DEVELOPMENT OF AN INTELLIGENT APPROACH TO ENHANCE POULTRY PRODUCTION IN THE STATE OF PUNJAB

Thesis Submitted for the Award of the Degree of

DOCTOR OF PHILOSOPHY

in

Computer Science and Engineering

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Transforming Education Transforming India

LOVELY PROFESSIONAL UNIVERSITY, PUNJAB

2024

DECLARATION

I, hereby declared that the presented work in the thesis entitled “Development of an Intelligent Approach to enhance the Poultry Production in the state of Punjab” in fulfilment of degree of **Doctor of Philosophy (Ph. D.)** is outcome of research work carried out by me under the supervision of Dr Manik and Dr Nonita Sharma, working as Associate Professor in the Department of Computer Science and Engineering of Lovely Professional University, Punjab, India and Indira Gandhi Delhi Technical University for Women (IGDTU), Kashmere Gate, Delhi, India respectively. In keeping with general practice of reporting scientific observations, due acknowledgements have been made whenever work described here has been based on findings of other investigator. This work has not been submitted in part or full to any other University or Institute for the award of any degree.

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CERTIFICATE

This is to certify that the work reported in the Ph. D. thesis entitled “Development of an Intelligent Approach to enhance the Poultry Production in the state of Punjab” submitted in fulfillment of the requirement for the award of degree of **Doctor of Philosophy (Ph.D.)** in the Computer Science and Engineering, is a research work carried out by Baljinder Kaur, 42100402, is bonafide record of his/her original work carried out under my supervision and that no part of thesis has been submitted for any other degree, diploma or equivalent course.

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ABSTRACT

India's experience with poultry farming has shown that it can increase agricultural output both per hectare and per person. Livestock play a crucial role in agricultural systems by producing milk, meat, manure, and draught power, among other things. However, not everyone has the financial means to keep tiny ruminants or cattle. Because it is more economical for the poor, poultry has a wider appeal to this group of individuals. Chicken and eggs are two examples of animal products that make good sources of protein. A whopping 98% of the poor reside in rural areas. Enhancing village poultry production, which consists primarily of indigenous chickens, will help close the supply-demand gap for poultry products, generate income for rural populations, and protect the nation's resources for poultry. There is a demand for protein that is produced and processed in a sustainable, effective, and secure manner, such as chicken, due to the growing world population. People all throughout the world rely heavily on poultry and eggs as sources of nutritional protein. Therefore, if these animal food sources are to continue to be a significant source of human nutrition as the population grows, they must be produced in a way that reduces their cost and increases their availability. The industry will be better able to satisfy the rising demand if new methods are applied to poultry production and processing systems. The chicken industry's consumer and retail expectations have led to an increase in a diversity of production and feeding systems with varying restrictions and knowledge bases. Commercial chicken farming relies on routine bird monitoring, minimum human labour, and other factors to be profitable and productive. Technology advancements that are improving in precision and getting cheaper are the modern answer to this problem. Multiple elements of the industry could be improved by implementing artificial intelligence (AI) in chicken production and management. This technology has the potential to enhance animal welfare, limit disease transmission, raise breeding standards, and decrease waste since it can gather data that prompts thoughtful responses. It is not surprising that automated poultry monitoring is attracting a lot of interest in the field of study given its numerous promising implications.

There is an urgent need of improving the welfare of poultry. The study in question focuses on analyzing the existing approaches used in the poultry farms of Punjab. Herein, survey was conducted to gather the data from 111 farms in various districts of Punjab to address the various issues faced by the farmers for which they need some solution. Furtheremore , N-BEATS (Neural Basis Expansion Analysis for Time Series Forecasting) model is developed to provide accurate forecasting of the poultry data taking into consideration the variations in various conditions like temperature and humidity , thus providing and Intelligent approach for enhancing the poultry production. The performance of the N-BEATS architecture was compared with that of other deep learning models namely LSTM, GRU, RNN, CNN, Bi-LSTM. The N-BEATS model outperforms the above mentioned deep learning models .It is the best-performing model among the used models as it has the positive R-squared and the lowest errors across all measures. It seems to be the best at capturing the patterns in the dataset without overfitting to noise or outliers. In addition to this, the study discusses an image processing approach for predicting the abnormalities in the behavior of the poultry for diseases. For this purpose, various convolutional neural network (CNN) models are used i.e SoloConvLayer model, TriConvLayer model, FiveConvLayer model, MobileNet V2. Based on the comparison, it was observed that the TriConvLayer model performs best as compared to all the other models. TriConvLayer has an accuracy of 98% and the size of the model is very small, making it compatible with mobile application. Thus the TriConvLayer model is used in a mobile application (HenScan) for disease detection. The fecal images are uploaded on this application which then predicts about the disease and also provides information about the symptoms, prevention and cure measures and the recommendations for preventive actions. This innovative approach to provide a practical solution for poultry farmers to manage and mitigate disease outbreaks effectively.

ACKNOWLEDGEMENT

First of all, I pay my gratitude to the Almighty for conceding me an opportunity and strength to successfully accomplish this assignment.

I would like to thank my esteemed supervisors – Dr. Manik and Dr. Nonita Sharma for their invaluable supervision, support and tutelage during the course of my Ph.D degree. I owe my deep sense of gratitude to the dynamic academicians and generous guides, who all along have been an immense source of encouragement to me in completing this work. They really spared time for academic interaction with me.

My heartfelt gratitude and indebtedness goes to my loving parents (Ranjit Singh and Gurjeet Kaur) for their blessings, encouragement, and assistance. The efforts of my husband and Brother (Simardeep Singh and Randeep Singh) deserve great appreciation for understanding and cooperation.

Finally, I very sincerely acknowledge the cooperation of my friends, who provided encouragement when it seemed impossible to continue. The discussions and unwavering support from my peers at the university have enriched my research experience, making this journey not only possible but also enjoyable. Their presence and insights have been pivotal in navigating the complexities of my research topic. Also, I would like to thank all the authors whose studies have been quoted in this study.

Baljinder Kaur

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INTRODUCTION

1.1 INTRODUCTION

Punjab is well-known for its vigorous agricultural techniques, and poultry raising is an integral part of this agricultural environment. The poultry industry is an essential part of solving food security issues, which are becoming more pressing due to the growing population and the need for more protein-rich foods. Poultry farming, however, is not immune to the problems that plague other agricultural pursuits, such as the emergence of new diseases and the wasteful use of available resources. Within this framework, the incorporation of intelligent methods has encouraging prospects for enhancing production efficiency, reducing risks, and guaranteeing long-term growth in the poultry industry. A state in India known as Punjab, commonly called the "Granary of India," has a long history of farming. Wheat, rice, and maize have all been traditionally grown there due to the area's good climate and rich soil. But the poultry industry has been growing rapidly in recent years, becoming a popular and profitable way to diversify agricultural revenue and increase yields. As a result of this shift, the poultry sector has to come up with new ways to use technology to increase production and profits [1-4].

Fundamental to this new way of thinking is the idea of intelligent agriculture, which improves many parts of farming by using state-of-the-art technology like data analytics, the Internet of Things (IoT), and artificial intelligence (AI). Utilizing data-driven insights and predictive analytics allows farmers to make well-informed decisions, anticipate possible obstacles, and optimize operations for increased output. There is tremendous opportunity for intelligent ways to transform conventional poultry farming methods and solve widespread problems in this industry. Improving disease control is a top priority for Punjab's poultry producers. Poultry health and production are immensely at risk during infectious disease outbreaks, which in turn cause farmers to incur economic losses. Another issue that makes disease control efforts more difficult is the indiscriminate use of drugs, such as antibiotics. Because of this, smart disease monitoring systems may be very helpful in detecting and containing epidemics as soon as they happen. These systems enable farmers to monitor critical parameters of chicken health, including heat, humidity, and behavioural patterns, through the integration of Internet of Things (IoT) sensors, machine learning algorithms, and real-time data analytics. This allows for the prompt identification of possible health issues and the implementation of remedies.

Optimizing feed management procedures is an important part of chicken production, and intelligent ways can help with that. A large chunk of production costs goes toward feed, and wasteful use of feed can cut into profits. Smart feeding systems allow farmers to track feed consumption trends and customize nutritional compositions for birds according to their needs. These systems are integrated with sensors and actuators. For optimal growth rates, minimal feed wastage, and improved feed conversion ratios, AI systems may assess nutritional data and suggest individualized feeding regimens. The use of these smart feeding technologies allows poultry producers to save money while getting the most out of their feed. Intelligent methods have the potential to transform many aspects of chicken housing and environmental control systems, including disease management, feed optimization, and environmental control systems. It is crucial to keep chicken houses at an ideal temperature and humidity level to guarantee the well-being of the birds kept inside. Poultry are more likely to experience stress, respiratory problems, and decreased production in environments with extreme temperature changes, poor ventilation, and high amounts of airborne contaminants. With the use of sensors and actuators, intelligent climate control systems can keep an eye on environmental factors all the time and make the necessary adjustments to the HVAC, lighting, and ventilation to keep things just right. In addition, algorithms for predictive analytics may foresee changes in the environment and take proactive measures to reduce hazards, which improves production efficiency and protects the health of chickens.

Precision farming has opened up new possibilities for improving chicken output in Punjab. Farmers may learn a lot about land use patterns, plant life dynamics, and weather patterns by using drones, geospatial data, and satellite photos. Strategic decisions on land management techniques, resource allocation, and poultry farm site selection can be aided by this data. In addition, water, fertilizers, and pesticides may be precisely applied using precision farming, which maximizes yields while decreasing wastage and environmental effect. There is a huge window of opportunity to transform agriculture in the State of Punjab through the creation of a smart strategy to increase chicken production. Farmers in the poultry industry may improve their operations, make better use of their resources, and secure the future of their industry by utilizing data analytics, artificial intelligence, and the internet of things. Being a frontrunner in chicken production and food security, Punjab is well-positioned to achieve the larger objectives of agricultural modernization and economic diversification through the use of intelligent farming methods. The future of poultry farming in Punjab is filled with great promise, thanks to the stakeholders' unwavering commitment to innovation and collaboration. The revolutionary power of intelligent techniques is what will drive this progress.

1.2 BACKGROUND OF POULTRY PRODUCTION IN PUNJAB

The agricultural landscape of Punjab, often called the "Granary of India," includes a substantial amount of chicken farming, which has a long and storied history in the region. Punjab is a famously agricultural region in northwest India that is perfect for chicken production due to its rich soil, pleasant climate, and well-established irrigation infrastructure. When Punjab experienced a dramatic shift in agricultural practices during the Green Revolution in the 1960s and 1970s, leading to greater productivity and food security, the state's chicken industry got its start. As a result of government assistance programs, modern farming practices, and the introduction of high-yielding crop types, Punjab became one of India's foremost agricultural centers during this time. Along with conventional crop cultivation, chicken farming became a significant supplemental revenue stream for farmers throughout this agricultural revolution.

Poultry farming in Punjab began as agrarian backyard activities, with farmers raising birds for personal use or sale at nearby markets. But the poultry industry in Punjab expanded and modernized quickly due to rising demand for chicken meat and eggs and technological advancements. The state saw a proliferation of commercial poultry farms that used modern technology, automated processes, and varieties of birds selected for their meat or eggs. The chicken business in Punjab is booming, which is great news for the state's economy and for the people's diets. People from all walks of life are involved in Punjab's poultry industry, from individual farmers to huge integrated poultry corporations, as well as input suppliers, processors, distributors, and retailers. Its strategic location also makes it easy to ship poultry to nearby areas, thus solidifying the state's position as a national leader in the poultry industry.

Companies in Punjab handle different parts of the supply chain, from breeding and hatching to processing and distribution, making it an integrated poultry production system. In order to maximize efficiency and profit, these interconnected businesses take advantage of technology advances, economies of scale, and managerial knowledge. Furthermore, it is not uncommon for poultry corporations and individual farmers in Punjab to get into contract farming agreements. In these arrangements, the poultry companies guarantee the farmers access to markets and provide technical support while the farmers rear poultry birds under contract. Punjab's poultry sector is confronted with multiple obstacles. The rising demand for chicken products is putting pressure on the industry to find ways to increase production without compromising animal welfare or environmental sustainability [5]. Disease outbreaks, feed availability and pricing, waste management-related environmental problems, and unpredictable market prices are other challenges that the business faces.

1.3 IMPORTANCE OF ENHANCING POULTRY PRODUCTION

In addition to making substantial contributions to economic growth, sustainable development, and food security, poultry farming is vital in satisfying the world's need for animal protein. There are a number of reasons why increasing chicken production is of utmost importance in the Indian state of Punjab. For human consumption, poultry is an important source of critical minerals, micronutrients, and high-quality protein. Poultry products, including eggs and meat, provide an inexpensive and easily available source of nutrition in a nation like India, where protein insufficiency and malnutrition are common problems, particularly for susceptible groups like pregnant women and children. Improving health outcomes and decreasing the burden of illnesses connected to malnutrition may be achieved by increasing chicken production in Punjab, which would help meet the nutritional demands of the people [6-8].

When it comes to areas like Punjab, where most people rely on agriculture for a living, poultry farming offers a great economic potential. Rural economies benefit from the poultry business because it generates revenue, employs people, and diversifies the economy. Farmers may raise their revenue and living standards by putting money into raising chicken production [9]. Poultry farming is a great alternative for smallholder farmers since it often involves less initial investment and results in faster returns than other agricultural operations. Raising the output of chickens helps the economy and farmers out in the long run. There is a multiplier impact on economic growth caused by the numerous auxiliary sectors involved with poultry farming. These include transportation, veterinary services, feed manufacture, equipment suppliers, and equipment. An increase in chicken production has the potential to enhance rural development, create jobs in related businesses, and add to GDP growth in Punjab, a state whose economy is heavily dependent on agriculture.

When it comes to improving food security and reducing the effects of climate change, poultry production is vital. Poultry farming produces more protein with less inputs (land, water, and feed) than conventional animal agricultural methods. This effectiveness lessens the strain on natural resources and lessens emissions of greenhouse gases, making chicken farming more sustainable and eco-friendly. We can help save the ecosystem and prepare for the effects of climate change by advocating for sustainable chicken farming methods in Punjab. Improving chicken production has several societal advantages beyond its nutritional and economic importance. Opportunities for income production and entrepreneurship presented by poultry farming benefit women and underprivileged communities. Poultry farming is an important economic and social tool for women in rural Punjab, where it is practiced by many [10-13]. In addition, for underprivileged populations and rural areas without many job options, poultry farming can be a means of escaping poverty and becoming more integrated into society.

Raising the output of chicken in Punjab is crucial for several reasons, including meeting nutritional demands, enhancing livelihoods, boosting economic growth, and ensuring environmental sustainability, among many others [14-16]. The people of Punjab and its agricultural economy may benefit from a fully developed chicken industry if the province invests in sustainable methods, cutting-edge technology, and encouraging legislation.

1.4 OVERVIEW OF POULTRY FARMING PRACTICES IN PUNJAB

A major agricultural sector that helps sustain Punjab, India's economy and food supply, is poultry rearing. Punjab is now one of the country's top states for chicken production, thanks to its ideal climate, plenty of resources, and government assistance. This comprehensive review explores the many facets of chicken farming in Punjab, including farm methods, breeds, diet, disease control, environmental factors, and technology advancements [17]. There are mainly two approaches to poultry production in Punjab: intensive and free-range. Intensive systems comprise of housing complexes with regulated ambient conditions, feeding systems that are automated, and systems for managing trash. These methods are widely used in commercial chicken farms because they increase the yields. When birds are allowed to roam freely in open areas, they are able to engage in more natural activities such as foraging and scratching. Though land limits and biosecurity concerns make free-range farming less frequent in Punjab, it is becoming more popular among small-scale farmers who are targeting niche markets [18-21].

