DESIGN AND DEVELOPMENT OF AN ONTOLOGY-BASED HAZELNUT DATABANK FOR TURKISH HAZELNUT CULTIVARS USING CROP-SPECIFIC OPEN DATASET

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ABSTRACT

Agriculture is one of the oldest professions in the history, it still plays the main role in economy for almost entire countries around the world. The activities performed by farmers in agriculture domain have been changed and developed over thousands of years. There have been several challenges that agriculture sector is facing like population growing, labor migration, in addition many young people are reluctant to work in the agricultural field.

By 2050 population will increase with 2 billion mean while arable land will growth with only 4%, that means lower agricultural yields versus demand, higher crop prices, and increased food security concerns if farmers continue to adopt traditional agricultural methods. The emerging technologies such as Artificial Intelligence (AI) and Internet of Things (IoT) can be used to provide robust solutions for overcoming the challenges in the context of agriculture. In addition, such technologies can help farmers for performing agricultural activities more precisely and for protecting agricultural crops from climate changes in a more effective way.

The main objective of this thesis is to develop an integrated databank software system by using two different AI models to classify the Turkish Hazelnut Cultivars. While classifying the cultivars, databank is using ontology-based open data sets in different formats such as RFD/XML and RDF/JSON. Furthermore, an IoT-based device has been developed to classify the cultivars. The databank consists of a web-based and desktop-based applications. The AI models have been developed using .NET ML with the accuracy 90.34% and Python with the accuracy 85.32% respectively.

Key words: IoT, AI, Smart Agriculture, .NET ML, Python, Hazelnut Classification, Turkish Hazelnut Cultivars Classification, Hazelnut Databank.

TÜRK FINDIK ÇEŞİTLERİ İÇİN ÜRÜNE ÖZGÜ AÇIK VERİ SETLERİ KULLANILARAK ONTOLOJİ TABANLI FINDIK VERİ BANKASI TASARIMI VE GELİŞTİRİLMESİ

ÖZET

Tarım, tarihin en eski mesleklerinden biridir ve halen dünyanın hemen hemen tüm ülkeleri için ekonomide en temel rolü oynamaktadır. Çiftçilerin tarım alanında gerçekleştirdiği faaliyetler binlerce yıl içinde değişmiş ve gelişmiştir. Nüfus artışı, işgücü göçü gibi tarım sektörünün karşı karşıya olduğu çeşitli zorluklar var, buna ek olarak birçok genç tarım alanında çalışmak konusunda isteksiz.

2050 yılına kadar nüfus ortalama 2 milyar artarken ekilebilir araziler sadece %4 oranında büyüyecek, bu da talebe kıyasla daha düşük tarımsal verim, daha yüksek mahsul fiyatları ve çiftçiler geleneksel tarım yöntemlerini benimsemeye devam ederse artan gıda güvenliği endişeleri anlamına geliyor. Yapay Zeka (AI) ve Nesnelerin İnterneti (IoT) gibi gelişmekte olan teknolojiler, tarım alanındaki zorlukların üstesinden gelmek için sağlam çözümler sağlamak için kullanılabilir. Ayrıca bu tür teknolojiler, çiftçilerin tarımsal faaliyetlerini daha hassas gerçekleştirmelerine ve tarımsal ürünleri iklim değişikliklerinden daha etkin bir şekilde korumalarına yardımcı olabilir.

Bu tezin temel amacı, Türk Fındık Çeşitlerini sınıflandırmak için iki farklı AI modeli kullanarak entegre bir veri bankası yazılım sistemi geliştirmektir. Veri bankası çeşitleri sınıflandırılırken RFD/XML ve RDF/JSON gibi farklı formatlarda ontoloji tabanlı açık veri setleri kullanılmaktadır. Ayrıca, çeşitlerin sınıflandırılması için IoT tabanlı bir cihaz geliştirilmiştir. Veri bankası web tabanlı ve masaüstü tabanlı uygulamalardan oluşmaktadır. AI modelleri, sırasıyla %90.34 doğrulukla .NET ML ve %85.32 doğrulukla Python kullanılarak geliştirilmiştir.

Anahtar Kelimeler: Nesnelerin İnterneti, Yapay Zeka, Akıllı Tarım, .NET ML, Python, Fındık Sınıflandırma, Türk Fındık Çeşitlerinin Sınıflandırılması, Fındık Veri Bankası.

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Dieaa ALDARA

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CHAPTER 1

1. INTRODUCTION

Turkey is the first country in the production of hazelnuts, 60% of world production is produced in Turkey. Hazelnut cultivation provides job opportunities for about 4 million people directly or indirectly in Turkey. The areas occupied by hazelnut cultivation in Turkey are estimated at about 550-600K hectares. Usually classifying Hazelnut varieties is done manually so it needs a lot of efforts and time.

This thesis is going to design and develop an ontology based Hazelnut databank for Turkish Hazelnut cultivars using crop specific open dataset.

This model will classify Turkish hazelnut cultivars using ML, the model will have an IoT device that consists of Raspberry Pi computer, the proposed application will use the camera to take a photo for hazelnut then send it to the model to classify then send the result back to stakeholder.

Beside of IoT device the propose application will also support web application, Windows form app, and web API.

An open data bank will be available to researchers who would like to apply further studies on Hazelnut, that data bank will contain all images that classify using the application.

Two models have been developed using python and .Net framework. The network structure and the performance of each model will also discuss in this thesis.

CHAPTER 2

2. LITERATURE REVIEW

Focus of the Thesis

The novel of this thesis can be explore in two sides, developing hazelnut cultivars classifier based on AI using different frameworks, then consume that model using IoT based application, web API based application and web application. AI model has been developed using Python and .Net framework, the study provided comparison between both models during developing steps and the performance of each model.

IoT based application has been developed using Raspberry pi computer with a camera, the training Python model has been installed to raspberry pi computer, the user can take an image using provided camera, then captured image will send to python classifier, and lastly the result will be shown to the user.

Web based application consist of an html web page where user can upload the studied image, that image will forward to the model and the result will be returned to the user.

.Net model will consume using web API and Windows form application. A friendly interface has been developed in the scope of this project, the interface has browse button to choose the image, after choosing it, the image will display on the window, and the result will be displayed on the screen once the model makes the predict.

An open data bank has been created using the proposed model, the bank will be available for researchers to apply further studies in agriculture domain specifically about hazelnut.

Image classified by the model will upload to the data bank according to its class.

The open data bank will give the researchers chance to do further studies in order to develop smart applications in hazelnut field not only in Turkey but all over the world.

2.1 Related Work

The need for technology adoption is increasing as traditional farming methods would not be able to meet the demand for food. (United Nations. (n.d.). UN calls for urgent action to feed the world's growing population healthily, equitably and sustainably).

The development of Internet of things (IoT). (Sharma, D. K., Bhargava, S., & Singhal, K. (2020). Internet of Things applications in the pharmaceutical industry. *An Industrial IoT Approach for Pharmaceutical Industry Growth: Volume* 2, 153–190). has potential to transform the way agriculture is done. IoT is a network of physical objects that can be used to collect and exchange data. (Matta, P., & Pant, B. (2019). Internet of things: Genesis, challenges and applications. Journal of Engineering Science and Technology, 14(3), 1717-1750).

The use of the Internet of things can help to reduce the number of manual tasks that are performed in agriculture. It can also make the farming process more profitable by allowing the system to make informed decisions. The combination of the Internet of things and artificial intelligence (AI) (Shi, Y., Yang, K., Yang, Z., & Zhou, Y. (2022). Motivations and organization. Mobile Edge Artificial Intelligence, 3–5), can create powerful systems that can perform various tasks and operations with accuracy and reliability just like human brain.

These systems can be used to perform different tasks such as speech recognition and visual perception. (Yang, L. B. (2020). Application of Artificial Intelligence in Electrical Automation Control. Procedia Computer Science, 166, 292–295). The combination of artificial intelligence and the Internet of things is considered one of the most promising technologies for agriculture.

Artificial Intelligence, sensors, and robotic systems have been used in the development of precision agriculture (PA) or precision farming (PF). This is a broad concept that refers to the use of technology to improve the efficiency of farming. The concept of PF is a control system that monitors the various aspects of a farm's environment and crops. This system can help improve the quality of the farm's produce. (Paustian, M., Theuvsen, L. (2017). Adoption of precision agriculture technologies by German crop farmers. Precision Agric 18, 701–716), (Zhang, N., Wang, M., & Wang, N. (2002). Precision agriculture—a worldwide overview. Computers and Electronics in Agriculture, 36(2–3), 113–132.), (Abdul Hakkim V.M, Abhilash Joseph E., Ajay Gokul AJ, Mufeedha K. (2016) Precision Farming: The Future of Indian Agriculture. J App Biol Biotech; 4 (06): 068-072. DOI: 10.7324/JABB.2016.40609), (Pierce, F. J., & Nowak, P. (1999). Aspects of Precision Agriculture. Advances in Agronomy, 67(C), 1–85), (Stafford, J. v. (2000). Implementing Precision Agriculture in the 21st Century. Journal of Agricultural Engineering Research, 76(3), 267–275).

The aim of IoT is to collect real time data. However, this data is in most often is not organize or structure. At the beginning of the technology's development, the data collected by the device was very limited. There was no need for AI to perform any processing. The complexity of IoT systems eventually led to the need for more sophisticated analysis tools. AI algorithms are capable of handling the vast amount of data collected by IoT (Big Data). They can then provide useful insights to improve the efficiency of the system. New methods and techniques for problem solving and automation were introduced in the field of agriculture, some of these include machine learning, natural language processing (NLP), and artificial neural networks (ANN) (Sneha, P., Thirumal Kumar, D., Saini, S., Kajal, K., Magesh, R., Siva, R., & George Priya Doss, C. (2017). Analyzing the Effect of V66M Mutation in BDNF in Causing Mood Disorders: A Computational Approach. Advances in Protein Chemistry and Structural Biology, 108, 85–103), Computer Vision (CV).

ANN and CV are commonly used in research studies related to the automation in agriculture. Aside from the usual methods, machine learning can be used to perform on labeled or unlabeled data as well. Most of the automated systems in agriculture follow the supervised learning techniques. ANN is widely used in the development of complex classification systems.

ANN is inspired by the principles of biology. It can learn complex relationships using a layer-by-layer approach. Deep learning based on CV techniques are commonly used in agriculture to perform various tasks are generally built based on Convolutional Neural Network (CNN).

