponed Based Anti Terrorism Robot**
	Mert Demir
15:00	**Electromagnetic Weaponed Air Robot**
	Mert Demir
15:15	**Artificial Intelligence - Human Health-Genetic Algorithm And Diet**
	Hüseyin Fırat Kayıran, İlknur Abacı
15:30	**Effect of Deep Learning Feature Extract Techniques on Respiratory Sounds**
	Osman Ballı, Yakup Kutlu
15:45	**Use of Artificial Intelligence in Production of Desired Quality Steel in Ladle Furnaces in Iron and Steel Industry**
	Gökçe Özdeş, Yakup Kutlu
16:00	**Usage of Machine Learning Methods on Precision Agriculture Applications**
	Yekta Can Yıldırım, Mustafa Yeniad
16:15	**Identification of a Nonlinear DC Motor Model with Particle Swarm Optimization**
	Şeniz Ertuğrul, Masoud Abedinifar, Ömer Faruk Argın
16:30	**The Use of Turkish NLP-capable Humanoid Robot in Education of Autistic Children**
	Kadir Tohma, Yakup Kutlu
16:45	**Closing Talk**
	Yalçın İşler, Yakup Kutlu
17:30	**Private Meeting for the Organization Committee**

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