Poultry in Punjab comes in many forms, with both native and alien breeds being common. Indigenous cattle breeds, such as the Kadaknath and the Punjab Brown, are highly prized for their high meat quality, resilience to diseases, and adaptability to their specific environments. Cobb, Ross, and Hubbard are some of the exotic varieties that are appreciated for their quick development and excellent meat yield efficiency [22]. Additionally, there are several crossbreeding initiatives that aim to improve desirable qualities like feed conversion efficiency and disease resistance. Various stages of chicken production have distinct nutritional needs, thus feed is specifically designed to fulfill those needs (e.g., chick, grower, layer). Nutritional supplements, minerals, vitamins, and protein sources (such as fishmeal or soybean meal) are common components in poultry feed. Feed mills in Punjab manufacture a variety of feeds, including both standard and specialty varieties, to meet the varied demands of poultry farmers. More and more people are turning to digestive aids, immune boosters, and general performance enhancers like probiotics and enzymes.

The spread of diseases is a major problem for chicken producers since it reduces their production and ultimately their profits. Newcastle disease, infectious bronchitis, and coccidiosis are prevalent illnesses that can be easily prevented with vaccination programs. To reduce the spread of illness, biosecurity measures are required in place, including monitoring systems, disinfection techniques, and limited access to farms. In addition, veterinary care that is both prompt and thorough will aid in the management of epidemics and the protection of chicken flocks. Poultry well-being and output are significantly impacted by environmental elements as illumination, ventilation, humidity, and temperature. It is absolutely essential to have efficient cooling and ventilation systems in Punjab to avoid heat exhaustion and respiratory issues due to the hot and humid weather. Layers' feed intake, reproductive performance, and egg production may all be enhanced with proper illumination. In addition, reducing pollution and ensuring sustainable manufacturing are both made possible by effective waste management procedures.

Innovations in technology can completely transform the way chickens are raised in Punjab, leading to more efficiency, output, and care for the animals. Feeding, watering, and climate control systems that are automated save labor expenses and maximize resource usage [23-25]. In order to help farmers can make educated decisions, sensor-based technologies and remote monitoring devices that allow for the collection and manipulation of data in real-time. The development of disease-resistant breeds and the optimization of feed efficiency in chicken production are two areas that show great potential for advancements in biotechnology and genetic engineering. Animal care and ecological sustainability are paramount in Punjabi poultry farming, which employs a wide range of techniques to maximize output. If the poultry industry wants to keep up with the rising demand for its products and face new issues as they arise, it will need to embrace innovative technology and best management practices. In order to solidify its position as India's foremost chicken production hub, Punjab should encourage cooperation among relevant parties and the sharing of relevant information.

1.5 HISTORICAL PERSPECTIVE OF POULTRY FARMING IN PUNJAB

The history of poultry farming in Punjab is extensive, encompassing the domestication of birds for their flesh and eggs, including chickens, ducks, and turkeys. There is a strong relationship between the agricultural, cultural, and economic past of this area and the development of chicken farming there. The historical path of chicken farming in Punjab is explored in this section, which traces its origins, development, and significance over time.

- **Ancient Origins:** Poultry farming in Punjab has its origins in the domestication of birds for human consumption, which occurred in prehistoric times. Domestic poultry may have been present in the area as early as the Harappan civilisation (3300-1300 BCE), according to archaeological findings. Ancient peoples relied on domesticated chickens as a reliable source of nourishment due to the high value of both the meat and the eggs they produced.

- **Medieval Period:** The agricultural techniques of the several medieval lords and dynasties that controlled Punjab led to considerable improvements in poultry production in the region. Through the dissemination of new farming practices and the formation of cooperative agricultural societies, the Mughal Empire was instrumental in expanding the agricultural sector, which included the raising of fowl.

- **Colonial Era:** Poultry farming was one of several agricultural activities that underwent radical transformations during British colonial control in India. Native chickens were bred with contemporary poultry breeds brought over from Europe by the British. Commercial poultry farms also began to spring up during this time, mainly to meet the needs of the expanding colonial government and city dwellers.

- **Post-Independence Period:** There was a watershed moment in Punjabi poultry farming when India gained its freedom in 1947. In an effort to increase food production and attain self-sufficiency, the government launched a number of agricultural reforms. As a result of these efforts, poultry farming became more important, with the goals of increasing output, bettering breed quality, and supplying the population's nutritional requirements.

- **Green Revolution:** Poultry farming was one of several agricultural practices in Punjab that saw dramatic transformations during the Green Revolution of the 1960s and 1970s. A dramatic increase in agricultural output occurred as a result of the widespread use of modern farming practices, high-yielding crop varieties, and increased mechanization. Because of these developments, poultry farming became more efficient, and farmers started using new techniques to keep up with the rising demand for chicken.

- **Technological Advancements:** Technological developments in the last several decades have significantly transformed chicken farming in Punjab. Increased output and profit margins have resulted from the use of modern management techniques, automated poultry equipment, and genetically enhanced breeds. In addition, farmers can now keep a closer eye on and better manage their poultry operations thanks to the integration of IT and digital technologies.

Poultry farming is becoming a major player in Punjab's agricultural industry, making a big impact on the state's economy and food security. The state's poultry sector is booming, with both large-scale commercial operations and smaller-scale private farms contributing to it. Poultry products, including eggs and chicken meat, are eaten by individuals from all walks of life. Looking at chicken farming in Punjab across time reveals how it has changed from the ancient world to the present day [26-28]. The agricultural techniques, culinary culture, and economics of Punjab have been greatly influenced by poultry farming, which has its roots in ancient civilizations and continues to be an integral part of the modern agricultural landscape. Future growth and innovation are likely to be fueled by the industry's ongoing evolution [29].

1.6 TRADITIONAL METHODS IN POULTRY FARMING

Poultry farming has a rich history that is deeply ingrained in traditional practices in regions like Punjab, where it has been an integral part of the agricultural economy and people's daily life for a long time. All aspects of conventional poultry farming, including housing, breeding, feeding, disease management, and labor use, are a part of it. In this article, we delve deeply into these traditional methods, shedding light on their continued use, challenges, and outcomes. The cultural and social heritage of a community is often reflected in the long-standing practices of traditional poultry rearing in Punjab and other places. Over time, the approaches have evolved to adapt to new resources, climates, and social needs. Industrialized poultry production disregards the entire animal and its role in the agricultural ecology, in contrast with conventional chicken farming approaches [30].

Natural selection and other methods of minimal interference are used in the breeding procedures of conventional chicken farms [31-34]. When choosing breeding stock, producers consider outward characteristics such as size, energy, and egg production ability. Inbreeding can lead to genetic limitations and reduced disease resistance when it occurs on a smaller scale. Depending on the area, traditional chicken coops can range from ornate structures made of mud, bamboo, or thatch to more rudimentary structures. Keeping the birds healthy and increasing their productivity is difficult in these buildings due to the lack of ventilation and temperature regulation, even though they provide some protection from the elements [35-37]. The lack of sophistication in many communities' methods to waste management poses a serious threat to both humans and the environment. Conventional chicken feed primarily consists of grain, leftover foods, and natural herbs. Nutritional imbalances, brought on by this method's low cost, often lead to less-than-ideal development and egg output [38-40]. The situation is exacerbated since farmers may lack knowledge about nutritional requirements.

Traditional chicken farming is prone to several illnesses because of problems like overpopulation, poor sanitation, and limited access to veterinary treatment. The main preventative measures include practicing good cleanliness and, on occasion, using traditional remedies. The continued threat of disease outbreaks to flock health and productivity highlights the need for improved management practices. Historically, egg production has been centered around Native American breeds that are renowned for their resiliency and ability to forage for food. Breeds like these may thrive in their natural habitats, but commercial hybrids have a far higher egg production capacity. Because of the ubiquity of home slaughtering processes, there is a considerable deal of variation in the quality and cleanliness of the meat that is produced. There is a lot of physical labor involved in typical chicken farming tasks such as feeding, watering, cleaning, and disease management. Even while everyone in the family usually helps out, there can be a shortage of hands during peak seasons or when people just decide to leave town. There is a wide range of management styles among farmers; some rely on traditional knowledge, while others struggle to adapt to customer demands. The social and economic fabric of rural communities is woven with the thread of poultry farming, which provides money to smallholder farmers and invests in the health and well-being of rural populations. Conventional chicken farmers often face challenges with inputs, markets, and extension services.

Local knowledge and agricultural history have intertwined to form a complex web of activities that make up traditional poultry raising. They may have survived for decades thanks to these methods, but rural areas are now finding it difficult to adapt to the rapid pace of technology and globalization. A combination of conventional wisdom and cutting-edge scientific knowledge and managerial strategies is required for chicken farming systems to thrive in Punjab and beyond.

1.7 CURRENT CHALLENGES FACED BY POULTRY FARMERS IN THE STATE

Economic, environmental, and regulatory concerns are just a few of the many obstacles that poultry farmers in our state must overcome. Both the availability and price of chicken products for consumers and the profitability of poultry farmers are impacted by these concerns. The future of our state's poultry business depends on our ability to identify and overcome these obstacles. Rising production costs are one of the biggest problems that chicken farmers are having to deal with. A large component of the production cost is feed, and changes in feed costs can have a substantial impact on the profitability of chicken farming [16-17]. Farmers already have a hard enough time making ends meet without having to worry about the unpredictable costs of inputs like labor, energy, and medication. Chicken producers are still quite worried about the ever-increasing production costs, even though they have made great strides in streamlining and improving their production methods. Disease management and biosecurity pose an additional obstacle. The fast spread of viral illnesses among birds can cause enormous economic losses for poultry operations. Some of the most prevalent poultry diseases that farmers face include avian influenza, infectious bronchitis, and Newcastle disease. To stop the spread of illness, strong biosecurity measures like vaccination programs, disinfection standards, and farm access restrictions must be put in place. But even with all these precautions, chicken farmers still face the ongoing problem of disease control.

Poultry growers also face difficulties related to sustainability and environmental restrictions. Waste management and water contamination are two areas where the poultry industry's effects on the environment have drawn attention. Farmers face a hard and expensive challenge when attempting to manage chicken waste in an ecologically friendly way. This waste includes manure and wastewater. Poultry farms already face higher operational costs as a result of the increased compliance load caused by stricter rules pertaining to waste management and environmental requirements. Poultry growers face problems due to changes in customer tastes and market dynamics. Farmers must adjust their production methods to cater to the growing demand for organic and free-range poultry products as customer preferences shift. It may be necessary to make substantial adjustments to current infrastructure and management methods, and the shift to alternative production systems can be capital-intensive. Local poultry farmers' bottom lines can take a hit when demand for their products goes up or down or when they face competition from overseas. The availability of capital and credit is an additional obstacle that poultry producers, especially those operating on a smaller scale, must contend with. Financial institutions may be sparse in rural areas, making it even more difficult for farmers to secure funding for capital investments like new equipment or expansion projects.

Poultry farmers are unable to invest in modernization and expansion due to limited access to funding, which impacts their long-term competitiveness and sustainability [41].

Another factor that affects the chicken sector is insufficient infrastructure, like roads and storage spaces. Farmers face higher transportation expenses and delays in getting poultry goods to consumers due to inefficient transportation infrastructure. Furthermore, post-harvest losses might occur due to inadequate storage facilities, which in turn reduces the overall efficiency and profitability of poultry production. Significant obstacles arise for poultry farms due to legislative and regulatory constraints. It is difficult for farmers to do business in an atmosphere with inconsistent policies, excessive bureaucracy, and unclear regulations. One way to address these difficulties and make the environment better for poultry farming is to streamline regulatory processes, offer policy support to the business, and make sure that different government bodies are consistent with each other.

1.8 COMPARISON OF TRADITIONAL AND MODERN SYSTEMS

The formulation of a smart strategy to improve chicken production in Punjab can be aided by comparing traditional and modern procedures. Historically, chicken farming in Punjab has been marked by modest operations, reliance on human labor, and minimal technological inputs. On the other hand, state-of-the-art systems maximize output and efficiency by utilizing research in science, automation, and new technology. By comparing and contrasting these two methods, we can identify their advantages and disadvantages, which will help us develop a smart strategy that is adapted to the unique chicken sector of Punjab. Much of the region's poultry production has been based on time-honored methods that have been passed down via parents and grandparents. Poultry farming on a smaller scale include backyard installations or single plots of land tended by individual farmers. Management techniques are frequently shabby, with little technology and an emphasis on physical labor for activities like feeding, cleaning, and disease control. This strategy is limited, but it has a certain allure due to its simplicity and dependence on local expertise. Inadequate access to current scientific information and technological advancements reduces efficiency, which in turn increases vulnerability to illness and other risks.

A new way of thinking is reflected in the contemporary methods of chicken farming. In order to optimize efficiency, production, and profitability, these systems use state-of-the-art technology, scientific knowledge, and industry standards. Mechanized processes, large-scale operations, and advanced infrastructure define modern chicken farms in Punjab. Modern chicken farming makes use of a wide range of technological improvements, such as climate-controlled housing, automated feeding and watering systems, and enhanced disease monitoring techniques. In order to maximize the birds' growth and egg-laying capabilities while ensuring their health and well-being, biosecurity controls, dietary optimization, and genetic selection are methodically performed. While contemporary methods certainly have their benefits, they also present certain difficulties. Establishing and maintaining modern chicken farms requires a significant financial commitment, which is one of the key problems. Many small-scale farmers are unable to embrace modern practices due to the high expense of infrastructure, equipment, and technology. Modern systems' reliance on industrial-scale production methods has also sparked worries over animal welfare and environmental sustainability. Problems with ethics and the environment might arise from poorly managed intensive farming methods including overpopulation and restricted outdoor access. It would be a mistake to discount the benefits that conventional methods provide. A stronger bond with nature and its inhabitants, as well as a dependence on indigenous wisdom and materials, are all part of this. Many traditional farmers have extensive knowledge of their surroundings and are able to adjust their methods appropriately. In addition to bolstering rural economies and food security, small-scale enterprises can help alleviate food insecurity by creating jobs and establishing decentralized production networks [42].

An intelligent strategy to increase poultry production in Punjab must take advantage of both traditional and modern methods while reducing their drawbacks. A mixed model that takes the finest parts of each could be one way to go about it. The preservation of local knowledge and sustainability principles might be achieved by incorporating contemporary methods and technologies into traditional agricultural systems, which would increase efficiency and productivity. Affordable technology, such disease monitoring apps for mobile devices or solar-powered water pumps, could help conventional farmers upgrade their methods without requiring massive investments. The obstacles that impede small-scale farmers from embracing contemporary practices should be addressed. Offering smallholders specialized training, technical assistance, and financial incentives are all ways to help them. Furthermore, it is important to support efforts that promote ethical and sustainable agricultural methods, such as organic certification programs or agroecological techniques that emphasize the management of natural resources and biodiversity.