The combination of (IoT) and (AI) has been used in the development of (PF). Collected data from cameras and sensors will be analyzed to provide a decision-making process. It can also be used to detect diseases in livestock. (Abdmeziem, M.R., Tandjaoui, D., Romdhani, I. (2016). Architecting the Internet of Things: State of the Art. In: Koubaa, A., Shakshuki, E. (eds) Robots and Sensor Clouds. Studies in Systems, Decision and Control, vol 36. Springer, Cham), (Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013). Internet of Things (IoT): A vision, architectural elements, and future directions. Future Generation Computer Systems, 29(7),1645–1660)

A smart beehive system is an IoT and AI system that uses the data collected by its sensors to analyze and monitor the behavior of bees inside. It can provide the best possible conditions for the bees in order to improve their productivity. (Asikainen, M., Haataja, K., & Toivanen, P. (2013). Wireless indoor tracking of livestock for behavioral analysis. In 2013 9th International Wireless Communications and Mobile Computing Conference (IWCMC) (pp. 1833-1838). IEEE), (Huircán, J. I., Muñoz, C., Young, H., von Dossow, L., Bustos, J., Vivallo, G., & Toneatti, M. (2010). ZigBee-based wireless sensor network localization for cattle monitoring in grazing fields. Computers and Electronic in agriculture ,74(2),258–264), (Mamduh, S., Shakaff, A., Saad, S., Kamarudin, K., Kamarudin, L., Zakaria, A., Kamarudin, H., Ezanuddin, A., Saad, F., Nooriman, W., & Abdullah, A. (2012). Odour and Hazardous Gas Monitoring System for Swiftlet Farming using Wireless Sensor Network (WSN). Chemical Engineering Transactions, 30, 331-336).

Besides agriculture, other industries are also using AI and IoT to develop their smart systems. For instance, in health (Islam, S. M. Riazul & Kwak, Daehan & Kabir, Md. Humaun & Hossain, Mahmud & Kwak, Kyung. (2015). The Internet of Things for Health Care: A Comprehensive Survey. IEEE Access. 3. 678-708. 10.1109/ACCESS.2015.2437951), care and self-driving cars. (B. V. Philip, T. Alpcan, J. Jin and M. Palaniswami, (2019). Distributed Real-Time IoT for Autonomous Vehicles, in IEEE Transactions on Industrial Informatics, vol. 15, no. 2, pp. 1131-1140, doi: 10.1109/TII.2018.2877217).

IoT system is composed of various parts, such as things or objects that collect the data, cameras, and wireless sensors. In most cases, sensors are used in agriculture to collect information and conditions. There are 15 types of wireless sensors that are commonly used in this field.

1- **Acoustic Sensors**: The advantages of using an acoustic sensor are its low coast and fast response. it can be used to classify the seed based on the sound absorption spectra. For instance, detecting pests using this type of sensor can be done with sound absorption spectra. (Kong, Qingzhao, Hongli Chen, Yi-lung Mo, and Gangbing Song. (2017). "Real-Time Monitoring of Water Content in Sandy Soil Using Shear Mode Piezoceramic Transducers and Active Sensing—A Feasibility Study" Sensors 17, no. 10: 2395), (Srivastava, N, Chopra, G., Jain, P., & Khatter, B. (2013). Pest monitor and control system using wireless sensor network with special reference to acoustic device wireless sensor. In International conference on electrical and electronics engineering (Vol. 27)), (Gasso-Tortajada, Vicent, Alastair J. Ward, Hasib Mansur, Torben Brøchner, Claus G. Sørensen, and Ole Green. (2010). A Novel Acoustic Sensor Approach to Classify Seeds Based on Sound Absorption Spectra Sensors 10, no. 11: 10027-10039).

2- **(FPGA)-Based Sensors:** Various factors, such as humidity, plant-transpiration, and irrigation, have been started to be measured in FPGA sensors. Due to their high power requirements, they are only used for certain applications. (Millan-Almaraz, Jesus Roberto, Rene de Jesus Romero-Troncoso, Ramon Gerardo Guevara-Gonzalez, Luis Miguel Contreras-Medina, Roberto Valentin Carrillo-Serrano, Roque Alfredo Osornio-Rios, Carlos Duarte-Galvan, Miguel Angel Rios-Alcaraz, and Irineo Torres-Pacheco. (2010). FPGA-based Fused Smart Sensor for Real-Time Plant-Transpiration Dynamic Estimation Sensors 10, no. 9: 8316-8331), (Husni, M. I. (2018). Soil Moisture Monitoring Using Field Programmable Gate Array | Husni | Indonesian Journal of Electrical Engineering and Computer Science, (De la Piedra, Antonio, An Braeken, and Abdellah Touhafi. (2012). Sensor Systems Based on FPGAs and Their Applications: A Survey Sensors 12, no. 9: 12235-12264).

3- **Optical sensor:** Soils are known to have various properties such as their moisture, organic substances, and mineral deposits. Optical sensor can be used to measure these properties by analyzing the light reflected from the soil. The sensor then finds out how the changes in the soil's properties happened. (Murray, S. C. (2018). Optical sensors advancing precision in agricultural production. Photon. Spectra, 51(6), 48), (Povh, F. P., dos Anjos, W. D. P. G., Yasin, M., Harun, S. W., & Arof, H. (2014). Optical sensors applied in agricultural crops. Optical Sensors-New developments and practical applications, 141-163), (Pajares, Gonzalo. (2011). Advances in Sensors Applied to Agriculture and Forestry Sensors 11, no. 9: 8930-8932), (Molina, Iñigo, Carmen Morillo, Eduardo García-Meléndez, Rafael Guadalupe, and Maria Isabel Roman. (2011). Characterizing Olive Grove Canopies by Means of Ground-Based Hemispherical Photography and Spaceborne RADAR Data Sensors 11, no. 8: 7476-7501).

4- **Ultrasonic Ranging Sensors:** The advantages of using ultrasonic ranging sensor are its low coast and easy to implement. It can be used for various applications such as object detection and water consumption by plants. (Dvorak, J. S., Stone, M. L., & Self, K. P. (2016). Object detection for agricultural and construction environments using an ultrasonic sensor. Journal of agricultural safety and health, 22(2), 107-119), (Gómez Álvarez-Arenas, Tomas, Eustaquio Gil-Pelegrin, Joao Ealo Cuello, Maria Dolores Fariñas, Domingo Sancho-Knapik, David Alejandro Collazos Burbano, and Jose Javier Peguero-Pina. 2016. Ultrasonic Sensing of Plant Water Needs for Agriculture Sensors 16, no. 7: 1089), (Pajares, Gonzalo, Andrea Peruzzi, and Pablo Gonzalez-de-Santos. (2013). Sensors in Agriculture and Forestry Sensors 13, no. 9: 12132-12139).

5- **Optoelectronic Sensors:** An Optoelectronic sensor can be used to identify and map the distribution of weeds and other unwanted plants. This sensor can also be combined with a location information sensor to improve the resolution of the data. (Andújar, Dionisio, Ángela Ribeiro, César Fernández-Quintanilla, and José Dorado. (2011). Accuracy and Feasibility of Optoelectronic Sensors for Weed Mapping in Wide Row Crops Sensors 11, no. 3: 2304-2318).

6- **Airflow Sensors:** These sensors can measure the moisture content of soil, air permeability, and soil structure. They can also identify the type of soil. The pressure that's applied to the soil in order to push the air into the ground is then measured. It can be done on a fixed or dynamic positions. (García-Ramos, F. Javier, Mariano Vidal, Antonio Boné, Hugo Malón, and Javier Aguirre. (2012). Analysis of the Air Flow Generated by an Air-Assisted Sprayer Equipped with Two Axial Fans Using a 3D Sonic Anemometer Sensors 12, no. 6: 7598-7613).

7- **Electrochemical Sensors:** This tool is used to analyze the soil's nutrient levels by analyzing the various characteristics of the soil like PH [34], macro and micro nutrients in the soil are all measured with this sensor. (Yew, T. K., Yusoff, Y., Sieng, L. K., Lah, H. C., Majid, H., & Shelida, N. (2014). An electrochemical sensor ASIC for agriculture applications. In 2014 37th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO) (pp. 85-90). IEEE).

8- **Electromagnetic Sensors:** Soil can be measured with electromagnetic sensors to determine its ability to carry or accumulate electrical charge. These sensors can be used to identify electrical response, record electrical conductivity, and accumulate electrical charge. In addition, they can also be used to monitor the presence of organic matter and nitrates in the soil. (Cocovi-Solberg, D. J., Rosende, M., & Miró, M. (2014). Automatic Kinetic Bioaccessibility Assay of Lead in Soil Environments Using Flow-through Microdialysis as a Front End to Electrothermal Atomic Absorption Spectrometry. Environmental Science &Amp; Technology, 48(11), 6282–6290).

9- **Mechanical Sensors:** The mechanical sensors are used to determine the level of compaction in the soil. They can then record the force that was applied to the surface by strain gauges or load cells. A pressure unit is also used to measure the soil's mechanical resistance. The force that was required to go into the medium through the frontal portion of the tool is the ratio of the force that was needed to move the soil into place. (Yunus, M. A. M., & Mukhopadhyay, S. C. (2010). Novel planar electromagnetic sensors for detection of nitrates and contamination in natural water sources. IEEE Sensors Journal, 11(6), 1440-1447).

10- **Mass Flow Sensors:** This type of sensor is mainly used for yield monitoring, as it allows the system to measure the amount of grain that's moving through a combine harvester. (Hemmat, A., Binandeh, A. R., Ghaisari, J., & Khorsandi, A. (2013). Development and field testing of an integrated sensor for on-the-go measurement of soil mechanical resistance. *Sensors and Actuators A: Physical*, *198*, 61–68).

11- **Eddy Covariance-Based Sensors:** The sensor is used to measure the exchange of energy and greenhouse gases between the Earth and the atmosphere. It can be used to measure the surface-atmosphere flux of various greenhouse gases and energy sources. This technology has been preferred over other sensors due to its high accuracy and its ability to continuously measure the flux over large areas. (Schuster, Jason N, Darr, Matthew J, McNaull, Robert P, (2017) Performance benchmark of yield monitors for mechanical and environmental influences, ASABE Annual International Meeting 1700881.(doi:10.13031/aim.201700881).

12- **Soft Water Level-Based (SWLB) Sensors:** Soil moisture level sensors (SWLBs) are used to monitor the flow and level of water in agricultural areas. They can also be used to analyze the effects of rainfall and other water sources on the ecosystem. (Moureaux, C. *et al*. (2012). Eddy Covariance Measurements over Crops. In: Aubinet, M. Vesala, T. Papale, D. (eds) Eddy Covariance. Springer Atmospheric Sciences. Springer, Dordrecht.

13- **Light Detection and Ranging (LIDAR):** This technology is widely used in agriculture to perform various tasks, such as land mapping, segmentation, and 3D modelling. (Crabit, Armand, François Colin, Jean Stéphane Bailly, Hervé Ayroles, and François Garnier. (2011). Soft Water Level Sensors for Characterizing the Hydrological Behaviour of Agricultural Catchments Sensors 11, no. 5: 4656-4673). It can also be used to monitor the soil type and its degradation, and produce a 3D map of the entire plant. In addition, it can also be used to estimate the biomass of various trees and crops. (Weiss, U., & Biber, P. (2011). Plant detection and mapping for agricultural robots using a 3D LIDAR sensor. *Robotics and Autonomous Systems*, *59*(5), 265–273).

14- **Telematics Sensors:** A telemetry sensor is a device that collects data from various sources such as remote locations and operations of machines. These can then be used to improve the efficiency of operations by monitoring the condition of the components then the machine does not have to visit that location again. (Montagnoli, A. Fusco, S., Terzaghi, M. *et al.* Estimating forest aboveground biomass by low density lidar data in mixed broad-leaved forests in the Italian Pre-Alps. *For. Ecosyst.* **2**, 10 (2015). Through the use of these services, farm managers can keep track of all the details related to their operations. This eliminates the need for manual entries and helps minimize the risk of equipment theft.

15- **Remote Sensing:** These sensors can collect and store spatial and geographical data. It can be used in various applications such as mapping and analysis, forecasting, and crop assessment. Similar to LIDAR, these sensors also find applications in agriculture, where they can be used to identify and monitor various pests and plants. (Mark, T., & Griffin, T. (2016). Defining the barriers to telematics for precision agriculture: Connectivity supply and demand (No. 1376-2016-109815)), (Jaafar, H. H., & Woertz, E. (2016). Agriculture as a funding source of ISIS: A GIS and remote sensing analysis. *Food Policy*, *64*, 14–25), (Yalew, S.G. van Griensven, A., Mul, M.L. *et al.* Land suitability analysis for agriculture in the Abbay basin using remote sensing, GIS and AHP techniques. *Model. Earth Syst. Environ.* **2**, 101 (2016)).

The gateway is another part of the IoT system. It's a combination of encryption, protocol, and data filtering. The data collected by sensors are then sent to the server by gateway. The communication technology of the IoT system is a major component that needs to be considered in order to ensure the efficient and effective sharing of data between various parts of the system like health system. Due to the increasing number of sensors and the need for reliable and secure data transmission, the use of 3G, 4G, and WIFI is becoming more prevalent. (Hegazy, I. R., & Kaloop, M. R. (2015). Monitoring urban growth and land use change detection with GIS and remote sensing techniques in Daqahlia governorate Egypt. *International Journal of Sustainable Built Environment*, *4*(1), 117–124).

The last part of IoT system is the Server or the Cloud, where the data will be stored in that part. Since the data is usually large and unstructured, traditional databases are not ideal for storing it. NoSQL databases are commonly used in the cloud to store these types of data. They are designed to store these types of data in a fast and secure manner.

AI application could be run in this part in smart IoT system. The data retrieved from the database in various formats, such as CSV, Excel, and Images. The pre-processing steps are usually performed to remove outliers and normalize the data. After the data is processed, it is divided into a train, a validation, and a test set. The various algorithms that can be applied to the data are based on the type of operation that will be performed.

A training dataset is used to train the model. The model is then subjected to various tests to check its accuracy and performance. The K-Fold Cross-validation method is used to check the model stability. The recall values derived from the data are then used to estimate the model's quality. Due to the variations in the architecture of CNN, its performance has been very promising in extracting image features from data. Once the model has been validated then it can be deployed in the cloud to generate results for unknown data. Through the smart agriculture model, farmers can now receive intelligent recommendations and decisions regarding to their farming operations. It can also help them make informed decisions and improve their efficiency. With the help of a smartphone, farmers can easily access the model and perform various actions. Farmers can also receive notifications regarding to the status of their operations through various forms of communication, such as email and text messages. Mobile applications are also commonly used to communicate with the farmers. These allow them to monitor and control their farm activities.

AI algorithms are capable of handling the vast amount of data collected by IoT. They can then provide useful insights to improve the efficiency of the system. CNN, ANN and RNN are some examples about AI algorithms has made significant progress in its development and performance in various ANNs. (G. V. Vivek and M. P. Sunil, (2015) Enabling IOT services using WIFI - ZigBee gateway for a home automation system, IEEE International Conference on Research in Computational Intelligence and Communication Networks (ICRCICN), 2015, pp. 77-80, doi: 10.1109/ICRCICN.2015.7434213), such as image segmentation, detection, and classification. CNN multiple feature extraction by setting up layers and convolution operations stages, which are mainly used for deep learning, have allowed it to perform exceptional performance.

A CNN model can classify an image by going through various layers, such as a convolutional layer, a filtering layer, and a fully connected layer. Convolution layer is used to extract the features from the images, while a 2D or 3D kernel is used to perform elementwise multiplication and sum the results. The following procedure generates a feature map of the object. Convolutional operations are helpful in various operations, such as edge detection and sharpening. The output of these operations is then assigned to the activation units. The ReLU, Tanh, and Singmoid activation functions are commonly used in the CNN to perform various pool operations. In the next stage, the CNN performs a reduction in the number of parameters in order to minimize the image size. Some of the important factors that are considered when performing the pool operation include Max pooling, average pooling, sum pooling, and min pooling. Max pooling takes into account the largest element from the previous layer's output. Average pooling takes into account the average of the patch values from the feature map. The next step involves generating a vector matrix of values that is then fed to a fully connected network. The model is then used to classify the outputs into various classes. Further details about CNN and ANN will be provided in the Neural Networks section.

Classification systems are widely used in agriculture sector. AI model that classify cherry fruit depends on its appearance, to achieve this, a combination of image processing techniques and CNN was used. (Indolia, S., Goswami, A. K., Mishra, S. P., & Asopa, P. (2018). Conceptual understanding of convolutional neural network-a deep learning approach. Procedia computer science, 132, 679-688).
Classifying lemons based on its shape, variant AI methods CNN, KNN, ANN, Fuzzy, SVM and DT were used. (Momeny, M., Jahanbakhshi, A., Jafarnezhad, K., & Zhang, Y. D. (2020). Accurate classification of cherry fruit using deep CNN based on hybrid pooling approach. *Postharvest Biology and Technology*, *166*, 111204).

Classification of corn seed varieties: Maintaining the purity of seed varieties is very important to ensure the crop yield and quality of their products. Traditional methods of classifying resulted in high error rates and time-consuming processes. With the help of AI, we can now classify seed varieties with high precision and reduce the time and coast. (Jahanbakhshi, A., Momeny, M., Mahmoudi, M., & Zhang, Y. D. (2020). Classification of sour lemons based on apparent defects using stochastic pooling mechanism in deep convolutional neural networks. *Scientia Horticulturae*, *263*, 109133).

Classification, and mapping of coffee fruits: The model was able to classify and detect coffee fruits using a computer vision system. It also mapped the fruits' maturation stage during harvest. (Javanmardi, S., Miraei Ashtiani, S. H., Verbeek, F. J., & Martynenko, A. (2021). Computer-vision classification of corn seed varieties using deep convolutional neural network. *Journal of Stored Products Research*, *92*, 101800).

Disease and pest infection detection in coconut tree: A computer vision model was developed to identify three different types of coconut disease: stem bleeding disease, leaf blight disease, and pest infection by the red palm weevil. (Bazame, H. C., Molin, J. P., Althoff, D., & Martello, M. (2021). Detection, classification, and mapping of coffee fruits during harvest with computer vision. *Computers and Electronics in Agriculture*, *183*, 106066).

Neural Networks

One of the most popular machine learning algorithm is Neural Network. The network structure consists of at least 2 layers, input and output layer, the network could also have one or multiple in between layers called hidden layers. Each layer has number of neuron with the same operation, each neuron accepts multiple inputs and produce one output.

The data will feed the network from the input layer, then process it through hidden layers then return the result from output layer, that process called Forward Propagation.

The result produced will compare with the actual result to make the output as close to real output.

Each neuron is contributing in that output is responsible about the error value, the way to reduce that error is by minimize the value / weight "w" of each neuron that are contributing more to the error while moving back through the network, that process called as Backward Propagation. The complete cycle "backward Propagation and Forward Propagation" is called an Epoch.

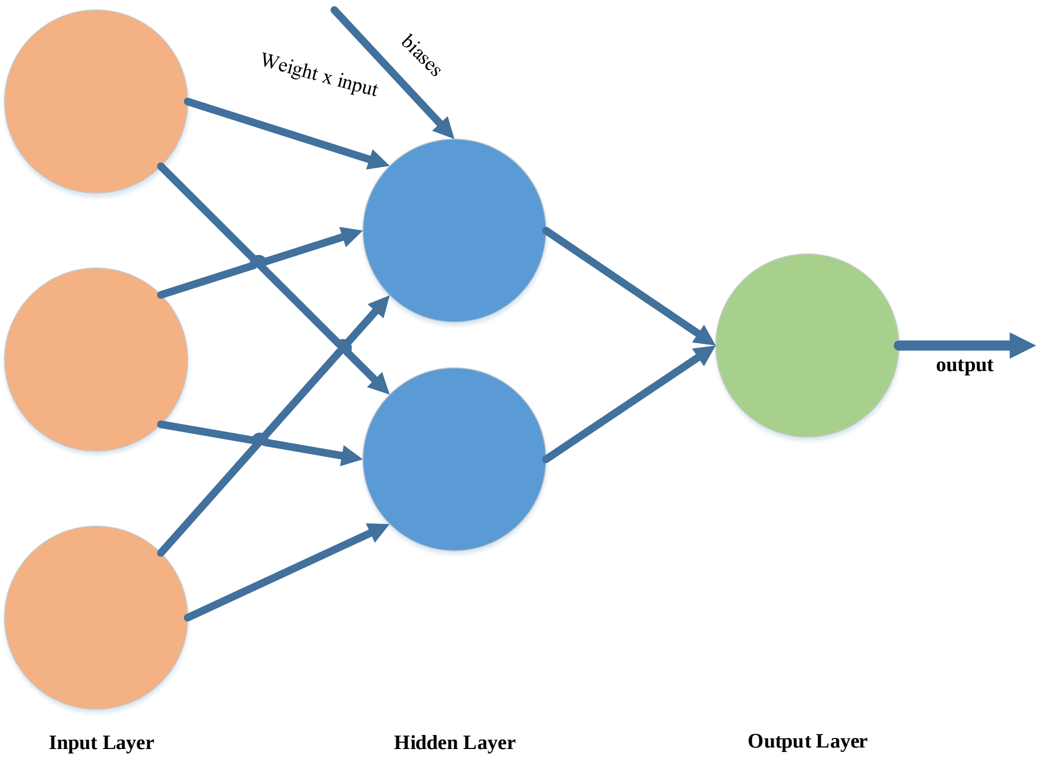

Figure 1. Neural Network Structure

Weight and biases are initializing with random values at the first epoch. The images that will feed the network which is an 2D or 3D array will be converted into a ‘vector’ of pixels. Each neuron in the input layer will do multiply the input value with w then the output will be as an input to the neurons in the next layer. Each Neuron in the next layer will add its input to the bias value then apply activation function on the result to produce its output. The aim of training is find the boundary line that will be used in classifying, activation function will convert the Decision boundary from being a linier into a non-liner which is more efficient in classification. Figure 2 shows the graph of linear and non-linear functions.