1.9 IMPACT OF TECHNOLOGY ON POULTRY FARMING

Technology has had a huge effect on poultry farming, changing the game from the old ways of doing things to the current, efficient chicken industry. Poultry farming has been greatly enhanced in productivity, animal welfare, and environmental sustainability thanks to the pervasiveness of technology at every step of the process, from managing the hatchery and breeding to processing, distribution, and manufacturing. The field of chicken breeding and genetics has benefited greatly from technological advancements. Scientists have been able to create chicken breeds that are genetically better because to advances in biotechnology and genetic engineering. These breeds have desirable qualities like faster growth, more meat production, better resistance to diseases, and better feed efficiency. Poultry farmers can maximize their flocks' genetic potential through selective breeding and genetic selection processes, leading to better products and more profits. New methods of housing and managing chickens have also been made possible by technological advancements. These days, state-of-the-art chicken farms have state-of-the-art climate control systems, automated feeding and watering systems, and environmental monitoring sensors to make sure the birds are grown in the best possible environment. With the help of automated technologies, we can increase yields while decreasing labor requirements and stress on the birds. This, in turn, leads to better product quality and more consistent growth rates.

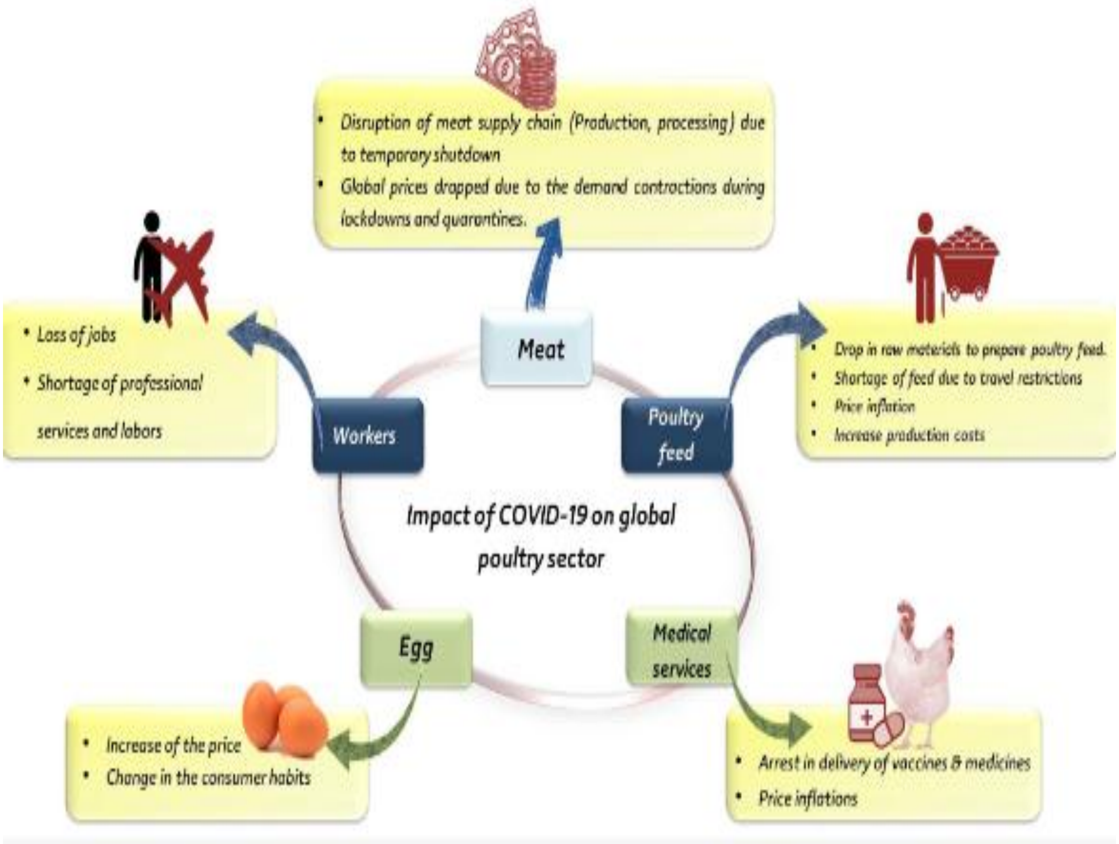


Figure 1.1 : Poultry Production and Sustainability

When it comes to managing and preventing diseases in chicken production, technology is vital. The ability to quickly and accurately diagnose infectious diseases is a boon to farmers, who may then take appropriate action to avert disease outbreaks thanks to modern diagnostic techniques like enzyme-linked immunosorbent assays (ELISA) and polymerase chain reaction (PCR) testing. Technology also helps with biosecurity measures including vaccination programs, disinfection routines, and restricted access zones, all of which work to keep flocks healthy and reduce the likelihood of disease spread. Farmers can now maximize production efficiency and make data-driven decisions thanks to the integration of information technology and data analytics, which has also revolutionized poultry farming operations. Farm management software and IFMS give farmers access to up-to-the-minute information on KPIs including feed consumption, growth rates, mortality rates, and production costs [44].Farmers may enhance their profitability and sustainability by assessing this data and implementing focused interventions to identify areas for improvement and optimize resource allocation. Recent developments in food safety and traceability technologies have bolstered regulatory compliance in the poultry business and increased consumer trust in poultry products. The use of automated evisceration machines, portioning machines, and vacuum packaging systems, among others, guarantees clean handling and reduces the likelihood of contamination while processing. In addition, RFID (Radio Frequency Identification) tags and blockchain technology make supply chains open and traceable, so buyers can see where their chicken came from and make sure it's safe and healthy.

Poultry nutrition management has also been transformed by the emergence of feed formulation and precision nutrition technology. These tools allow farmers to optimize feed formulations according to the unique nutritional needs of their flocks. The use of algorithms and predictive modeling allows feed management software and automated feed mills to precisely combine and dispense feed ingredients, guaranteeing feed efficiency and optimum nutrient balance. To further improve sustainability in chicken production and lessen dependence on conventional feed sources, technology also allows for the use of alternative feed ingredients like algal meal and insect protein.

1.10 MOTIVATION

A new age of sustainable agriculture and economic success has dawned with the creation of an intelligent strategy to increase chicken production in the state of Punjab. The chicken industry in Punjab is vital to the food security and livelihoods of millions of people in India and is one of the most important parts of the country's agricultural landscape. Nevertheless, conventional approaches sometimes fail to address the increasing needs of a rapidly expanding population, in addition to the difficulties presented by changing weather patterns and limited resources. So, optimising efficiency, production, and sustainability through the integration of smart technologies has the potential to radically alter the chicken farming industry.

Integral to this revolutionary path is the application of state-of-the-art technology like data analytics, the Internet of Things (IoT), and artificial intelligence (AI). Poultry farmers may now make better decisions with the help of AI by analyzing data in real-time, using predictive modeling, and utilizing machine learning techniques [45-48].This allows them to anticipate possible problems, improve disease control techniques, optimize feed formulas, and guarantee healthier flocks with increased yields. With the help of Internet of Things (IoT) devices, poultry farms can be remotely monitored and controlled, which reduces operating costs and the need for human intervention. Farmers may optimize the environmental conditions for maximum productivity by making rapid modifications to characteristics such as temperature, humidity, air quality, and water consumption that smart sensors installed within the chicken houses monitor.[49]

The massive volumes of data produced by chicken farms can be uncovered with the use of data analytics. Farmers can enhance their production methods, maximize resource use, and spot inefficiencies by studying patterns and trends in historical data. Additionally, farmers may make proactive decisions with the use of predictive analytics, which can foretell market trends, demand variations, and disease outbreaks. This allows them to react quickly to changing circumstances and reduce risks. There is tremendous opportunity for economic empowerment and rural development in Punjab with the implementation of a smart strategy for chicken production. Smallholder farmers can boost their incomes, negotiating leverage, and market access by utilizing technology. The region's economy grows and prospers as a result of smart farming methods since they increase employment and entrepreneurship in the agritech sector.

The smart method of chicken production helps the environment and saves resources, in addition to the bottom line. Fowl farming has a negative effect on land, water, and air quality, but farmers can lessen this effect by increasing feed efficiency and decreasing wastage. Additionally, precision farming practices reduce chemical inputs, which helps maintain ecological balance and protects biodiversity. The effective application of an intelligent strategy to chicken production relies heavily on teamwork and the exchange of information. For smallholder farmers to embrace innovation and overcome adoption barriers, public-private partnerships can help with technology transfer, capacity building, and access to funding. In addition, farmers can be equipped with the knowledge and abilities to fully utilize intelligent technologies and incorporate them into their farming methods through extension services and training programs [50-54].

1.11 PROBLEM STATEMENT

Poultry farming is an important part of Punjab's agricultural economy, which benefits farmers' incomes and the food distribution system as a whole. Nevertheless, the poultry sector encounters numerous obstacles that impede its progress and effectiveness, notwithstanding its significance. Disease outbreaks, feed shortages, environmental issues, and unpredictable market needs are among these challenges. An astute strategy that incorporates state-of-the-art technology and fresh approaches is urgently required to overcome these obstacles and boost poultry production in Punjab. While guaranteeing farmers' sustainability and profitability, this method should strive to maximize different areas of poultry farming, such as feeding, disease management, breeding, and waste management.

The volatility of consumer demand is a major obstacle to chicken farming in Punjab. Farmers can lose money due to overstock or undersupply conditions caused by changes in consumer tastes and market trends. Data analytics and market forecasting algorithms could be a smart move for chicken production since they could reliably predict patterns in customer demand[55-58]. Farmers can improve their profitability and decrease the risk of financial losses by making informed decisions about the production and marketing of chicken products by examining historical data, market trends, and customer behavior. The destructive impact of disease outbreaks on poultry farms is another major obstacle in chicken production. Poultry flocks are vulnerable to fast-spreading diseases like avian flu and Newcastle disease, which can cause significant economic losses and high mortality rates. An astute strategy for disease control could include the use of cutting-edge diagnostic tools like polymerase chain reaction (PCR) and serological assays for early illness detection and prompt control actions. Furthermore, farmers would be able to take preventative actions to safeguard their flocks if AI and machine learning algorithms were to detect patterns of disease and forecast future outbreaks.

The nutritional status of the birds is another important factor that affects their well-being and the amount of food they produce when raised as chicken. A substantial amount of production expenses go towards poultry feed, therefore finding the sweet spot for feed composition is crucial for making the most money. Precision feeding and individualized diet formulas suited to the unique requirements of various chicken breeds and phases of production could constitute an astute nutritional strategy[59]. Farmers may maximize feed efficiency, decrease waste, and enhance flock health and performance by utilizing technologies like automated feeding systems and near-infrared spectroscopy. Poultry farming also has to take environmental impact into account, especially in heavily populated areas like Punjab. Pollution of water and soil, as well as emissions of greenhouse gases, are some of the major environmental problems that can result from improper disposal of poultry waste. Anaerobic digestion systems and nutrient recovery technologies are two examples of cutting-edge waste management solutions that could be used to transform chicken manure into biogas and organic fertilizers. Farmers may enhance the sustainability of their businesses and meet regulatory requirements by recycling poultry waste and limiting environmental effect [60-64].

1.12 SCOPE OF RESEARCH

Analyzing present poultry farming techniques, identifying important issues, and exploring innovative technologies and methodologies are all part of the scope of developing an intelligent approach to boost chicken output in the state of Punjab. Part of this effort will include gathering data on how different things like diet, illness control, breeding methods, and environmental variables influence the well-being and output of chickens. Furthermore, data-driven solutions and artificial intelligence (AI) integration are all part of the plan to enhance poultry farming operations, decision-making, and farmers' yields and profits. Intelligent methods in poultry production can only be effectively implemented and adopted with close cooperation between all parties involved, including government organizations, agricultural specialists, technology suppliers, and individual chicken farmers[65]. In the long run, we hope to see Punjab's poultry business flourish and become more efficient so that we can keep up with consumer demand for premium chicken products and help farmers better their living conditions.

Research Goals

- Analyzing and researching current methods employed in chicken farms.
- The aim is to create a smart strategy to improve poultry production in Punjab by controlling humidity and temperature..
- Developing an image processing-based method to identify disease-related alterations in poultry behavior.
- To examine and verify the suggested methodology.

A major step towards transforming the agricultural scene of the Punjab region has been made with the implementation of an innovative strategy to increase chicken production. Considering Punjab's prominence as an agricultural hub in India, there's great potential for intelligent technology to improve efficiency, sustainability, and productivity in the chicken farming industry. The application of precision agriculture methods developed for chicken production stands out as a major contributor. With the use of cutting-edge sensors, data analytics, and machine learning algorithms, farmers can keep a close eye on their poultry birds in real-time, tracking metrics like temperature, humidity, feed consumption, and health indicators. To ensure the health of the flock, this fine-grained monitoring system allows for the early identification of any abnormalities or symptoms of disease, enabling swift action and preventative measures. In addition, by using predictive analytics models, we can maximize output while minimizing waste by anticipating when it is best to feed, vaccinate, and alter the ecosystem.

Intelligent automation systems are yet another huge step forward for Punjab's chicken industry. Machines that gather eggs, regulate the temperature, and automate feeding systems all work together to make previously labor-intensive jobs easier, cheaper, and safer. Additionally, these mechanized systems can be coupled with intelligent algorithms that, given real-time data inputs and predetermined parameters, can adaptively modify the environmental conditions within chicken homes. Not only does this make sure the birds are happy and healthy, but it also helps farmers make more money. Poultry farmers are empowered with actionable insights and educated strategies through the implementation of data-driven decision support tools. Breeding programs, stocking densities, disease management protocols, and marketing strategies can all be informed by data collected from a variety of sources, including weather patterns, market trends, poultry farming practices, and disease outbreaks. As a result, farmers may maximize their investments' returns while being nimble and sensitive to ever-changing market conditions.

Optimized feed formulations that meet the unique nutritional needs of various chicken species and phases of production are made possible through the integration of precision nutrition technologies. Feed compositions can be fine-tuned to maximize nutrient absorption, growth rates, and feed efficiency by utilizing genetic algorithms and predictive modeling techniques. In addition to helping with resource management and conservation, this boosts the birds' general well-being and productivity. Farmers can now keep tabs on their chicken operations from the convenience of their mobile devices or computers thanks to remote monitoring and management solutions. Farmers are able to prevent losses and keep operations running smoothly thanks to real-time alerts and notifications that inform them of key events or when they deviate from predefined standards. In addition, the use of remote monitoring makes it easier for researchers, veterinarians, poultry producers, and agricultural extension agencies to work together and share information, which promotes a mindset of innovation and constant development in the poultry sector [66].

1.13 IMPACT TO THE SOCIETY

Revolutionizing the agricultural landscape and society in multiple ways could be achieved through the creation of an intelligent technique to boost chicken production in the state of Punjab. The agricultural economy of Punjab relies heavily on poultry production, which helps provide food security, boosts economic growth, and creates jobs. The industry as a whole may benefit greatly from smart technology and fresh approaches, which will increase efficiency, longevity, and profits.

First and foremost, Punjab's agricultural output stands to benefit greatly from the implementation of smart strategies for chicken production. Farmers may improve several parts of chicken farming with the help of AI, ML, and the IoT (Internet of Things), including environmental monitoring, disease control, nutrition management, and breeding. In order to optimize yields and minimize losses, producers can use data-driven decisions made possible by AI-powered systems to assess massive volumes of data pertaining to the health, behavior, and performance of poultry. The health and productivity of the chicken flock may be guaranteed by using predictive analytics to foresee disease outbreaks, optimize feed formulations, and optimize environmental conditions [67-68].

The long-term viability of Punjab's agricultural sector can also be enhanced by a strategic approach to poultry production. To reduce trash in the environment, save energy, and slow global warming, sustainable chicken raising is a must. Optimization of resource usage, reduction of waste, and mitigation of environmental impact are three areas where intelligent technology provide novel answers to sustainability issues in poultry production. In order to maximize nutrient absorption and minimize waste, feed compositions can be optimized by AI-powered algorithms. This approach minimizes resource use. Internet of Things (IoT) devices can track how much water, electricity, and waste a chicken farm produces, so farmers can find inefficiencies and fix them specifically to reduce their impact on the environment. The smart method of chicken production can lessen the impact of climate change and contribute to the preservation of Punjab's natural resources by encouraging sustainable farming methods.

The state of Punjab stands to gain significantly economically and socially from the creation of a smart strategy for chicken production. Especially in rural areas and among smallholder farmers, poultry farming provides a substantial income and number of jobs for millions of people in the state. Farmers may improve their livelihoods and socio-economic well-being by embracing intelligent technology that increase production and profitability. Poultry farmers in Punjab may enhance their earnings by lowering production costs, increasing market competitiveness, and improving market access through the implementation of AI-powered solutions.

Innovation and entrepreneurship in agriculture can be fostered through the creation of new possibilities for qualified individuals in sectors like robotics, data science, agricultural engineering, and other related areas through the integration of intelligent technologies in chicken production. The intelligent approach to chicken production has the potential to alleviate poverty, develop rural areas, and promote equitable growth in Punjab by equipping farmers with the information and skills needed to thrive in the digital era. Improving Punjab's food security and nutrition can be greatly aided by adopting an intelligent approach to chicken farming. Eggs, meat, and other poultry products are great additions to a healthy diet since they provide a lot of protein, vitamins, and minerals. Consumers in Punjab will have easier and cheaper access to chicken products thanks to clever technology that boost productivity and efficiency in poultry farming. Public health outcomes can be improved, and malnutrition can be addressed, especially among at-risk groups like pregnant women and children. In addition, by increasing nutritional variety and decreasing dependence on traditional crops, poultry farming helps diversify agricultural productivity and improve food security. The smart strategy for chicken farming can help the people of Punjab in the long run by making sure they have access to healthy, reasonably priced chicken.

Chapter – 2

LITERATURE REVIEW

This chapter explores the creation and implementation of a smart strategy to enhance chicken production in the rural area of Punjab, India. The project aims to optimise production via the integration of intelligent technologies and solve current issues in the poultry business, which is crucial to the state's economy and food security. At the outset, the chapter gives a thorough review of the chicken industry in Punjab as it is right now, touching on important issues such feed management, operational inefficiencies, and disease outbreaks. Artificial intelligence, data analytics, and sensor technologies are subsequently integrated into the theoretical framework of intelligent methods. Making better decisions, allocating resources more efficiently, and increasing overall production efficiency are the primary goals of using these technologies. Offering practical consequences for stakeholders, policymakers, and poultry producers, this chapter adds to the developing conversation on intelligent ways in agriculture. Discussed are the possible societal and economic effects of the intelligent system on the poultry sector in the State of Punjab. It is emphasised that in order to guarantee robust and sustainable poultry production in the area, a paradigm change led by technology is necessary.

2.1 INTRODUCTION

In order to replace inefficient manual systems with automated ones, people are turning to rapidly developing technologies like the Internet of Things (IoT) and cloud computing. The Internet of Things (IoT) has far-reaching effects on practical fields that stand to benefit greatly from the use of smart technologies, such as healthcare, transportation, and agriculture [1]. The Internet of Things (IoT) not only makes the domains in which it is utilised more efficient and effective, but it also makes their management easier. The incorporation of new technology into the applications of several fields is causing rapid development in many areas, including agriculture [2]. While some poultry farmers are making efforts to modernise their operations, others persist in utilising manual processes. To bolster the poultry business, the Internet of Things (IoT)-based Smart Poultry Monitoring and Egg Production Prediction System (IoT-SPMEPPS) has arrived. Poultry producers can automate their operations, save all data securely, and increase the amount and quality of their meat and eggs using this technology. By enhancing the current system with IoT technology, this system further supports chicken farming as a stable food supply and a source of high revenue. Additionally, the system allows farmers to track and assess how well their company is doing, and to plan based on data analysis utilising Machine Learning (ML) [3].

Poultry farming is a subset of livestock farming that involves the domestication of birds for their flesh or eggs, often ducks, chickens, geese, or turkeys. Chickens, of which there are two main types: broilers (chickens raised for meat) and layers (chickens raised for eggs), make up the vast majority of poultry. Internet of Things (IoT)-based smart poultry monitoring and egg production prediction system with an emphasis on hens. But after they're elderly and no longer lay eggs, you may eat these chickens. Poultry farming is a viable option in areas where there is a shortage of land for housing or other enterprises due to population growth since it does not need large plots of land or large initial investments. The demand for eggs and chicken meat is also on the rise. Consequently, the person is involved in raising chickens [4]. The need for animal protein is rapidly increasing, and with it, the influence of poultry farming on human lifestyle. Poultry is common in more rural regions. In 2017, around 69% of all poultry producers were raising a flock of hens. the value of chicken to the nation in combating undernourishment, particularly among children younger than five, and youth unemployment, thanks to the substantial cash generated by commercialised poultry farming [5].

All throughout the globe, the conditions in which poultry farms are set up have a significant impact on the industry. In industrialised countries, the hazards of illness, transportation, and storage are often increased by government intervention and technological developments. Conversely, private poultry farms in developing nations rely on antiquated and labor-intensive production, transportation, and storage practices [6]. Problems with shipping and storage, as well as an absence of adequate tools to limit the impacts of a disease epidemic, often cause losses in such situations. The majority of Punjabi entrepreneurs are interested in chicken farming, which is something the province is proud of. There were between 60,000 and 65,000 registered commercial farms in 2017, and the poultry sector employed roughly 2 million people directly or indirectly.

Integrating a microprocessor with sensors for temperature, gas, and light intensity, as well as a food valve and GSM, allowed for the design and implementation of this system. This concept allows the farmer to remotely control the feeding process using mobile phone while the physical conditions are adjusted automatically. The system's Achilles' heel is that it failed to take water's relative importance into account. Additionally, there is no automated system for collecting and counting eggs, and there is no camera set up to remotely watch the chicken farm. Boonsong et al. [7] suggested a method that sends data on humidity and temperature to the cloud every five seconds. One issue with this technology is that it doesn't automatically regulate the temperature and humidity levels after monitoring them based on the results. In their proposal, Boopathy et al. [8] included Internet of Things (IoT) devices that would run on farm-specific settings. In order to protect against burglary and fire, door and gas sensors are installed. Additionally, environmental characteristics are gathered and saved to ThingSpeak. One drawback is that the system can't automatically control feeding systems and environmental factors after data collection and transmission to ThingSpeak.application that uses internet of things techniques to oversee and manage a chicken farm. Thanks to the microcontroller's integration with wireless sensors, the heating and ventilation systems operate automatically and without human intervention. Data is stored in the cloud, allowing the farmer to access up-to-the-minute information about his farm. The lack of an automated method for collecting and tallying eggs is a drawback. There is no forecast made following the analysis. A working model is built that can detect when data values go above certain thresholds by collecting environmental factors using an Internet of Things (IoT) and wireless sensor network. The lack of a method for counting eggs and making predictions is a drawback. Prior studies have shown that the current system does a good job of making poultry operations easier, but there is a lack of data collection and analysis for both the present and the future of egg production in relation to environmental factors and past egg production. The goal of this work is to generate an Internet of Things (IoT) prototype that can track the number of eggs laid and utilise that data to forecast future egg production in a poultry house.

In recent years, poultry farming has emerged as one of the most dynamic and lucrative subsectors of the livestock industry, with profits ranging from half a percent to half a fifth of total sales [9]. The construction of housing, the purchase of waterers, feeders, day-old chicks, and feed are all expenses that farmers incur while raising poultry. Poultry growers recoup their investment in chickens when they begin to lay eggs. Like other agricultural sub-sectors, chicken farming has been impacted by the large growth in population, notwithstanding its benefits. Demand for food rises in tandem with the population, which puts a strain on arable land. In order to meet the difficulties brought about by a growing population, farmers will need to adopt new technological practices. Poultry and eggs, according to studies conducted all around the world in April 2019, improve food quality overall. This is because eggs are a great source of protein and vitamins. Poultry and eggs should be widely available and inexpensive, according to the Food and Agriculture Organisation (FAO). This is particularly true in underdeveloped nations where people often struggle to afford healthy food. People suffering from malnutrition, expectant mothers, nursing mothers, the elderly, and small children all benefit greatly from eating chicken and eggs [10].

The health and productivity of chickens are significantly impacted by environmental factors including temperature and humidity. The hens' ability to develop and lay eggs is negatively impacted by the presence of high concentrations of gases such as ammonia and carbon dioxide in poultry houses. It is impossible to keep hens healthy and productive on a poultry farm if their living circumstances are not properly managed. Processes that must be overseen including managing the amount and quality of food, water, and environmental variables like temperature, humidity, gases, and daylight hours. Automating, controlling, and managing poultry farming remotely is the emphasis of this work, which aims to build and prototype an Internet of Things

(IoT) based smart poultry monitoring and eggs production forecast system. This system will make the poultry farm safer and more pleasant for the birds and will address the issues that cause hens to lay fewer eggs or not lay eggs at all. The goal is to increase egg production and decrease the risk of health problems for both the chickens and the humans who consume their meat and eggs. Also, this approach is designed to make it easier for chicken keepers to visit the coop less often, which means less work for them. Gas sensors are used to keep an eye on the hens' fire safety. Data collected from the farm will be saved in a database on a cloud server and on the farmers' website, which will be accessible via the Internet-connected system that will be created. The data generated by sensors placed around a farm allows the farmer to keep tabs on the farm from any location and get alerts by SMS and alarm. As soon as a problem arises on the farm, the farmer may step in and fix it [11].

The health of chickens might be affected by the Internet of Things (IoT) based smart system for monitoring and predicting output in poultry farms. Automating poultry farming procedures, remotely monitoring the farm, and analysing data acquired from the farm are the main goals of this project. The goal is to plan and anticipate future egg output. Poultry farms that use IoT see a significant uptick in both the quality and quantity of their meat and eggs. A large portion of the global population relies on agriculture for subsistence, but this industry is facing serious challenges as a result of land scarcity brought on by rapid population expansion, according to a World Bank analysis. People are becoming bigger while the land stays the same. Poultry farming, whether for layers or broilers, often doesn't need a large plot of land, which helps alleviate the issue of land scarcity. So, if we want to make the most of limited resources, raising chickens is the way to go. Betterment of the poultry sector is the goal of the initiative. If this initiative goes through, it will allow farmers to keep tabs on their hens and their farm from any location at all time, which should lead to increased productivity. Additionally, issues pertaining to the mismanagement of poultry farms, such as chicken illnesses, stunted growth, and poor egg production, will be handled [12].

2.2 CONCEPT OF POULTRY PRODUCTION AND INTELLIGENT APPROACH

Poultry production, as a subset of livestock production, contributes to a nation's economic and social development as well as its citizens' biological needs by helping to alleviate food insecurity, providing jobs for those involved, and increasing their incomes. The process begins on the first day of their lives and continues until they reach maturity, requiring a combination of agricultural inputs, money, labour, and business skill. Poultry production inefficiencies might stem from environmental, socioeconomic, or demographic causes. Yet, farmers cannot be held responsible for their inefficiency due to the effects of some external circumstances, including weather and government regulations, which are beyond their control. The administrative abilities of farmers may be affected by socioeconomic issues, which in turn influence their efficiency. Some examples of these socioeconomic factors include the farmer's age, education level, years of experience raising poultry, availability of credit and extension services, social networks, farm size, gender, and involvement in non-farming income generating activities.

The researchers found that the two most important variables impacting productivity in chicken farms were age and education level. The study's findings showed that younger farmers outperformed their older colleagues in terms of productivity. Currency depreciation and very ineffective government policies exacerbated the problem. The technical efficiency of the farmers is improved by the increased knowledge and information gained from farming experience, as well as by the high levels of competence in farming practices and management [13]. An individual's capacity to disperse risk, adjust to changing weather patterns, and learn new farming techniques are all enhanced by years of experience in the field Using stochastic frontier production, when the technical efficiency of chicken production was calculated , it showed that it was 87% in the semi-hilly region, 94% in the central region, 86% in the south- western region, and 87% in Punjab state. Technical efficiencies are positively and strongly correlated with a farmer's age, education level, and experience, according to their model.

2.3 INTELLIGENT APPROACH FOR DECISION MAKING

The analytical process in traditional decision support begins with a specified set of input data. Following the algorithm's instructions, one processes the data sequentially until one reaches a conclusion. In this context, the algorithm is crucial since algorithms are a kind of knowledge representation. It is necessary to modify or reconstruct algorithms in the event that the problem's knowledge changes. It is necessary to create a new system in order to solve new problems in the same area. In contrast, experts in the field often use a cognitive approach instead of an algorithm [14]. They depend on their vast store of information, which might include facts, statements, their own errors, and the trial-and-error approach. Intelligent Approaches are the machines' analogues to human specialists. Using a knowledge base as a distinct component, the Intelligent method complements the cognitive method and places an emphasis on knowledge. The Intelligent Approach's fundamental structure remains unaltered when new information becomes available. Reasoning capacity is an additional benefit. They may provide justifications for certain decisions.

2.3.1 Importance of Poultry Intelligent Approach

Poultry farmers confront a myriad of difficult concerns, including but not limited to: medication-related issues with poultry farm goods, issues with location and water, parasites and diseases in poultry products, and feeds for poultry products. Using an Intelligent Approach, you can tackle all of the aforementioned poultry problems. In contrast to traditional computer programmes, Intelligent Approach programmes attempt to find solutions to issues by using reasoning techniques that are similar to those used by humans, such as reasoning based on beliefs, logic, rules of thumb, and experience [15]. To better handle the kind of impromptu decision making that contemporary farmers face, Intelligent Approaches in agriculture may combine the viewpoints of separate fields like horticulture, agricultural meteorology, plant pathology, and entomology. When it comes to helping farmers make the integrated decisions they need on a daily basis to tend to their crops, Intelligent Approach is among the most important tools at their disposal. Researchers in several areas of agriculture have found success using computer-based Intelligent Approach, as seen in the papers analysed in this section. In light of the above, it is important to design a computer-based Intelligent Approach that is easy for student researchers to use, taking into account factors such as the problem's complexity, software's familiarity, and the researcher's level of comfort with the tool.

2.3.2 Benefits of Intelligent Technology in the Poultry Industry

Modern innovations in chicken farming technology have taken automated control of the raising system's processes into account. Laying pens, grill houses and brooder houses are all part of the automated machinery. Once an egg has been deposited, the laying cages are programmed to remove it automatically. This lessens the likelihood that the laying hens will peck at and consume the eggs [16]. In some technological setups, the broilers' cages function as self-closing and -opening mechanisms that restrict the hens' mobility. This allows them to save energy, which is then used for bodybuilding purposes. Hence, more rapid expansion occurs. There has been less waste due to the efficient scaling of feeds made possible by the automated feeding apparatus. The feeding equipment's characteristics have helped farmers and enterprises save money on feed, allowing them to maximise profit. The energy that would have been utilised by personnel to feed the animals has been saved by this technology. Consequently, labour costs are lowered, resulting in a drop in manufacturing costs.