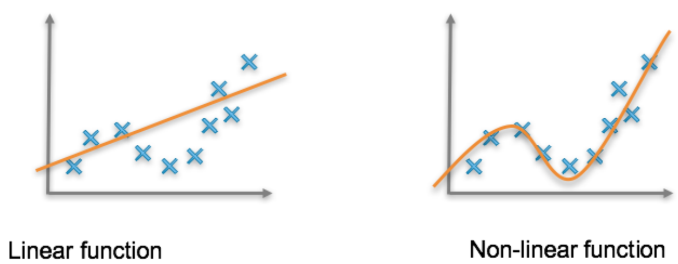

Figure 2. Liner and non-liner boundary

Neural network has different type, this thesis will explain within some details 2 type of neural network, CNN and ANN and the different between them.

Artificial Neural Network “ANN”: a network of multiple layers where each layer consists of a number of neurons / perceptrons, because the inputs are processed only in forward direction so this network known as Feed-Forward Neural network.

With the help of activation function ANNs are able to learn any nonlinear function, the network has ability to learn weights that map any input to output. Nonlinear activation function allows this network to learn any complex relationship between input and output.

ANN down sides can be summarized into three points

1- In image classification, converting 2 dimensional image into one dimensional vector then the number of trainable parameters will dramatically increase when the size of image increase
2- losing spatial features of the image that means the network cannot detect the object if it was located in different places of the image.
3- Vanishing and Exploding Gradient: this issue is related with backpropagation algorithm that is used to reduce the error using derivative operation, the weight of network will have updated through backpropagation, this issue occurs in networks that have huge number of hidden layers.
4- Capture sequential information from input data cannot be done using ANN so this network is not a good option to process audio data.

Convolution Neural Network (CNN): The best solution for image classifying is using CNN network, the basic different between CNN and ANN is the Kernels / filters which is the main part in Convolution Neural Network, that filter is used to extract the features in order to build features map by sliding it on the entire image.

The kernel size plays a massive roll in the network performance, small kernel can extract larger amount of information that means more features from the input, also smaller kernel will lead to a smaller reduction in layer dimensions, that allow to build deeper structure with no concern about applying more computation during training that can lead to Vanishing and Exploding Gradient.

Applying filter on image help to solve issues like spatial features from an image so CNN can detect the object wherever it is located in the image.

Parameter sharing is another advantage of CNN, a single filter / kernel is used across different part of input to produce the feature map.

CNN support Pooling feature to reduce the dimensions and computation, it also reduces overfitting since the parameters are less.

CNN structure can be divided into 2 parts, feature extraction part and classification part.

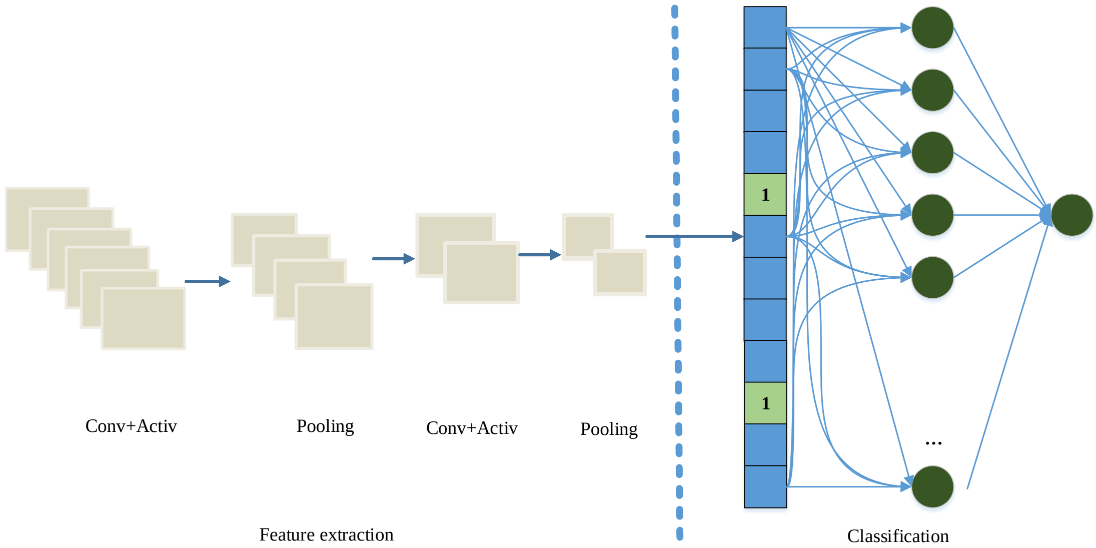

Figure 3. CNN structure

Activation functions: improve the decision boundary by converting it from linear to nonlinear curve, there are different types of activation functions.

Relu is one to one mathematical operation, it returns the max value between zero and the input, so if the input value is less than zero then the function will return zero otherwise the input will be returned.

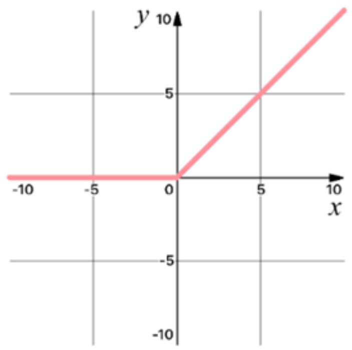

Figure 4. Relu activation function

Tanh is another activation function return value in range between -1 and +1.

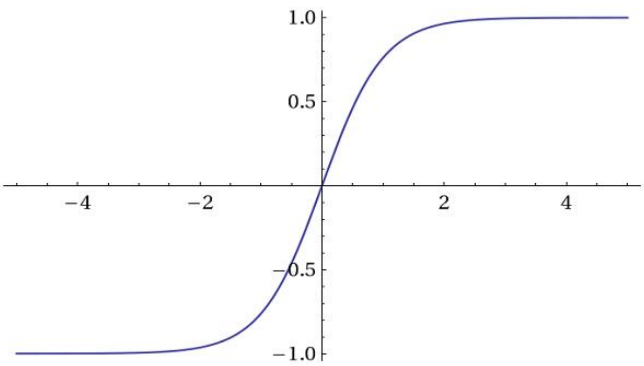

Figure 5. Tanh activation function

Step function returns 0 if the input value is negative or 1 if it is positive. Figure6

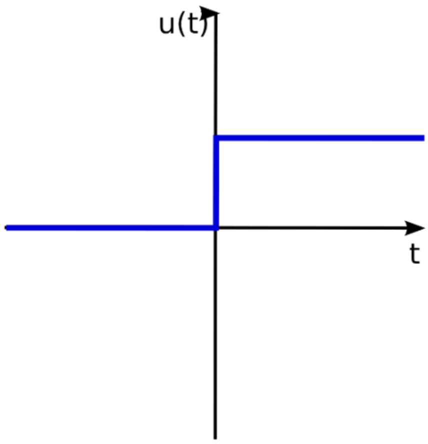

Figure 6. Step function

Sigmoid is similar to tanh however it returns a value in the range between 0 and 1 Figure 7

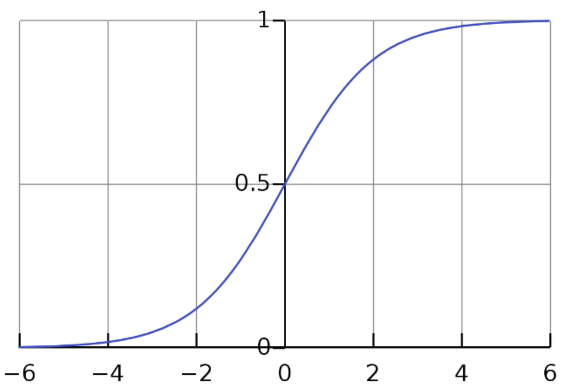

Figure 7. Sigmoid function

2.2 Contributions

- ✓ This paper reviewed research applied on IoT based applications in agriculture domain.

- ✓ The paper reviewed Artificial Intelligence based applications in agriculture domain.
- ✓ Proposed Hazelnut cultivars classifier model based on .NET.
- ✓ Proposed Hazelnut cultivars classifier model based on Python using CNN.
- ✓ Proposed open dataset system for Hazelnut cultivars.
- ✓ Proposed smart IoT system for classifying hazelnut using python model.
- ✓ Proposed smart web system for classifying hazelnut for python model.

Proposed smart web API for classifying hazelnuts for both python and .Net model.

This paper provide comparison between .Net and python model, the comparison will cover implementation steps and the performance of each model.

CHAPTER 3

3. METHODOLOGY

3.1 Introduction

The proposed model has two parts. AI part and IoT part. Two classifiers version have been developed in the scope of this thesis, .NET model and Python model. The same dataset has been used for training the models. The dataset of 17 classes have been used, each class contain 250 image. Images have been token using mobile phone camera.

In Python version, CNN network with 4 layers has been built, ImageDataGenerator was used to extend the dataset.

In. NET version classification images scenario has been picked up from available scenarios were designed by ML library that belongs to Microsoft.

IoT part consists of the camera and Rassperipy computer, the trained model installed on Rassperipy computer, the user will take a picture of any hazelnut using the camera, then the system will upload that image to the server, the image will be classified by the model then the result will be sent to the user meanwhile, the image will upload to the data bank into its appropriate class.

3.2 Design Science Research Methodology (DSRM)

Design Science (DS) is a scientific study and creation artifacts that are developed for solving particular problem in Information System IS.

Many research methods suppose the target of study is already there however in IS field the target of study is most often not there yet but instead must be designed.