In order to make activities less harmful to the environment, every technology has a purpose. Dripping technology, which helps save water and makes it cheaper to purchase, was born out of this need. The birds will always have access to water when they need it thanks to dripping technology. Dripping technique also prevents manure from becoming bad since water can't get through. The high nutritious content of chicken manure makes it the favoured choice of agricultural and fish growers. The effective preservation of manure requires this method. Commercial chicken farms have benefited from the introduction of brooding devices. There is a self-turning mechanism in the apparatus that allows the eggs to be heated to the perfect hatching temperature. In only 21 days, the brooder may hatch hundreds of eggs. The hatchability rate of eggs laid in a brooder is much higher than that of eggs laid on a hen's eggshell. The machine can increase the high hatching rate since it uses regulated settings, which are crucial to the procedure. Ideal conditions, such as low humidity and good air circulation, are necessary [17].

Availability of environmental controller technology that can modify the temperature and humidity of chicken houses has made poultry farming more feasible in temperate zones. With this apparatus, birds can weather storms and other severe weather events that would have killed them if they were raised outside. In order to improve the birds' raising settings, the controller lets the producers collect data that is important for building new conditions. Every day, data is captured and saved by the computerised controllers for future study. The adoption of the grill colony technique has allowed for the production of poultry in a small area, as compared to the free-range method, which has made indoor bird raising more feasible [17–18]. The producers have been able to retain twice as many birds under this approach as they would under a free-range system. The technology has optimised the return on investment for chicken farms. Worldwide, poultry production ranks high among the most lucrative agribusinesses. Raising birds was mostly done for household purposes in the past. But many have jumped on the bandwagon for the agricultural method as a result of technological developments and the prospect of a ready market. These technological advancements have eliminated the need for labour by streamlining the whole process, from hatching to raising. But further study is required to aid in the management of bird illnesses and pests.

2.4 EMERGING TRENDS IN POULTRY FARMING

A new way of doing things has evolved all throughout the globe. Poultry farms have gradually incorporated new technologies. The revenue from chicken farming has improved as a result of these changes. Unfortunately, their widespread use is hindered by the high cost and technical challenges that come with their use, particularly in less developed nations. The fact that their impact on employment levels is still up for debate is a major negative. Robots are becoming more popular in Thailand for the purpose of feeding chickens and other animals in an effort to keep them healthy [19]. "Nanny robots" developed by Cheroen Pokland Group notify farmers of impending disease outbreaks and recommend when to restock feed supplies. During the egg-laying stage, the robots are used to ensure the well-being of almost three million chickens. For example, when the robots identify a sick bird, they will alert the humans taking care of the bird to isolate it so it doesn't spread the disease. Using drones to keep an eye on the flock is another new fad in chicken farming. Uncertainty and scepticism, however, cloud this technical landmark. Drones may be a source of stress for chickens and other fowl, particularly those confined in cages. Contrarily, chickens raised in coops or free-range birds report far better reception of the technology. The success of the programme, however, depends on the birds' ability to be trained.

Similarly well-received is the new practice of using sensors to track specific birds of prey. Modern Asian poultry housing, like Big Dutchman, incorporates ammonia detectors implanted in each bird. Aside from that, sensors are used in the Republic of the Philippines to regulate and manage climatic changes in the hen houses. These variations include monitoring ventilation and temperature. To maximise the effectiveness of the birds' growing, Greengage employs a novel lighting system that makes use of sensors. Because they enable the birds more freedom of movement, using LED lights to continuously control the lighting and temperature helps to save money and enhances the birds' well-being [20]. Farmers might learn more about the health of their chickens with the help of sensors. Researchers may also study the birds in their natural habitat with the use of tags fitted with sensors, which would allow them to collect more data more effectively. Based on the behaviour of poultry birds, this observation might provide additional information about the best technique of poultry farming: caging or free-ranging.

2.5 TRADITIONAL APPROACHES IN POULTRY FARMING

Traditional methods have always been an integral part of poultry farming in the State of Punjab and many other parts of India. The traditional approaches have been crucial in the growth of the poultry business, but they have their own set of constraints that prevent it from reaching its maximum potential. Here we take a look at the essentials of conventional chicken farming methods, illuminating their methods, problems, and the need for new ways.

2.5.1 Conventional Farming Practices

Traditional chicken farming in Punjab has always relied on hard work, simple management techniques, and making decisions based on past experiences. In the past, farmers would use crude housing and feeding methods to raise chickens for meat and eggs. Much of the information used for disease control, breed selection, and breeding procedures has been handed down through the centuries [21]. Housing on conventional chicken farms is often plain and may not include contemporary conveniences like air conditioning or automatic ventilation. Although established for specific regions, traditional breeds could lack the desirable traits of contemporary, selectively bred breeds, such as rapid growth or resistance to certain diseases.

There is less of a focus on balanced nutrition in traditional feeding techniques, which often include grains and additives purchased locally. Some watering systems may be rather rudimentary, and the waste management practices may not adhere to contemporary ecological norms. Despite their usefulness, these methods may reduce industrial competitiveness and contribute to less-than-ideal manufacturing efficiency.

2.5.2 Limitations of Traditional Methods

While conventional poultry farming techniques have their place in history, they aren't without their drawbacks that make them less efficient, less productive, and less sustainable in the long run. Important environmental variables for healthy chicken development and growth—including temperature, humidity, and ventilation—are notoriously difficult to regulate precisely. Birds kept in conventional cages may be more vulnerable to illness and have lower reproductive rates due to inadequate protection from severe weather [22]. Conventional methods of disease management may not have the same level of scientific rigour as more contemporary ones, and they rely significantly on anecdotal evidence. The risk of disease outbreaks and greater death rates are both exacerbated by this. Nutrient runoff from improperly managed waste is one environmental problem that conventional agricultural methods may exacerbate, endangering both water and soil quality.

A further issue with conventional chicken rearing is its financial sustainability. Profitability of farms may be affected by inefficient use of resources, poor growth rates, and greater death rates. Traditional techniques may find it challenging to keep up with the increasing demand for sustainable, high-quality poultry products due to changing customer preferences and market factors.

2.5.3 Economic and Environmental Impacts

Traditional chicken farming techniques in Punjab have substantial economic and environmental implications. Feed conversion inefficiencies, slower growth rates, and greater mortality rates all add up to higher production costs from an economic perspective. The market competitiveness of local poultry products is therefore impacted by this. Smaller farms may struggle to compete with bigger, better-equipped farms that may take advantage of economies of scale [23]. Conventional chicken farming practices have the potential to worsen environmental problems including resource loss and pollution. Furthermore, conventional chicken rearing worsens the environmental impact due to the wasteful use of feed and water [23–24].

2.6 THE OPPORTUNITY OF POULTRY FARMING IN PUNJAB

There will be a lot of growth in emerging countries' cattle sectors during the next 20 years. Most of the growth will likely come from the chicken and egg industries. Punjab now has GP and PS breeding and marketing companies, thus the nation might benefit from this kind of opportunities. How well Punjab can cater the anticipated expansion is an important one. Due to insufficiency in domestic production, Punjab must import feeds and other necessities. It becomes necessary to consider alternate strategies in order to limit the anticipated increase in chicken farming. Supply and demand each have different potential for expansion. The majority of Punjab's poultry farms are demand driven. Factors influencing demand elasticity include increasing urbanisation, per capita income, and population size [24]. In the future, there will be a greater demand for chicken products due to the increasing urbanisation, income, and population of Punjab. The increasing demand suggests that the poultry sector in Punjab has room to develop.

Because of the welcoming climate for international investment, poultry farming in Punjab has the potential to expand. Foreign investors in the poultry industry will find

Punjab's government to be an accommodating place to do business. At the moment, the poultry sector in Punjab is home to only a handful of multinational corporations. Godrej, Sokuna, and New Hope are among the firms involved. Tax holidays, export incentives, and power subsidies are all examples of the present trend of government assistance that is likely to entice additional investors to the nation. There has to be an influx of multinational corporations into Punjab poultry farming to address the persistent demand and supply mismatch of chicken products in the province. The rising demand for processed meat and other processed foods is another element that is creating more opportunities for the poultry sector in Punjab to flourish. Fast food chains with global reach have set up shop in Punjab over the last five years, including McDonald's, A&W, and KFC. Fast food restaurants, in fact, seem to be popping up all the time [25]. The stores choose processed meat since it is hygienically butchered. More processing businesses may come up as a result of this development.

2.7 PROBLEMS AND CHALLENGES OF POULTRY FARMING IN PUNJAB

The exorbitant cost of poultry feed is another issue that chicken farmers must contend with. Getting enough feed that is suitable for the chicken breeds in Punjab is a big problem for the poultry subsector. The country's poultry industry relies on both natural and artificial feeding. Since maize is an essential component in the production of chicken feed, the recent announcement by Punjab of intentions to impose additional tariffs on maize imports has only served to exacerbate an already pressing issue. Furthermore, feed makers establish the high pricing for chicken feed. Raw ingredients used to make chicken feeds have seen significant price increases on global markets, driving up manufacturing costs. Feeding broilers in Punjab might cost anything from 45 percent to 50 percent of the whole budget. The main reason feeds are expensive is because nations like China, Germany, and Thailand import the majority of the components required to make feeds, including soybean meal, protein concentrates, and maize. Marketing and transportation of day-old chicks (DOC) have room to expand. The DOC market does not engage in price haggling. The supply typically dictates the price, but the seller is the one who sets it most of the time. The hatchery owners may sell the DOCs to farmers directly or appoint intermediaries who get a small fee.

The price of the egg and grill has room to grow. Currently, at the supply stage, middlemen decide on pricing. The real producers don't benefit from the pricing since middlemen rob them of most of the earnings and harass them. Not to mention that modern warehouses and targeted advertising avenues are severely lacking. Department shops and motels often sell processed birds. Birds weighing between 1 and 1.5 kilogrammes are more popular with consumers than larger birds. Size, colour, look, and sex are the four main factors that affect the price of indigenous chicken. There are almost twice as many broilers attracted to indigenous chicken. Sort, hue, and species are the three main criteria for egg sales [26]. The kind of chicken or duck used to lay the eggs is a way to identify the origin of the eggs. Native American eggs cost around 6% more than farm-raised eggs. Additionally, compared to brown shell eggs, white shell eggs are 10% cheaper. Egg costs fluctuate throughout the year, with summer being the most expensive and winter being the most affordable.

2.7.1 Poultry Farm Environment

In order to maintain the healthy poultry farm environment , the use of new technology in chicken raising to increase output while decreasing emissions of greenhouse gases is required. In order to lessen emissions of (CO2) and (NH3), the authors examine current smart poultry management systems that provide optimum feeding procedures. With an eye on enhancing productivity, forecasting health and welfare outcomes, and decreasing greenhouse gas emissions, the study analyses a range of technology and future research paths connected to smart poultry management systems. It sheds light on how the poultry sector may optimise feeding procedures, increase production, and reduce greenhouse gas emissions via the use of smart technology. Along with discussing the difficulties of implementing such a smart platform, the essay highlights the research gap in multi-criteria decision-making.

The health and productivity of hens and grill chickens are directly impacted by the breeding conditions of poultry. During the breeding season, it is ideal for the temperature in the coop to remain within the specified range for each age group of hens, since their thermal comfort range varies mostly with age. Heat or cold stress may increase the likelihood of disease, decrease food intake, and impact the wellbeing of a flock. Their mucous membranes and airways become dry due to the rapid rate of heat loss via evaporation caused by low relative humidity [27]. However, grill chicken performance could suffer in very hot and humid conditions.

Ammonia (NH3) is the most significant pollutant released into the environment as a result of poultry rearing. Factors that increase production include temperature, humidity, type of litter, ventilation rate (VR), pH, and the conversion of uric acid to NH3 when birds consume protein. Other important variables are manure age, temperature, humidity, and the age of the birds themselves. Both the seasons and virtual reality have an impact on the concentration and emissions of NH3 in chicken houses. Ammonia has a deleterious effect on ecosystems, the environment, and human and avian health. Although levels as high as 25 ppm of NH3 are still considered safe, the recommended amount of exposure is lower than 10 ppm. The conventional method of raising grill chickens involves housing the birds in a brick shed, which often has a wooden floor and is covered with grill litter. The physical environment includes examples like these. Grill trash and other nearby things may collect moisture from bird droppings.

2.7.2 Current Status of Poultry Production in Punjab

The chicken business in Punjab, sometimes called the "Granary of India," has grown substantially over the years, making a big impact on the agricultural and economic scene in the state. As the demand for chicken products continues to rise, Punjab's poultry industry has grown into an important player in the state's economy. Poultry farms in the state vary from small-scale family-run businesses to massive commercial complexes. The favourable climate and plenty of feed supplies have contributed to the development of this sector [28]. Poultry in Punjab mostly consists of two segments: grill and layer. Many of the region's chicken and other poultry products come from grill farms, which are primarily concerned with meat production. At the same time, layer farms provide the egg market, which accounts for a significant amount of eggs eaten in the area and the states nearby. India produces more chicken meat than any other country and third-most eggs in the globe. Every year, 260 million layers in India lay 3.4 million tonnes (74 billion) of eggs, while 3000 million broilers generate 3.8 million tonnes (74 billion) of chicken meat. More than 4 million people are directly or indirectly employed by the poultry industry, which contributes around Rs.70,000/- crores to the national GDP. Poultry litter, an excellent organic fertiliser, is created annually as a byproduct and amounts to about 2-2.5 million tonnes. There are a few areas in the nation where the poultry sector is very concentrated. Tamil Nadu, Andhra Pradesh, and Telangana are the most populous states in India, followed by West Bengal, Punjab, and Maharashtra.

Poultry has become increasingly popular during the last 20 years. It now makes up almost 45 percent of the world's meat consumption. Nearly 95% of India's total egg output comes from chickens, with the remaining 5% coming from ducks and other livestock (DADF, 2014). Due mainly to large difference in production levels, the availability of eggs is very non-uniform throughout the nation. The urban population eats a disproportionate share of the eggs and meat generated by industrial sources, whereas the rural and tribal communities have relatively limited access to these foods. Despite its fast expansion, the poultry industry has recently faced several challenges that must be resolved in order for it to become a viable company. These include the increasing cost of feed, the appearance of new or reemerging illnesses, the unpredictable market price of eggs and broilers, and many more.

2.7.3 Poultry Production Systems

Technological advancements and larger production units have contributed to the fast growth of chicken production. The shift in focus has been towards intense commercial production systems that use hybrid birds expressly developed for either egg or meat production, as opposed to the traditional small-scale production methods that rely on indigenous species with dual use [29]. Improving and developing the commercial poultry business begins with introducing alien genetic material. Native birds tend to be more resilient and resistant to endemic illnesses, whereas introduced strains tend to be weaker. Enhanced housing, management, and veterinary care, in addition to specifically formulated concentrate diets, are necessary to reach the higher productive potential. Still, other technical advancements build upon the introduction of new genetic material.

In terms of operational volume and biosecurity level, the FAO divided chicken production systems into four distinct groups. Since more commercialization is linked to further segmentation of various stages in the value chain—from input supply to retail distribution of the product—the four groups are best defined as "sectors" rather than "systems" (Upton, 2007). Industrial and commercial systems may have better formal biosecurity measures in place, but the increased bird population density in these systems raises the risk of infection and the severity of disease outbreaks. Soil, air, and water pollution, as well as issues with waste disposal, are linked to an increase in production concentration. There is a wide range of manufacturing systems and value chains within each industry.