Design Science Research (DSR) is scientific method and research standard utilized in information systems sector to create artifacts that construct solutions for real chalanges

(Perjons and Johannesson, 2014) (Costa et al. 2020).

***Table 1**. DSR Guidelines*

Guideline	Description
Guideline 1: Design as an artifact	Produce artifact in form of Constructs Models Methods Instantiations
Guideline 2: Problem Relevance	The objective is developing technology based solutions to important and relevant business problems
Guideline 3: Design Evaluation	evaluating the utility, quality, and efficacy of design artifact in terms by well executed evaluation methods
Guideline 4: Research Contributions	Effective DSR should provide clear and verified contribution within the fields of create system, create foundation and/or create methodologies
Guideline5: Research precision	precision methods should be applied in both constructing and evaluating the created system
Guideline 6: Design as a Search Process	Effective artifact requires utilizing available means to reach desire end
Guideline 7: Communication of Research	Descriptive presenting of DSR to technology-oriented and management-oriented audiences

DSR has another definition, DSR is “Design science research is a research paradigm in which a designer answers questions relevant to human problems via the creation of innovative artifacts, thereby contributing new knowledge to the body of scientific evidence. The designed artifacts are both useful and fundamental in understanding that problem”.

Artifacts:

It is the output of a design that can be used to solve a practical problem by interacting with a context (Johannesson and Perjons, 2014), and it could be constructs, models, methods, instantiations.

Ex.

Artifact: a distributed system that automatically take a measure of 2 planes tend to have a collision

Practical problem: air plane collision avoidance

Context: Pilot, air traffic controller, planes, sensors...

Interaction: in order to avoid collision, the artifact interact with context (Pilot, sensors... etc.).

DSR Guidelines:

To help practitioners improve their understanding of the design-science process. (Hevner et al., 2004) also proposes seven guidelines that will help them effectively apply the discipline.

Design Science Research Methodology (DSRM) was created by Peffers et al to introduce a process framework for analyzing and developing design science. Figure 8 shows the steps involved in the process.

- Problem recognition and stimulation: definition of the research problem and justification of a solution's value.
- Objectives of a solution: conclude the purposes of a solution from the definition of the problem
- Design and development: design the artifactual solution
- Demonstration: proof of the artifact's usefulness for solving the problem
- Evaluation: Monitoring and measuring how good the artifact supports a solution to the problem
- Communication: Communicate the problem and its importance, the artifact, its utility and novelty, the rigor of its design, and its effectiveness to researchers and other relevant audiences.

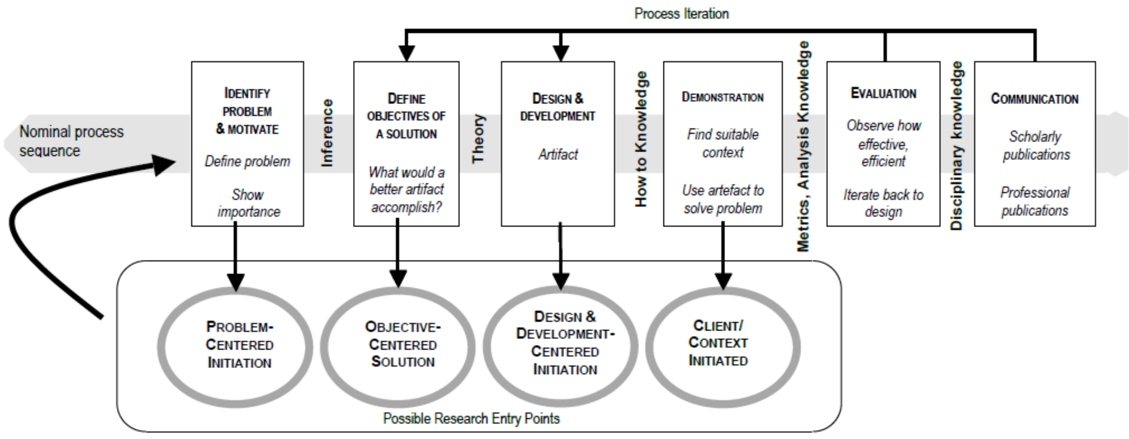

Figure 8. Design Science Research Methodology (DSRM) Process Model

DSRM is quite utilized in the development of various applications and frameworks in the Information Systems discipline. It has been adopted in various processes such as the design of IS, web-based knowledge mapping system, performance-oriented approach, mobile phone-based agriculture market information service, ICT-enabled service, HR planning structure, solution for extracting user requirements, business intelligence (BI) in the cloud, hospital-based business intelligent system, knowledge transfer analysis structure, real-time information system concerning emergency department crowding, UI prototypes for evaluations in practice-oriented research, agroecosystem for agriculture industry, contextualized digital health innovation ecosystem structure, forest management and virtual reality.

3.3 Adopting Design Science Research Methodology

(Peffers et al., 2006) has been applied for this thesis, involves a six-step process. It involves identifying the problem, the objective of the project, developing and designing, evaluating and communicating the results to the end users.

There are four artifacts that have been produced as part of the project.

1- Designing and developing the classifier using Python which is shown in Figure 9.
2- Designing and developing the classifier using .NET. It has been reprented in Figure 9.
3- Developing IoT based application to take image then send to classifier then upload to classified image to the data bank. It has been presented in Figure11.

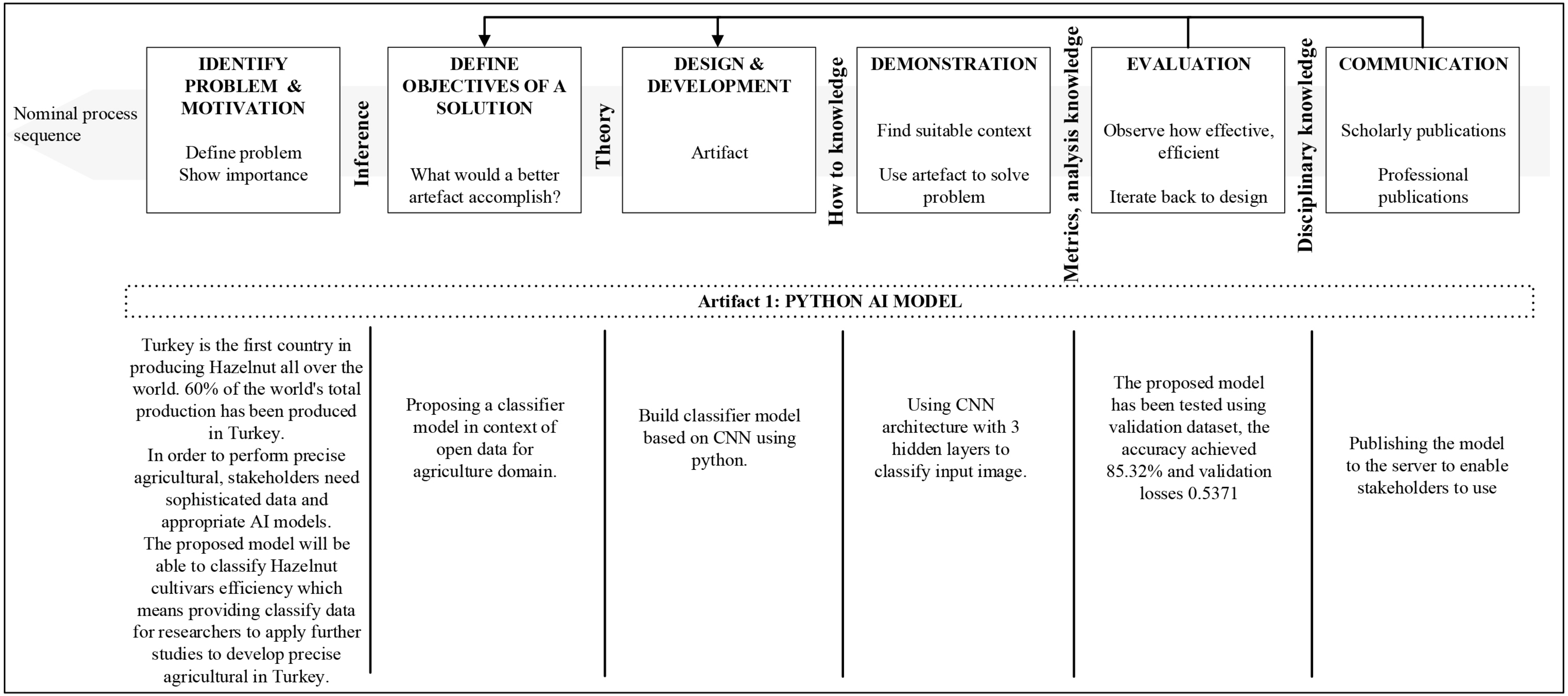

Figure 9. DSRM Process for the Artifact 1

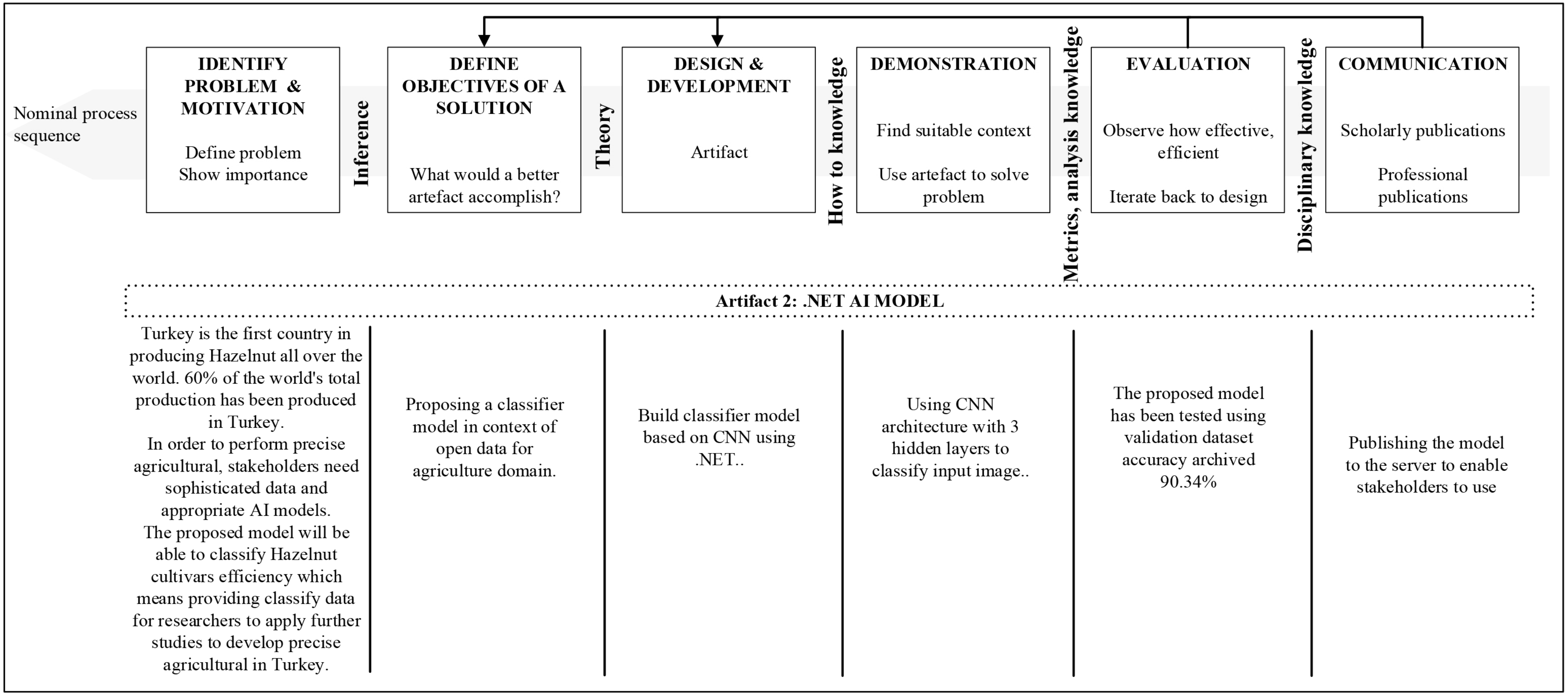

Figure 10. DSRM Process for the Artifact 2

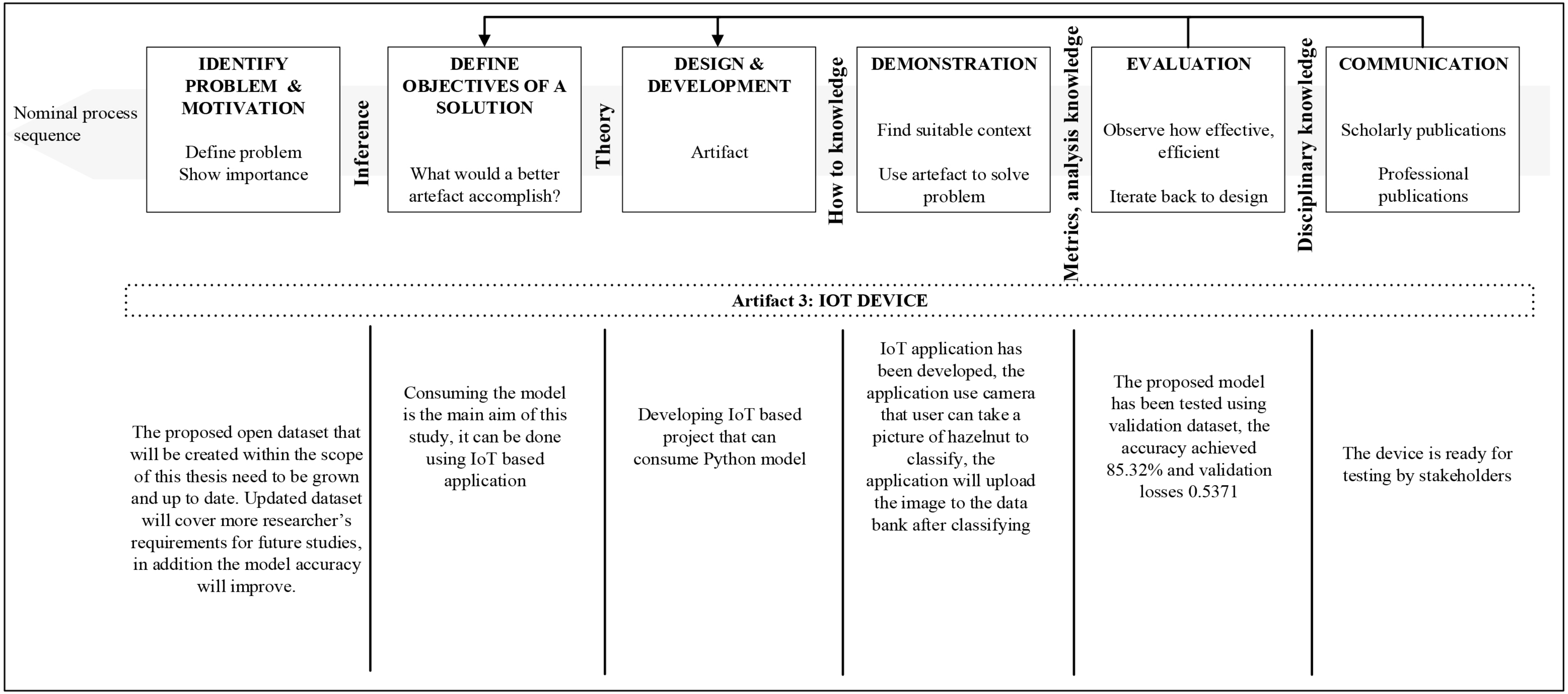

Figure 11. DSRM Process for artifact 3

CHAPTER 4

4. SYSTEM IMPLEMENTATION

4.1 Preparing the Dataset

A dataset of 250 images for each hazelnut cultivar have been taken, the camera was sited 20 cm away from the hazelnut, a white background was used with no special light. Four to five photos were taken from different angles for each hazelnut.

the dataset contains 17 hazelnut cultivars located into subfolders represent classes, class are:

1) Çakıldak
2) Kara
3) Palaz
4) Tombul
5) Uzunmusa
6) Sivri
7) Yassı Badem
8) Foşa
9) Yuvarlak Badem
10) Kuş
11) Kargalak
12) Kan
13) Kalınkara
14) Incekara
15) Cavcava
16) Allahverdi
17) Acı

The Hazelnut Trait Ontology (HTO) (Aydin, Sahin, and Mehmet Nafiz Aydin. (2020). Semantic and Syntactic Interoperability for Agricultural Open-Data Platforms in the Context of IoT Using Crop-Specific Trait Ontologies Applied Sciences 10, no. 13: 4460), has been used to create an open data sets regarding each one of Turkish Hazelnut Cultivars in to open formats such as RDF/XML and RDF/JSON. After the classification process of any hazelnut cultivar has been completed these datasets are being used to get detailed information about the relevant hazelnut cultivar. The nut size, kernel size, kernel weight, Shell Thickness, Kernel Cavity, Kernel Ratio, Blank Nut Ratio, Shrivel Kernel Ratio, Abortive Kernel Ratio,

Double Kernel Ratio, Cracked Nut Ratio, Moldy Kernel Ratio, Weevil Kernel Ratio, Pellicle Removal Ratio, Fibrousness, Time of Leaf Bud Burst, Time of Ripening, Time of Male Flowering, Time of Female Flowering, Time of Leaf Fall, Protein Content, Fat Content, have been used to provide detailed information about the cultivars (Balik, Hüseyin & Balık, Selda & Beyhan, Neriman & Erdogan, Veli. (2016). Hazelnut Cultivars).

The aim of developing hazelnut ontology is to distripute regular properties of hazelnut and also bring out worldwide standard criteria about hazelnut.

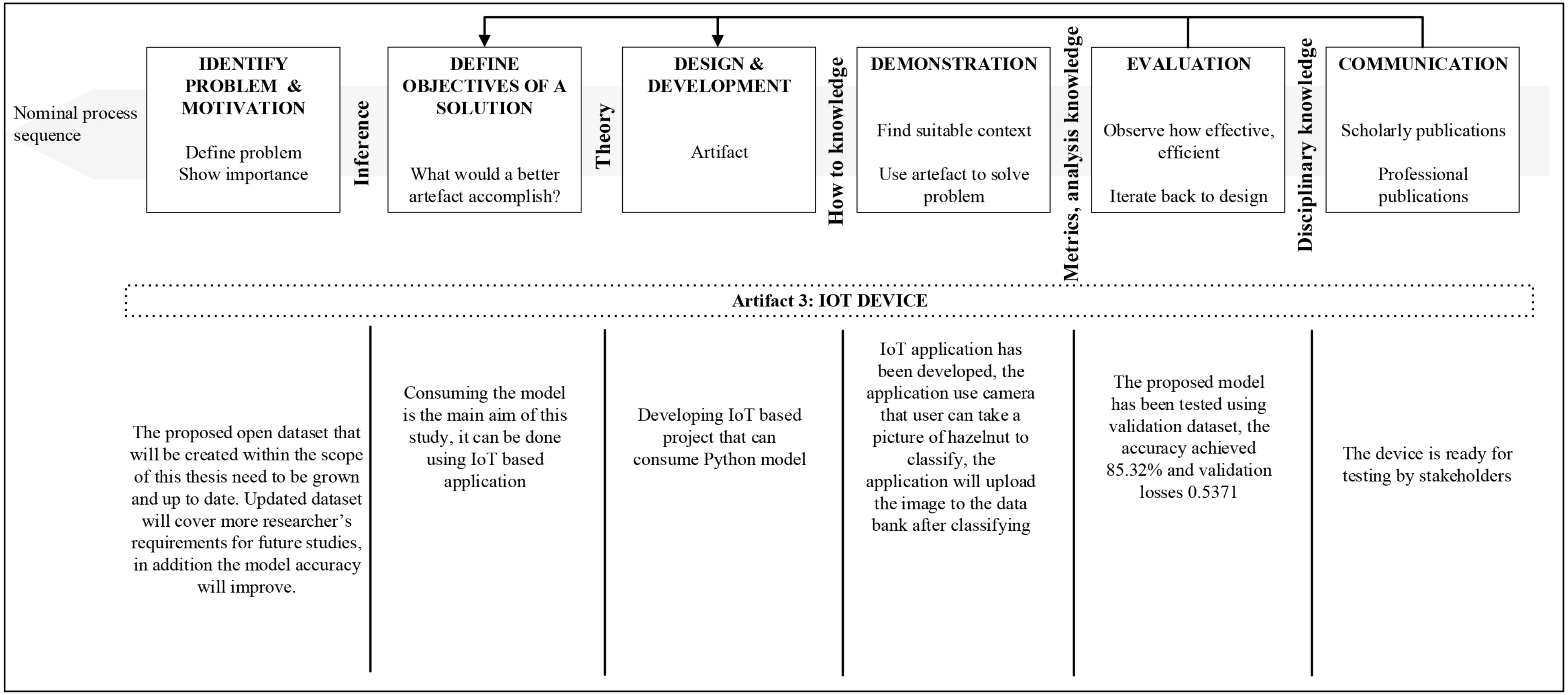

Figure 11. DSRM Process for artifact 3

4.2 Data Preprocessing

In proposed model the images have been resized to 110 x 220 px.