2.8 CHALLENGES FACED BY POULTRY FARMERS

Despite the industry's expansion, Punjabi poultry farmers face a number of obstacles that cut into their output and income. Among the most pressing issues are the following: insufficient infrastructure, feed costs, unpredictable market pricing, and disease outbreaks. Strict biosecurity protocols and disease control strategies are required due to the ongoing danger posed by avian illnesses including avian influenza and Newcastle disease. Poultry producers also face financial difficulties because to the unpredictability of feed pricing, which are affected by things like changes in raw material costs and worldwide market patterns. Farmers already confront a lot of uncertainty in making decisions, and market volatility only makes things worse [30].

2.8.1 Poultry Management

Farmers must diligently oversee their farms to maintain the well-being of their hens if they want to provide fresh eggs and meat. Poor management of a poultry farm may lead to underachievement in terms of both growth and productivity, ultimately resulting in lower revenue and more bird deaths. As a result of its farmers' proficiency with intensive systems, India ranks third in global egg output and fifth in global meat production. Housing, feed, and egg production are the three most important considerations when beginning chicken farming with laying hens.

Housing :

Proper housing, including access to fresh air, enough light, and a sunrise, is essential for healthy chicken development and the production of high-quality eggs and meat. Houses and cages are the two most common ways to keep hens. Here are some guidelines for chicken housing: 1 square metre for every twenty chicks, gestating between one and four weeks, 1 square metre for every ten adolescent chickens, gestating between one and five months and 1 square metre for every five laying hens. Chickens of the same age group do best when housed or caged together. The administration of young chicks, adolescent chickens, and laying hens is distinct, thus they all reside in separate homes or cages. Chicks, for instance, need a warm place to hatch and starter-grower feed. Chickens that lay eggs have specific dietary and housing needs that are distinct from those of young chicks and adolescent birds. This is why hens are kept in groups called broods, and they are all the same age [31].

Feeding :

A hen's ability to develop and produce eggs is greatly affected by the quality of its diet and water. The following is a balanced diet that the husbandry must give their hens according to their phases of growth if they want to acquire a high fair revenue from poultry farming: Chicks are fed 15 grammes of food and 40 to 50 millilitres of water between the ages of 1 and 3 weeks; 25 grammes of food and 50 to 60 millilitres of water between the ages of 3 and 5 weeks; 35 grammes of food and 60 to 70 millilitres of water between the ages of 5 and 8 weeks; 50 grammes of food and 70 to 80 millilitres of water between the ages of 8 and 10 weeks; A young chick between the ages of 10 and 20 weeks old is fed 60 grammes of food and 80 to 100 millilitres of water; A laying hen needs 130 grammes of food and 180 to 200 millilitres of water, while a teenage chicken between 20 and 21 weeks old should have 100 to 120 millilitres of water and 120 grammes of food. A teenage chicken between 22 and 23 weeks old should have 140 to 160 millilitres of water and 120 grammes of food. Corn, soybean, sunflower, salt, shells, bones, vitamin premix, and other elements make up the balanced diet. These are a few items that go into making a well-rounded chicken feed.

Poultry farming challenges :

Inadequate housing, high-priced chicken feed, illnesses, management, and medical accessibility are some of the problems plaguing the poultry farming industry. Poultry farms have poor production and high death rates due to all these issues. To overcome these obstacles, poultry producers must provide their hens with high-quality feed, maintain a clean environment, and guarantee that their chickens are regularly vaccinated. [32]

2.9 TRADITIONAL APPROACHES IN POULTRY FARMING

Traditional methods have supported the poultry business in Punjab, a state with a long history of poultry production. Traditional methods, although useful to a degree, come with their share of problems that prevent ideal chicken production and have their own set of limits. This section explores the specifics of conventional chicken farming practices, illuminating its features, limitations, and the need of technological improvements.

2.9.1 Conventional Farming Practices

The free-range and semi-intensive methods have long been the backbone of Punjabi poultry production. When birds are given the freedom to fly around in a free-range environment, they forage for food items like grains and insects. Because it reduces the need for additional feed, this strategy is economical. But there are problems with disease management, predators, and keeping track of each bird's health and output metrics.

However, with the semi-intensive method, birds are confined to a certain area but still have some access to the outside. In comparison to free-range systems, this one enables more precise regulation of nutrition and health. The focus is on physical labour for activities like feeding, monitoring, and disease management, and farmers often use feed supplies that are accessible locally.

2.9.2 Limitations of Traditional Methods

Even while conventional methods have kept chicken farming going, they have a number of drawbacks that reduce output and cut into profits. Inaccurate nutrition and feeding practices pose a serious problem. When making decisions, traditional farmers often depend on gut feelings and past experiences instead than hard evidence. The poultry's general well-being and development might be negatively impacted by insufficient nutrition and inefficient feed consumption.

Furthermore, conventional approaches fail miserably when it comes to disease control. Disease prevention and management become more difficult when early detection techniques and monitoring capabilities are inadequate. Furthermore, the use of physical labour for different jobs raises the possibility of human mistake and inefficiency. Furthermore, conventional chicken production has a negative effect on the environment. Managing garbage and preventing pollution are two potential problems that can arise from using open-air systems. Concerns about the long-term viability of these practices are growing in tandem with the sector.

2.9.3 Economic and Environmental Impacts

Efficiency and cost-effectiveness are two of the main economic concerns with conventional chicken rearing. Expenses for operations rise because of the amount of physical work involved in feeding, cleaning, and monitoring. The economic sustainability of conventional poultry farms is further affected by output inconsistencies caused by disease outbreaks or inadequate management approaches [33].

Land use and waste management are two areas where conventional practices have a pronounced negative effect on the environment. The potential overexploitation of land resources and worsening of environmental conditions are outcomes of open-air systems. Furthermore, land and water quality are endangered when chicken excrement is disposed of improperly.

2.10 TECHNOLOGY IN POULTRY FARMING

Businesses in Punjab and throughout the globe have used chicken farming technologies to accomplish their goals. The use of technology in industrialised countries' poultry farming systems will be the subject of future research, with a focus on Finland's model, which has shown both greater output and decreased waste. An intelligent approach is a computer programme that can solve issues at a level equal to or higher than a human expert. These programmes often take the form of web-based applications that incorporate expert knowledge about a specific problem area. An organization's knowledge base is created and maintained by a knowledge engineer who gleans information from domain experts and converts it into production rules. The inference engine then uses several methods for acquiring knowledge to capture the information, which it subsequently provides as recommendations on how to fix the issue. Agricultural workers might benefit from it as a training tool due to its explanation feature. Acquiring expert knowledge is key to achieving high yield in poultry production. With this knowledge, farmers can make informed decisions about various factors, such as the type of disease affecting poultry, its cure, and how to prevent future occurrences. Both the operational and planning stages of chicken production may benefit from using Intelligent Approach to make decisions [33–34]. The system may help the extension workers at the village, district, and/or government level make decisions about providing farmers with suitable advise at the operational level. Using Intelligent Approach, decision-makers may determine the water, vaccination, and feed needs of the poultry at the planning stage.

2.10.1 Technological Interventions in Poultry Production

A new age of efficiency, accuracy, and sustainability has dawned on poultry farming, thanks to a slew of technology innovations. Automation, data analytics, sensors, and the incorporation of the Internet of Things (IoT) are just a few of the technical innovations that have had a profound effect on chicken farming.

Automation in Poultry Farms :

Due to its ability to improve farm management and streamline a number of operations, automation has quickly become an integral part of contemporary chicken farming. The regulation of environmental conditions in chicken houses is an important topic for automation. Automated climate control systems ensure that the ideal circumstances for bird development are achieved by regulating the temperature, humidity, and ventilation. In addition to making sure the birds are healthy, this helps boost production by increasing feed conversion rates. Chicken nutrition management has also been transformed by automated feeding systems. By delivering precise amounts of feed at set times, programmed feed dispensers allow for precise feeding. This permits individualised feeding plans that meet the specific nutritional needs of chickens of varying ages, which in turn reduces food waste [34].

Also, automated egg collecting methods cut down on labour expenses and protect eggs from harm. These devices have sensors that can identify when eggs are present, and then they carefully gather and transfer the eggs to a designated location. Not only does this make things go more smoothly, but it also guarantees that the eggs are clean and of high quality.

2.10.2 Use of Data Analytics and Sensors

A new age of precision farming has begun in the chicken business with the combination of data analytics and sensors. Through the use of data analytics, farmers are able to extract useful information from the mountain of data produced by their operations. In order to optimise production operations, farmers might analyse metrics including feed consumption, water use, and environmental variables [35]. Data gathering relies heavily on sensors, which provide real-time information on several facets of chicken husbandry. To make sure the birds are always in the best possible environment, environmental sensors keep an eye on things like humidity, temperature, and air quality. The birds can help find illnesses early and take preventative actions by wearing sensors that evaluate their health.

In addition, specific avian tracing and tracking is now possible thanks to smart tags and RFID (Radio-Frequency Identification) technology. This improves biosecurity measures by allowing for the rapid identification and isolation of possibly infected individuals, in addition to aiding in the monitoring of their development and health.

2.10.3 Integration of IoT in Poultry Management

A web of interconnected, intelligent gadgets has emerged because to the proliferation of the Internet of Things (IoT), which has completely altered the way chicken farms communicate and collaborate. Intelligent monitoring systems, asset tracing, and machine control are some of the Internet of Things (IoT) uses in chicken farming. In order to keep tabs on and manage various parts of the farm, smart monitoring systems use networked sensors. By way of illustration, farmers can now remotely evaluate the conditions within the poultry houses thanks to automated surveillance cameras that are linked with IoT systems. This allows for real-time video monitoring, which enhances security.

Efficient management of resources and equipment is guaranteed by asset tracking with IoT technology. Farmers may keep tabs on their vehicles' whereabouts, use, and maintenance requirements by affixing tags that are Internet of Things (IoT) enabled. This results in more efficient use of resources, less downtime, and lower costs overall [36]. Traditional agricultural methods have been completely transformed by technological interventions in chicken production, which include data analytics, sensors, and the Internet of Things (IoT). Not only do these innovations make chicken farms more productive and efficient, but they also help make chicken production systems more sustainable and affordable. Combining these technologies ushers in a new age of precision farming in the poultry sector by laying the groundwork for smart methods.

2.11 ROLE OF ARTIFICIAL INTELLIGENCE IN POULTRY PRODUCTION

2.11.1 Machine Learning Applications

In the context of transforming chicken production, machine learning (ML) emerges as a critical component. Machine learning algorithms can sift through mountains of data, empowering poultry producers to optimise their operations in every way..

- **Disease Prediction and Prevention:** The prediction and prevention of diseases is one area where it has found noteworthy use. Health data from chicken farms may be analysed by ML algorithms to find trends that lead up to disease outbreaks. In order to reduce the effect of illnesses on flock health, this permits preventative actions like targeted immunisations or alterations to ambient circumstances.

- **Optimized Feed Formulation:** The development of optimal feed compositions may be aided by AI-driven models. These algorithms provide accurate feed formulation recommendations that maximise growth rates while minimising waste by taking into account things like nutritional needs, developmental phases, and environmental considerations. This helps with sustainable resource management and makes chicken farming more financially viable..

- **Predictive Analytics for Production:** Using both past and present data, ML models can predict how production will go. Egg output, growth rates, and resource needs may all be predicted in this way. By using these kinds of predictive analytics, farmers are able to better plan and distribute their resources, which in turn increases production while decreasing expenses[37].

2.11.2 AI-driven Decision Support Systems

Poultry producers now have access to strong decision support systems powered by AI. These systems provide real-time information and management advice to help run the farm more efficiently.

- **Environmental Control and Monitoring:** Parameters inside chicken houses are monitored and controlled by AI-based technologies. These systems use data from sensors to control the environment, making sure the chickens are healthy and performing at their best. Reduced stress and improved general well-being for the birds are the results of automated modifications that continually optimise their environment.

- **Precision Livestock Farming:** Precision livestock husbandry, which uses AI to track and manage each animal individually, is a relatively new idea. Artificial intelligence (AI)-enabled sensors and cameras can monitor each bird's activity, well-being, and efficiency. Improving the flock's production and wellbeing is possible because to this degree of individualised monitoring, which enables early diagnosis of abnormalities, fast intervention, and personalised treatment.

2.11.3 Robotics in Poultry Farming

One example of how AI has the potential to revolutionise several industries is the use of robots in chicken farming.

- **Automated Poultry House Management:** In poultry farms, robots with artificial intelligence skills automate a number of jobs. Things like feeding, collecting eggs, and cleaning up afterward fall under this category. Not only can automated solutions make farmers' lives easier, but they also guarantee that these chores are executed consistently and accurately, which boosts operational efficiency.

- **Disease Detection and Monitoring:** Robots driven by artificial intelligence may be used to identify and monitor diseases. Drones fitted with imaging sensors and artificial intelligence algorithms may scour vast regions for symptoms of flock stress or disease outbreaks. Because of this, farmers may optimise flock health and minimise disease transmission by taking prompt preventative actions.

- **Enhanced Animal Welfare:** Animal welfare is improved by the application of robots in chicken farming. Controlled access to outside areas or interactive gadgets within the poultry house are examples of automated systems that may provide enrichment activities for the birds. This has a beneficial effect on the birds' behaviour and health, and it also satisfies ethical norms.

AI is bringing about a new age of smart and efficient agricultural operations, which is having a profound impact on poultry production. Several parts of chicken farming may be improved with the use of machine learning apps, decision support systems powered by artificial intelligence, and robotics integration [36-37]. With the constant advancement of technology, there is great potential for AI to revolutionise poultry farming by enhancing sustainability, productivity, and farm management in general.

2.12 SMART FARMING PRACTICES

Several facets of chicken production may be optimised via the use of smart farming approaches, which make use of modern technology. In order to boost productivity, save expenses, and improve farm management as a whole, these methods combine data-driven decision-making with automation and precision approaches. Smart farming methods must be used in the poultry farming industry in Punjab if we are to help farmers overcome the obstacles they encounter and advance sustainable development. Here we will look at the main components of smart farming as they pertain to chicken production.

2.12.1 Precision Agriculture in Poultry Farming

Agricultural activities are closely monitored and managed via the use of technology in precision agriculture. Precision agriculture, as it pertains to chicken farming, is all about making the most of what you have, increasing output while decreasing waste. Precision feeding is an important part of this process. It involves using data on the birds' health, development, and the composition of their diet to create specific feeding programmes. This reduces feed waste, a major expense in chicken production, and guarantees that birds get the nutrients they require [37].

In addition, sensor technologies are used in precision agriculture to monitor the conditions in chicken homes. Environmental factors like humidity, temperature, and air quality may be measured via sensors. Farmers may use the data from these sensors to improve the health and production of their chickens by creating an ideal environment for them to live in. By adjusting airflow based on real-time data, automatic ventilation systems can make sure birds are comfortable and reduce the risk of illnesses linked to poor air quality.

2.12.2 Smart Feeding and Nutrition Management

Utilising technology, smart feeding systems optimise and personalise feed distribution according to the unique requirements of birds or groups. These systems customise feeding schedules and compositions based on data from several sources, including weight, age, and health state. Birds' health, growth rates, and feed prices are all positively impacted by this method of precise feeding, which also lessens the environmental effect due to reduced nutrient excretion. The use of sensors and internet of things devices to evaluate feed nutritional content and poultry health status is another development in nutritional monitoring. With the use of proactive management tools, farmers may quickly change feeding plans based on real-time data on nutritional levels and bird health. Automated feeders that use RFID (Radio-Frequency Identification) technology can detect when birds are near and then give them the right amount of food.