Due to the small size of the dataset then data augmentation has been implemented using "ImageDataGenerator", that help to generate more images in order to improve the accuracy of the model. Batch size which is the desire number of generated images has been set to 100. Rotations, Shifts, Flips, Brightness, Zoom and rescale are available options for generation images, in this model rescale option with 1. /255 has been selected, this operation has been applied to entire pixels for every single image.

4.3 Building Classifier with Python

A model with four layers has been created, the first layer was initialized with 32 filters and kernel size 3X3, relue activation function has been selected, the input shape was 110 x220 which is the width and high of image, in addition to 3 colors channel RGB then final input shape will be (110, 220, 3)

MaxPooling2D with kernel 2x2 has been applied for the output of the first layer.

The second layer 'The first hidden layer' was the same like input layer, the only different is the number of filters used, 64 filters have been used in this layer.

In the third layer the number of filters has increased to 128 filter, the forth layer also has the same number of filters.

Flatten layer then applied to have output with 1D.

Callbacks parameter have been used in order to save the model that has the best weight depend on val_loss.

The data have been fitted to the model for training, Epochs set to 70, the best saved model has val_loss = 0.5371 and va_accuracy= 0.8500.

Consuming the model: The saved model has been loaded using model.load_weights function. The process that have applied on training images should also have been applied on tested images, therefor test image need to resize to 110 x220 to have the same model input shape beside of resizing, rescale with 1. /255 should also applied.

4.4 Building Classifier with .NET

To train model in .NET framework ML library should be installed to the project, the library provides pre design models for different scenarios, Image classification has been picked from those scenarios then training process started, the process long depends on the dataset size.

Training has done with validation accuracy 90.34%. The architecture used was ResNet50.

What is the ResNet50 Residual Networks?

stacking more layers to deep convolutional neural networks will efficiently

help to solve complex problems in computer vision since that different layer can extract more features then the model accuracy gets high result, however at some point the deeper network perform might regression then the model accuracy will decrease on training and testing data.

That regression is not because of Overfitting, it might be result of the network structure, or activation and optimization function, or in most cases it's because vanishing or exploding gradients. ResNet50 is a deep convolutional neural networks with 50 layers use skip connection technology to avoid vanishing or exploding gradients effects.

Skip connection concept is adding the original input to the output of convolution block Figure 12 shows the different between tradition and ResNet

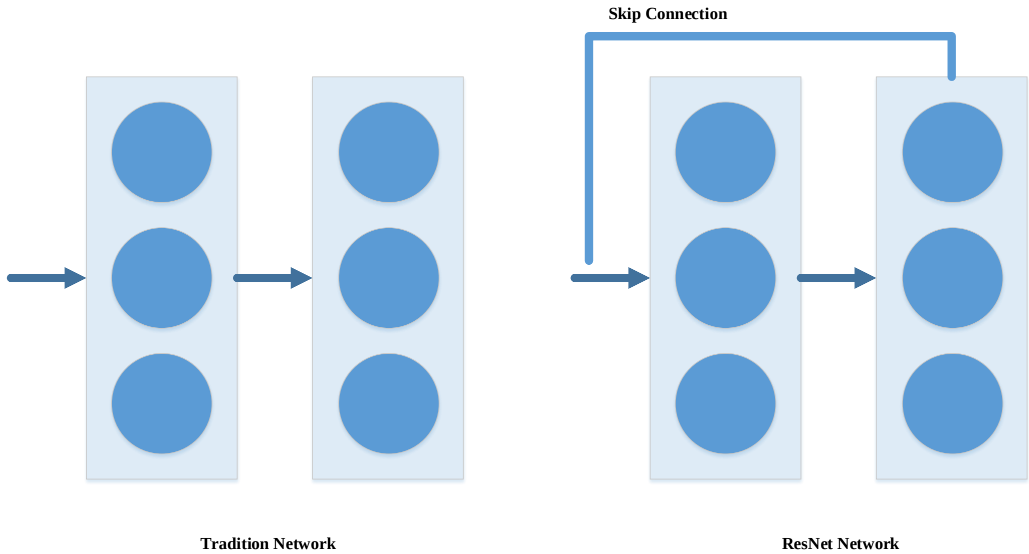

Figure 12. Difference between tradition and ResNet architecture

Residual networks contain blocks where each block has different layers representing in Figure 13.

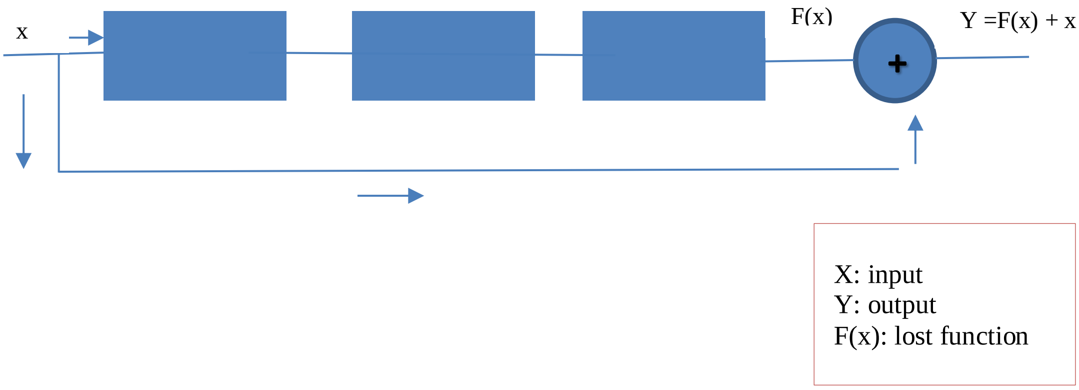

Figure 13. Residual block

Y = f(x) is the novel point that any Machine learning algorithm try to achieve, on the other hand by using skip connection the logic behind ResNet has been became y = f(x) + x

During training the algorithm tries to achieve the point where y = x by making f(x) = 0 then the input will be equal to the output. Therefore, in tradition networks the model trains on the base of y while in ResNet the train is base is f(x)

Skip connection helps to avoid vanishing or exploding gradients effects.

Figure 14 the structure of ResNet50 layers

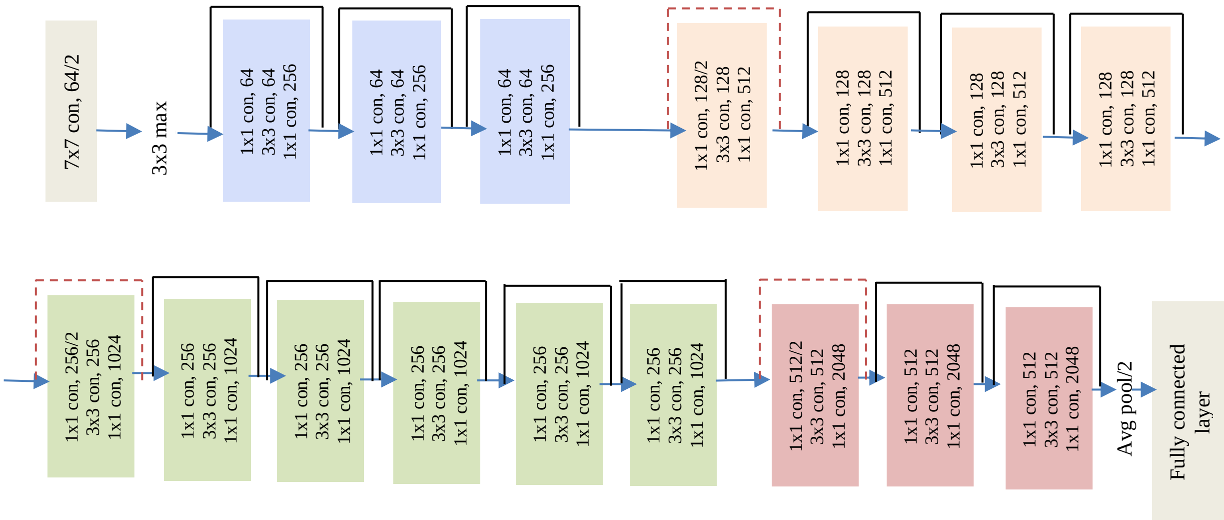

Figure 14. ResNet50 structure

For resizing the image this formula uses: [(n+2p-f /s) + 1] * [(n+2p-f /s) + 1]

n: image size

p: padding which is 3 in ResNet

s: stride (resize value)

f: filter size

Skip connection has 2 types

1- Identity block: use if the size of input is equal to the output
2- Convolution block: use if the size of input is not equal to output, in that case to get the same size then a convolution block is using wither Conv 1x1 filter or using padding like the previous formula. Figure 15 Difference between Identity and Convolution block.

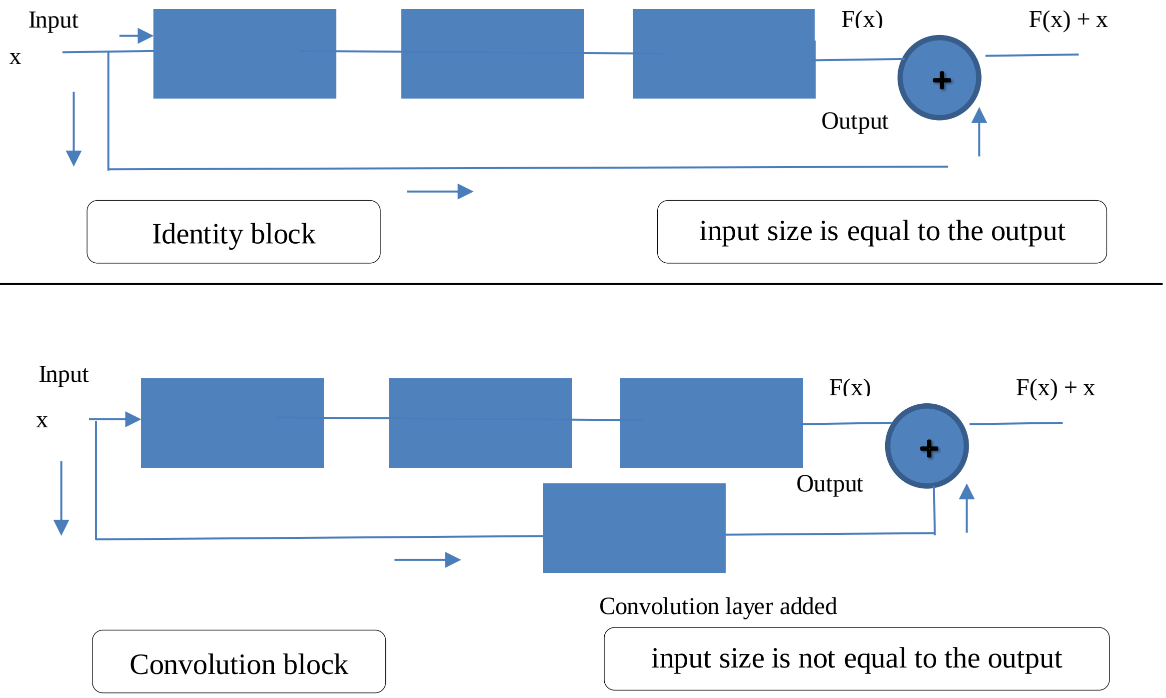

Figure 15. Difference between Identity and Convolution block

4.5 Development of IoT-based Classification Device

IoT based application has been implemented using Raspberry pi3 computer, the classifier trained using Tensorflow which is an open-source platform for machine learning, it is an ideal choice for researchers and developers who are looking to build and deploy advanced applications. It has a variety of tools and libraries that help them to develop a machine learning applications. The library has been installed using Wheel, appropriate version of Tensorflow should be chosen depends on the machine architecture.

In order to provide the best experience to users, the Graphic User Interface 'GUI' has been added to the application using Tkenter library which is already installed to any Raspberry pi computer. The interface contains three buttons; first buttons is for triggering the camera, the second button is for capturing the photo whereas the classification process will trigger by pressing the 3ed. button. Classification result will be shown using text box.

4.6 Development of Web APIs and Web Application for Python

To be sure that proposed model can be consumed using different platforms a web API application has been developed.

Fast API library was used to build the API. One of the fastest ways to develop web Python applications is through the FastAPI framework. It's easy to learn and fast to code.

FastAPI framework is built on top of Pydantic and Starlette, which makes it incredibly fast to code. It also comes with a variety of features, such as: intuitive, and robust editor support.

The library has been installed into the environment using pip.

FastAPI support all APIs functions like get, post, update, edit and delete…

In proposed application the only operation that we need to define is the post operation, the path has been specified inside the function create_upload_file, this function has accept an image, that image will upload and save in imgs folder then hazelnut_type() will trigger to make a prediction, the result will send back in json format then classify image will upload to open data bank specifically inside its corresponding folder according to classification result.

Beside of web API the model also can be consumed with web page, streamlit library has been used to build the web app.

Streamlit is an open-source Python library that makes it easy to create custom web apps for machine learning and data science.

The library should be installed to the environment in order to use in the project. The proposed web page contains the logo and welcome message, a browse button has been added for choosing the image to classify, the image will load and save to specific directory then the prediction function will be called to make a predict, then the result will be shown to the user, then classify image will upload to open data bank specifically inside its corresponding folder according to classification result.

4.7 Development of Web API for uploading classify image and Desktop form application to consume. Net model:

In order to consume .net model a desktop form has been developed using .net framework, the user can interact with the application using GUI, after selecting the image by click on browse button the image will display on GUI, the model will start classifying th e image after click on classify button, classification process start by creating an instance of trained model and initialized it with provided image, Predict function will call on the model object, the returned value will be saved in predictionResult variable in order to show on GUI using TextBox, the process will end after uploading classify image to open data bank specifically inside its corresponding folder according to classification result using API. To upload classifying images to proposed data bank a web API application has been developed with one controller name ImageController, this controller has one IActionResult function which accept 2 variables, classified image and the class name.

The GUI of Windows Forms App has been shown in Figure 16. The function first will save the file name into variable then rename it, then the function will initialize saved path according to the class name attribute, then the image will upload.

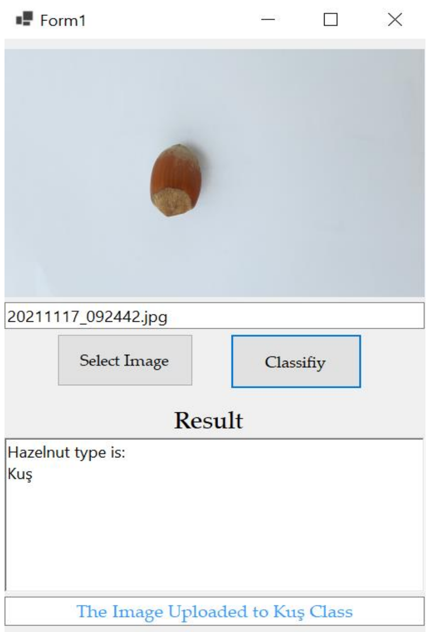

Figure 16. Windows Form App GUI

The GUI of Windows Forms App has been shown in Figure 16. The function first will save the file name into variable then rename it, then the function will initialize saved path according to the class name attribute, then the image will upload.

4.8 Evaluation of the System

4.8.1 Comparing the Accuracy of the Models

As previously mentioned, this thesis has been provided 2 different classifiers developed using different platform Python and .Net

Validation accuracy obtained in python model was 81,25% and the Validation loss was 0.6. In .Net model the values obtained were 90.34%. table 3

Table 3. Comparasion between Python and. NET Model

	Python	.Net
Accuracy	81.25%	90.34%
Architecture	CNN with 4 layers	ResNet50 - 50 layers
Training time	24 Hours	3 Hours
Dataset	Original dataset + Augmentation	Original dataset

4.8.2 Usability of the Classification Device

The classification device developed in the scoop of this thesis has been consumed using different application in order to be sure that it is usable for different users.

Stockholders or farmers are able to classify images using IoT based app which is easy to use, the user need to take a photo then pressing classify button then the result will show on the screen.

Another consumer has been developed using web API application that can be use by developers.

In addition, a Web application based also developed to consume the model

.Net model has been also consumed using Windows desktop application.

4.8.3 Performance Testing of Web APIs and Web Application

Python web application can be run on local machine using

“streamlit run” followed by the file name which has WebApp.py name in proposed application.

Figure 17 shows the GUI of the web page.

Figure 17. The screenshot of Web App

Pressing Browse button will open browse window for choosing an image. The system will display the image then the classification result will be shown Figure 18.

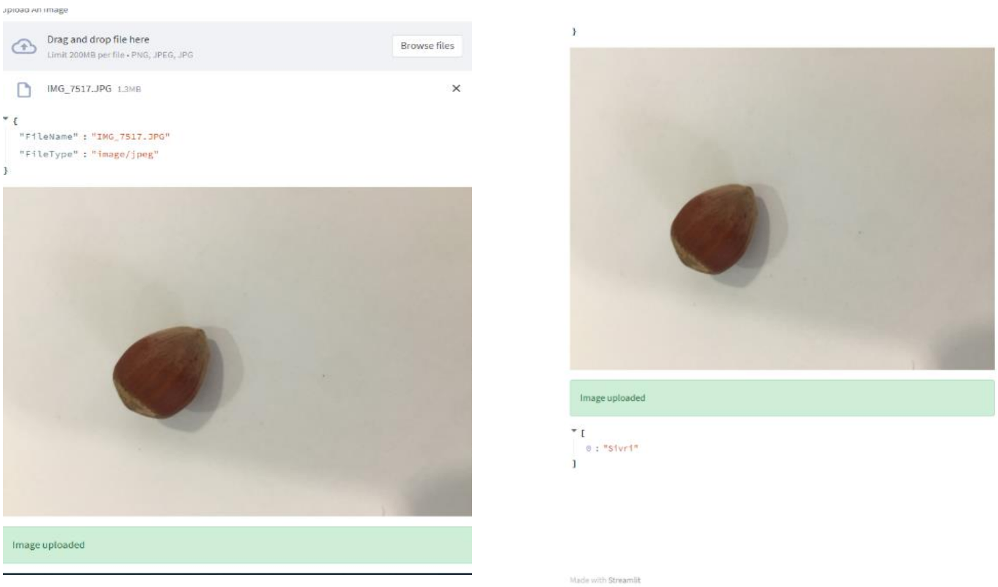

Figure 18. Output Page of Web App

Python API app: In order to request the model using API then the following URL should be requested

https://hazelnutapp.herokuapp.com/docs#/default/create_upload_file_uploadfile__post

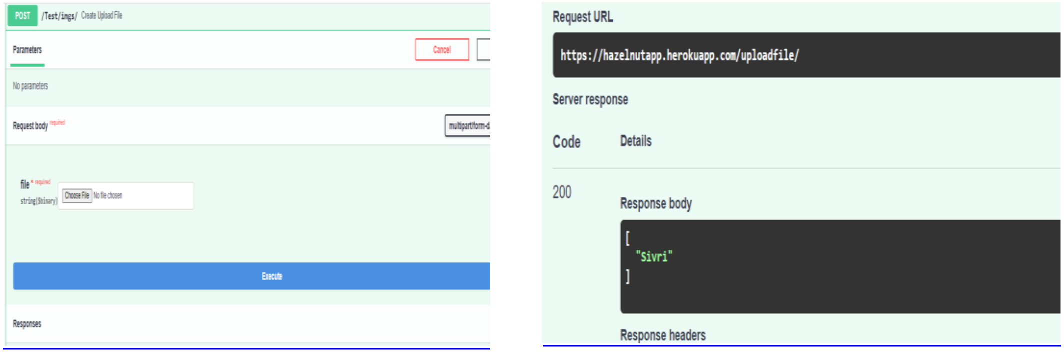

Figure 19. The API implemented for the classification

CHAPTER 5

5. CONCLUSION AND FUTURE WORK

This thesis proposes two Hazelnut classifiers using .Net and python framework based on open dataset to provide details information about hazelnut cultivars, those models are able to use by IoT devices, Web base application and desktop application, the propose application also provide web API application that help developers to consume the models.

Hazelnut ontology base has been used to create an open data sets regarding each one of Turkish Hazelnut Cultivars in to open formats such as RDF/XML and RDF/JSON.

An open dataset has been also created using the models by uploading classify images, the dataset will be available to use by researchers to add further study about Turkish hazelnut.

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APPENDICES

A. The source codes of .NET Model, Windows Forms App, WEB API are provided in https://github.com/diaadojj/ConsoleApp1.git.

B. The source codes of Python Model, Web App, and IoT app are provided in https://github.com/diaadojj/Thesis.git.

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