2.12.3 Monitoring and Control Systems

Implementing thorough monitoring and control systems is another component of smart farming methods in chicken production. To provide real-time insights on the farm's activities, these systems incorporate numerous technologies, such as sensors, cameras, and networking solutions. Poultry houses may be remotely monitored by farmers, who can then respond quickly to problems like equipment failure, disease outbreaks, or environmental crises. The administration of environmental factors is further improved by automated control systems. Using either historical data or current conditions, smart climate control systems may modify the HVAC system's heating, cooling, and ventilation settings. This helps save money and energy while also making sure the birds are safe [38].

2.13 BENEFITS AND IMPACTS OF INTELLIGENT APPROACHES IN POULTRY PRODUCTION

Poultry production has seen revolutionary changes in recent years due to the incorporation of intelligent techniques, which has had a favourable influence on many parts of the business and produced a myriad of advantages. Within the framework of the State of Punjab, this section delves into the significant impacts of using AI, ML, and smart technologies in chicken farming.

- **Increased Productivity and Efficiency:** The poultry farms in Punjab have become much more productive and efficient after using smart strategies. Many tasks, including feeding, monitoring, and data processing, have been made easier by automation made possible by artificial intelligence. With smart systems, tasks are executed precisely and on time, which maximises production and makes the most efficient use of resources. Also, with the help of machine learning algorithms and predictive analytics, farmers are able to make better judgements, which leads to better production planning and management of resources.

- **Economic Sustainability:** Poultry farming in Punjab is becoming more economically viable thanks to smart agricultural practices. A more economical manufacturing process is achieved via the use of automation, which lowers labour costs and minimises operational inefficiencies. With the use of analytics and real-time data monitoring, farmers may find ways to save money and make the most of their resources. This smart integration helps the state's poultry business as a whole and guarantees farmers a sustainable income.

- **Environmental Sustainability:** In order to promote environmental sustainability in the poultry business, intelligent measures are essential. Using these technologies, poultry farms may optimise their resource utilisation, which in turn reduces waste and minimises their ecological imprint. Smart farming technology enable precision agricultural methods, which in turn lead to more effective use of water, feed, and energy. Intelligent waste management systems also guarantee correct disposal and recycling, reducing the environmental toll of conventional chicken production.

- **Improved Animal Welfare and Health:** Smart technology and artificial intelligence have made great strides in protecting the health and well-being of chickens. The birds are kept in an ideal environment by automated monitoring systems that constantly check important parameters including humidity, temperature, and air quality. Early illness detection using machine learning algorithms allows for rapid intervention and lessens the likelihood of epidemics. Poultry of higher quality and a more favourable reputation are the results of improved living circumstances and preventative health management.

- **Enhanced Data-driven Decision Making:** Intelligent methods provide data analytics with useful information that chicken producers in Punjab may use. Data about chicken behaviour, environmental factors, and production parameters may be found in abundance thanks to the Internet of Things (IoT) and sensor integration. By analysing this data, advanced analytics technologies provide farmers the knowledge they need to make better decisions [39]. For sustainable and successful chicken farming, data-driven decision-making is essential for a variety of tasks, including feeding regime adjustments, disease outbreak management, and breeding programme planning.

- **Market Competitiveness and Quality Assurance:** Poultry producers in Punjab may boost their market competitiveness by adopting smart practices and becoming the first in their field to use new technologies. Consistent product quality that meets the high standards needed by customers is assured by automated procedures and quality control methods. Consumers may have faith in the safety and origin of chicken products from Punjab since smart technology can trace and follow the whole manufacturing process.

The State of Punjab has entered a new age of efficiency, sustainability, and competitiveness with the incorporation of intelligent techniques in chicken farming. The advantages are not limited to financial gains; they also include data-driven decision-making, animal welfare, and environmental protection. Intelligent ways are starting to make a difference in the business and will likely influence how chicken farming in Punjab is done in the future. This will provide a good example for sustainable and tech-savvy agricultural methods.

2.14 THE USE OF INFORMATION TECHNOLOGY (IT) IN POULTRY MANAGEMENT INFORMATION SYSTEM

Poultry farming has been made more efficient with the use of various technologies. Using these technologies, we have been able to eliminate illnesses, minimise feed and water waste, and enhance the number of chicks produced in a given area. Unfortunately, small-scale farmers cannot afford these technologies because of the high costs of purchase, maintenance, and operation. Environmental controllers, nipple drinking systems, low slats systems, temperature-controlled equipment, home building designs, grill colonies and modernised housing systems are all part of the strategies [40]. There have been huge benefits to the poultry sector from the use of technology. For example, in our modern era when climate change is a major environmental problem, the methods have been shown to work. Because their systems are so well-organized and managed, they are able to limit the amount of air pollution. Further reasons to use technology in poultry farming include monitoring stress levels, air quality that the birds breathe, early detection of disease outbreaks, and the desire to enhance yields through modification and enrichment [41].

The "farmer's internal system of practical knowing and learning" should be integrated with all this data to create a true cognitive system. In recent times, several unique solutions have been created to assist poultry farmers in efficiently managing their farms. Advanced systems monitor landmasses, climate patterns, and a plethora of other factors to determine whether a certain breed would thrive in a given area. These systems, collectively referred to as Poultry Farm Management Information Systems [42], tend to specialise in certain duties and employ proprietary specifications to put the offered functionality into action. In order to better serve their end users, these systems are gradually entering the Internet age and implementing some of the well-established networking techniques [43–44]. The Internet has many strengths, but it is also known to have several weaknesses, particularly when dealing with large numbers of stakeholders or networked objects (such as the Internet of Things). In addition, no universally accepted method has been developed to provide seamless and uncomplicated interoperability between various services and their respective stakeholders. These deficiencies will presumably be addressed by the infrastructures of the Future Internet (FI) [45].

Table 2.1 : Literature Review

Author (Year)	Title	Findings	Relevance
Ammad-Uddin et al. (2014) [1]	Wireless sensor network: a complete solution for poultry farming.	Any kind of poultry farm may benefit from the suggested CWNS-PF. With proper implementation of the seven key components of the suggested system, both the amount and quality of chickens raised may be enhanced, which in turn would benefit human health.	The wearable wireless sensor node might potentially be a valuable tool for early identification and outbreaks of sick hens, according to the proposed solution. On top of that, the technology will boost economic output, quality, and general agricultural output..
Archana, Uma & Babu (2018) [2]	A survey on: monitoring of poultry farm using IoT.	When the weather suddenly changes, the framework automatically monitors the aforementioned ecological metrics to see how things are changing. In addition, the sensor checks and controls the water level control and food control device. The system's sensors are all linked to the raspberry pi, allowing it to monitor and manage all data.	The database contains all the information about the poultry farm's natural conditions. This means that the setup provides a reliable automated system for monitoring the health of hens in a poultry farm without the need for human intervention..

Author (Year)	Title	Findings	Relevance
Arhipova et al. (2021) [3]	Smart platform designed to improve poultry productivity and reduce greenhouse gas emissions.	For the purpose of predicting the health, welfare, and production of poultry, this article examines the current state of research and emerging technology around smart poultry management systems. Few studies have examined the potential of a multi-criteria decision approach to enhance productivity and welfare while simultaneously decreasing emissions of greenhouse gases in the context of chicken farming.	The smart platform implementation challenges are carefully crafted to enhance poultry production while reducing greenhouse gas emissions.
Barot, Kapadia & Pandya (2020) [5]	QoS enabled IoT based low cost air quality monitoring system with power consumption optimization.	An effort to optimise power consumption, sensor throughput, and quality of service (QoS) levels in relation to accuracy is at the heart of the proposed study. Various indoor and outdoor locations have been equipped with the proposed Internet of Things (IoT) air quality monitoring system, which measures factors including temperature, humidity, carbon monoxide, particulate matter (PM), and particulate matter (PM2.5)..	At both indoor and outdoor locations, the suggested system is evaluated at different quality of service levels. Experiments have shown that the protocol in use ensures the dependable delivery of messages.

Author (Year)	Title	Findings	Relevance
Du et al. (2021) [15]	Design and implementation of intelligent gateway system for monitoring livestock and poultry feeding environment based on bluetooth low energy.	With an average packet loss rate of only 1.09%, the experimental findings reveal that the system built in this article considerably reduces the transmission delay of critical information. This approach handles unusual data more quickly and effectively than the conventional one.	In the event of heavy data concurrency, it increases the stability and reliability of communication while successfully resolving the short distance and poor efficiency of Bluetooth "point-to-multipoint" communication. As a result, mutations in the environment lead to less damage.
Griva et al. (2023) [17]	LoRa-based IoT network assessment in rural and urban scenarios.	We simulated these parameters in OMNeT++ with the help of the FLoRa free source framework. A parking lot model, as well as urban and rural simulations, were among the scenarios examined in this study.	According to the findings, optimising the critical parameters might significantly affect the rollout of smart networks.
Jácome, Rossi & Borille (2014) [24]	Influence of artificial lighting on the performance and egg quality of commercial	The results show that the criteria of egg quality are unaffected by artificial illumination programmes' effects on egg production. When layers are kept in open-sided buildings, as is	This analysis confirmed that, regardless of the artificial illumination programme, layers are photostimulated by light for over

Author (Year)	Title	Findings	Relevance
	layers: a review.	common in Brazil, intermittent lighting programmes are a suitable substitute. The primary pathway for the stimulation of egg production in fowls is transcranial light reception.	12 hours.
Mazunga et al. (2023) [31]	IoT based remote poultry monitoring systems for improving food security and nutrition: recent trends and issues.	The goal of this article is to provide researchers with the information they need to develop better remote poultry monitoring systems based on the internet of things (IoT) that increase profitability and productivity compared to current methods. In addition, this project aims to promote the use of automated poultry monitoring technology to enhance productivity in the poultry industry. Also, policymakers should be able to use this material as a reference when making decisions.	In a nutshell, the literature outlines the benefits and drawbacks of the suggested systems. Also included is an analysis of these freshly suggested systems. Also included are difficulties and potential ways to overcome them.

Author (Year)	Title	Findings	Relevance
Olaniyi et al. (2014) [35]	Design of an intelligent poultry feed and water dispensing system using fuzzy logic control technique.	In a deep litter poultry farming system, this method improves return on investment, decreases labour for poultry attendants, and boosts cost advantages.	The suggested system would be able to detect when the birds drink from the trough and intelligently administer feed and water based on the changes in the levels of these fluids as the birds eat.
Saleeva et al. (2020) [39]	Efficiency of poultry house heating and ventilation upgrading.	Research into the use of gas air heaters in meat chicken production revealed that when combined with heat recovery units, these devices can be used in 'hybrid' modes—i.e., with high pressure during the first period of grill operation and with depressurizing during the second period—by turning the air heaters into the primary heat generators and sources of heat for the air supply.	In addition to providing a high degree of veterinary and sanitary protection for the cattle via air disinfection, burning oxygen and combustion products had no detrimental impact on livestock production.
Huang et al. (2023) [19]	AoI-aware energy control and computation offloading for industrial IoT	Create a dynamic Markov decision problem to minimise energy usage in the long run while meeting AoI restrictions for processing data in real-time. We develop a smart Energy Control and Computation Offloading (ECCO) algorithm and use Deep Reinforcement Learning (DRL) methods for adapting to large-scale dynamic IIoT settings to fix the issue.	Compare our ECCO approach to both current DRL and non-DRL techniques, and do extensive simulation tests using real-world datasets. The findings show that our algorithm is superior.

Author (Year)	Title	Findings	Relevance
Kodali, Yerroju & Sahu (2018) [26]	Smart farm monitoring using lora enabled IoT.	Additional benefits, such as scalability, security, and resilience in creating IoT applications, are offered by the LoRaWAN protocol, also known as LoRa in the LPWAN sector, which are utilised in agricultural regions. A paradigm for smart farm monitoring is suggested in this article.	Data from sensors, such as temperature (°C), humidity (%), and soil moisture (%), is sent from the transmitter node to the reception node using the LoRa communication method in this architecture. In order to keep tabs on data in IBM Watson IoT platform and save it in IBM cloud DB service, the receiving node—which is Wi-Fi enabled-uses MQTT services.
Lashari et al. (2018) [28]	IoT based poultry environment monitoring system	Air temperature, humidity, O2, CO2 concentration, and NH3 concentration are only some of the environmental characteristics that the suggested software-based hardware can track. The efficient gathering of data for the specified parameters—which include source coordination and control—is the responsibility of the wireless sensor.	At several locations within the chicken house, the hardware is set up and running well. It was determined that the experimental setup was highly effective and precise. The poultry sector will benefit financially and environmentally from this plan.
Mahale & Sonavane (2016) [30]	Smart poultry farm monitoring using IoT and wireless sensor networks	This paper focuses on the technical solution for chicken framing management that is efficient, quality-oriented, cost-effective, and saves assets.	In order to regulate environmental factors using smart devices and technologies, this study aimed to examine the usage of an Intelligent System that utilised an Embedded Framework and Smart Phone for monitoring a chicken farm.

Author (Year)	Title	Findings	Relevance
Murugeswari et al. (2023) [32]	IOT Based Smart Poultry Farm	Poultry farms and other agricultural settings may find use for the suggested approach. Farming uses it for soil preparation, spraying plants, and fertilising them, while poultry farms use it to supply food in containers, keep temperatures stable with water sprinklers, and remove gas with soil mixtures. The user will find this proposed system beneficial. It was discovered that these factors are not only monitored by the system, but also successfully regulated. The ability to remotely access and operate the system using portable mobile devices made the framework highly beneficial for farmers.	To solve the industry's labour concerns and implement a semi-automatic process, the suggested system may feed the chickens instead of the worker.
Raghudathesh et al. (2017) [37]	IoT based intelligent poultry management system using Linux embedded system	It was discovered that these factors are not only monitored by the system, but also successfully regulated. The ability to remotely access and operate the system using portable mobile devices made the framework highly beneficial for farmers.	The technology maximises the use of resources, decreases the need for human intervention, and boosts poultry output.

2.15 SUMMARY

A giant leap forward in solving the problems that the poultry sector in Punjab has been experiencing is the creation of sophisticated methods for chicken production. It is possible to make chicken farming more efficient, sustainable, and compassionate by combining conventional techniques with technology interventions and using artificial intelligence (AI). Automation, data analytics, and the IoT were highlighted in the examination of technology interventions. From monitoring and control to precise feeding and nutrition management, these technologies provide new opportunity to optimise different aspects of chicken husbandry. A critical component in the development of modern chicken farming techniques was the use of AI. Enhancing productivity, maintaining economic viability, and developing sustainable practices are all possible with the help of machine learning applications, AI-driven decision support systems, and robots. Poultry health and farmers' bottom lines are both improved by smart farming techniques including precision agriculture and sophisticated monitoring systems. Poultry farming may reap several benefits by using sophisticated tactics. These measures may help strengthen the poultry business in Punjab by increasing efficiency, improving animal care, and making it more economically viable.

A game-changing approach to chicken farming in Punjab is unveiled by the convergence of smart technology. This is in line with worldwide trends in agriculture and solves present problems. Successful implementation and broad effect can only be achieved by coordinated efforts among farmers, industry stakeholders, and policymakers when these measures are used. The poultry business in Punjab is poised for significant positive results as it embraces a future that is smarter and more technologically sophisticated. Researchers, legislators, and industry experts in Punjab who are interested in smartly advancing poultry production in the ever-changing agricultural context will find this thorough assessment to be an essential resource.

Chapter – 3

RESEARCH METHODOLOGY

This chapter outlines four sections which include the adopted procedures for enhancing poultry production and poultry disease detection. In the first part of the study, data collection was done. The collected data was taken from 111 farmers in Punjab. An intelligent approach for the enhancement of the poultry production in Punjab by maintaining temperature and humidity is explained in the second part followed by the prediction of the abnormalities in the behavior of the poultry for diseases in the third part. Furthermore, fourth part discusses an mobile application named "HenScan" which is developed for the disease detection to ease the poultry farms.

3.1 DATA COLLECTION

Farmers all across the globe rely heavily on the revenue and job opportunities provided by the poultry farming business. Poultry farming has risen to prominence in the Indian state of Punjab, helping the local economy and satisfying rising consumer demand. Poultry farming, like any other agricultural business, confronts a number of obstacles that cut into its efficiency, profitability, and longevity. In order to study the challenges encountered by Punjab's poultry producers and to provide recommendations on how to address those challenges via the use of recent developments in computer technology, the survey was conducted to gather the information regarding the various methods and the techniques being using in the farming. The data was collected from 111 farmers in Punjab from different districts. The data has been collected by an open end Questionnaire which includes 35 questions regarding the various farming practices being followed by the poultry farmers. The questionnaire was created in English and Punjabi language taking in concern the education level of the farmers. This Questionnaire is attached in the annexure 1.The purpose of this collected data is to explore the major concerns faced by the farmers. Thus, the questionnaire targets the questions related to the problems of cannibalism being faced, the effect and the maintenance of the weather fluctuations, the death rate and the productivity rate in the various farms, labour related issues, cost and type of the feed and the vaccinations given to the birds etc. Also, the questionnaire consisted of the questions where the farmers were asked about the major problems they are suffering from and the type of solutions they feel they require from the advances in the computer system that could address the challenges they are facing in the poultry farming. The screenshot of a small section of the dataset collected is shown in the Fig 3.1

Name	District	State	What type of feed is being provided in Poultry Farms?	List of the various medicines being given to the chickens?			What are the methods being used to tackle the problem of cannibalism?	What are the various methods for the monitoring of the chickens to be free from the diseases?
Adamwal	Hoshiarpur	Punjab	Value Max Finisher	Bruton			No Issue Faced	Medicine, Properaring
Aima Mangat	Hoshiarpur	Punjab	Saguna feed	Sugi stress	Sugi electron		No Issue Faced	By Medicine time to time, spray every day
Arjanwal	Jalandhar	Punjab	Venky Feed	Figer	Himalaya	Oxymav	No Issue Faced	Seprated infected one
Arshkamal Poultry Farm	Hoshiarpur	Punjab	Venky Feed	Calcium	Liver tonic		No Issue Faced	Separated the infected one
Avtar singh Poultry Farm	Hoshiarpur	Punjab	Pre Starter, Starter, Finisher	Liver tonic	Bruton	Vitamin	No Issue Faced	By properhecking or Medicine
Baggu Farm	Amritsar	Punjab	Mesh feed	Gumboro	Coccidiostat	Oxymax B Antibiotic	Proper caring and cleaning	By security (with the help of medicine)
Bagroi	Hoshiarpur	Punjab	Value Max Finisher	Coccipro1 100 g	Wormout Tablet		No Issue Faced	By Medicine (occiprol 100g, Worm out tablets)
Baldeve singh Poultry Farm	Hoshiarpur	Punjab	Mesh feed	Antibiotic	Vitamin		No Issue Faced	By doctor
Bana	Shaheed Bhagat Singh Nagar	Punjab	Pre starter, starter, finisher	Toxol	G-promin		No Issue Faced	Cleaning with chuna or white wash and medicine
Bana	Shaheed Bhagat Singh Nagar	Punjab	Pre starter, Starter, finisher	Antibiotic	Vitamin		No Issue Faced	By Medicine (Antibiotic, Vitamin)
Banga Rural	Hoshiarpur	Punjab	Saguna feed	Kilverm	Coccipro1 100 g		Remove any badly injured birds	By security and Byleaning

Fig 3.1 : Screenshot of a Small Section of the Dataset

After one-to-one interaction with the various farmers and filling up the questionnaire as per the answers received from them. The data was transferred from the questionaries into an excel document. The data was then pre-processed. Afterwards, the analysis was done over the collected data. After reviewing, it was observed that maximum farms keep the hens in the cage free environment rather than keeping them in cages in the layers. This provides large roaming space to the hens and avoid the problem of cannibalism. Also when it was asked if the birds are suffering from cannibalism in their farms, most of the farmers reported that they are not suffering from such issue and if a few does they opt for proper cleaning of the places, isolating the injured birds and giving them salt. So almost all the farms have managed to handle this problem easily.

However, the various other questions were asked related to the feed quality and regime, the methods of maintaining cleanliness in the farms and at what intervals the cleanliness is performed, the various methods of monitoring the birds etc and it was observed that all these activities are labour intensive and can affect the health of the chickens.

Furthermore, the information related to various methods used to keep the birds free from the diseases, various vaccinations given to them and the cost of the vaccinations etc was gathered as this provided an idea that all such procedures increase the cost of managing the poultry farms and reduces the profit of the poultry farmers.

In addition to this, the questions were asked related to the average body mass, death rate, productivity rate, temperature and humidity ranges maintained in the farms and the various methods opted to control the optimal temperature and humidity in the farms. Many of the farmers use fans, coolers, cooling pads, wet curtains etc in summers and heaters in the winters and some were not aware about the optimal ranges of temperature and humidity to be maintained. As not maintaining optimal temperature and humidity conditions can make birds prone to various diseases and also affects the death rate and the productivity rate of the farms. In fact as per the farmers, accurate weather maintenance and the labour intensive tasks are the two main challenges faced in the maintaining poultry farms.

A basic approach which was followed to design the algorithm and components to be used is shown in the figure 3.2 The data is first collected and the problems are analyzed. After analyzing the problems, we search for different traditional and AI based possible solutions. In the next stage, we design an AI based algorithm to tackle the problem. The designed algorithm is then compared with the other possible solutions. The figure 3.3 and 3.4 provides a simple basic flowchart of the AI based solutions which are required to handle a few of the problems discussed above.

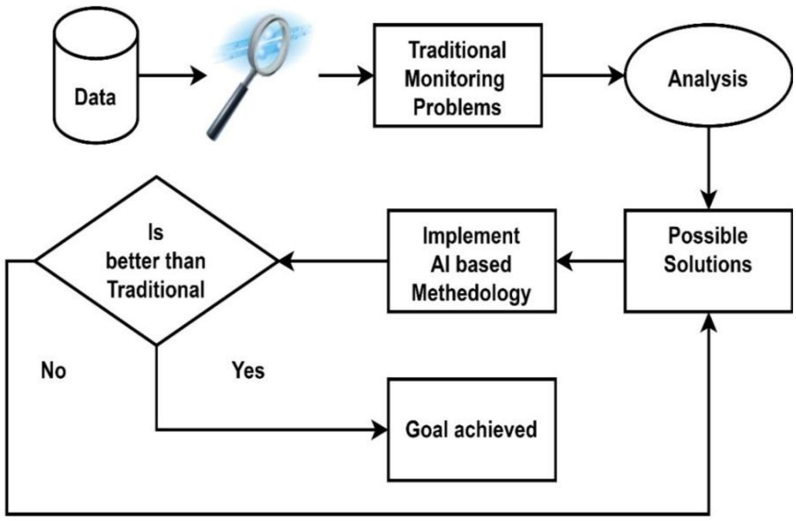


Fig 3.2 : A basic approach to design algorithm

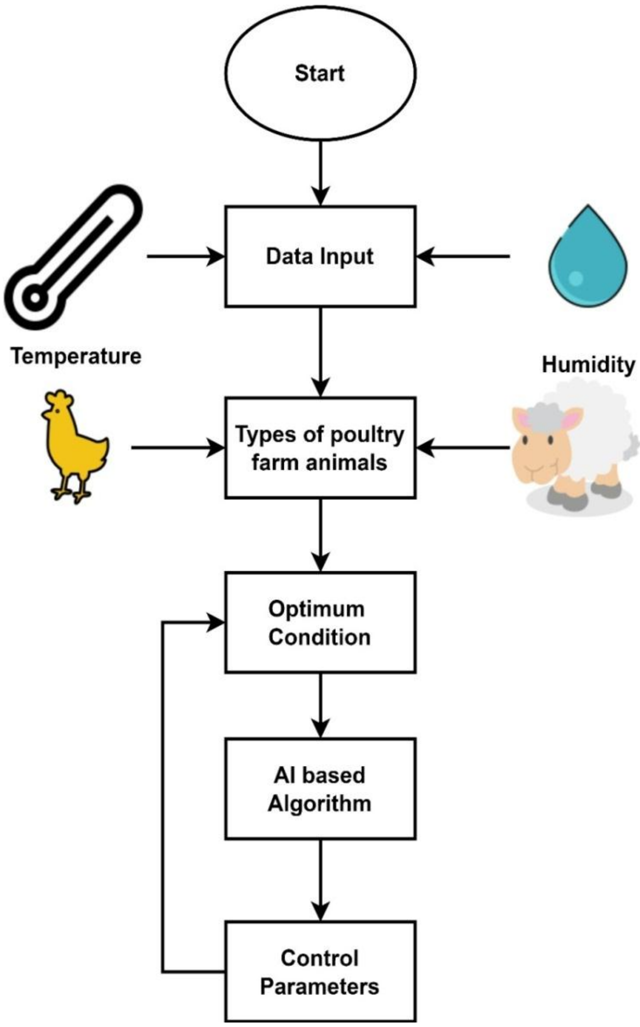


Fig 3.3 : AI based approach for temperature and humidity monitoring

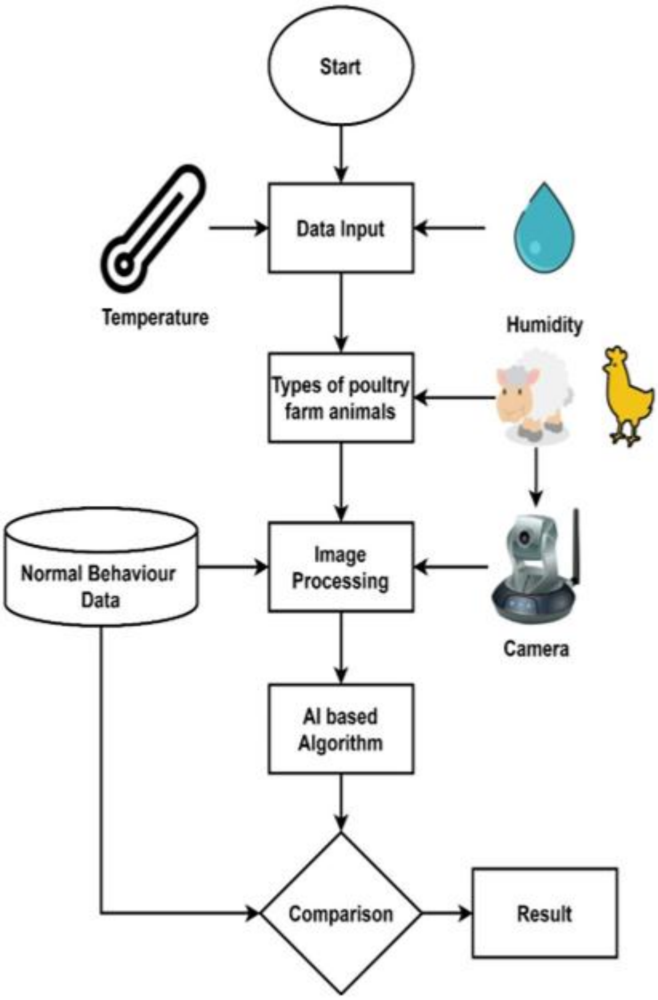


Fig 3.4 : AI based disease detection

Thus, following the above presented basic designs to solve the issues, we have developed N-BEATS architecture for multi-dimensional poultry data explainable forecasting. This provides the prediction regarding the possibility of the occurrence of the disease in the farms under certain specific values of temperature, humidity and feed.

Along with this, to provide a better image processing-based approach for disease prediction various models like SoloConvLayer, TriConvoLayer, FiveConvLayer models and a pretrained model named MobileNetV2 was executed over the fecal dataset and their results were compared. The model which performed best was TriConvLayer model, which was then used to develop a mobile application for the farmers for the disease detection in the chickens.

3.2 IMPLEMENTATION

3.2.1 To Develop an Intelligent Approach to Enhance the Poultry Production in Punjab by maintaining Temperature and Humidity

The agricultural economy depends heavily on the production of chicken, and accurate forecasting of poultry data is essential for maximising income, streamlining resource management, and maximising productivity. This section presents a novel use of the N-BEATS architecture for multi-dimensional poultry data explainable forecasting. Known for its precision in predicting time series, N-BEATS is a deep learning model that is used to forecast many aspects of chicken disease diagnostics. The data related to forecasting is a multivariate dataset based on the environmental parameters of poultry. The methodology improves the process of making decisions for managing chicken farms by utilising the capabilities of the N-BEATS model and incorporating an explainable AI (XAI) framework to clarify the model's predictions

I. PROPOSED FRAMEWORK

The ability to comprehend and transparently explain the forecasts produced by forecasting models is known as interpretable forecasting. It includes the methods that let users understand the reasoning behind a model's prediction, the variables that shaped it, and the degree of confidence the model has in its forecasts. This is especially crucial in fields where decisions must be made in light of anticipated results, since knowing the logic behind the projections may foster confidence in the model and its predictions. N-BEATS uses stacks of fully connected layers to model time series data, differing from other time series models that use recurrent or convolutional layers. The model consists of a series of blocks, each providing an ensemble of forecasts.

These blocks are structured in a way to incrementally capture different time series patterns like trends and seasonality. Each block in the architecture uses basis expansion techniques, like polynomials or Fourier series, to model the underlying patterns within the time series. Each block outputs two things: a forecast for the future values of the series and a backcast that reconstructs the input series. The backcast helps in removing already captured patterns from the data, enabling the subsequent blocks to focus on learning the residuals. The architecture uses a residual stacking approach where each block refines the forecast by focusing on the residuals left by the previous blocks. A key feature of N-BEATS is its interpretability. Each block can potentially be designed to capture specific types of patterns, making the model outputs more explainable. In the context of poultry data, which is likely multi-dimensional (involving various metrics like temperature, humidity, feed consumption, growth rates, etc.), N-BEATS can be adapted in the following ways.

(a) Multiple Time Series: Each dimension of the poultry data can be treated as a separate time series, and N-BEATS can be used to model each one individually or jointly. The input layer is accommodated to handle multiple input variables. To extend the N-BEATS model to a multivariate setting with 3 independent variables, denoted as ($X_1^{t-H+1:t}, X_2^{t-H+1}, X_3^{t-H+1}$).The basis of N-beats architecture are the blocks, which contains fully connected layers. It consists of forecast and backcast outputs viz. eq. (1) and eq. (2)

$$\hat{X}^{t-H+1:t} = Backcast\ (X, \Theta_B) \quad (1)$$

$$\hat{Y}^{t-H+1:t} = Forecast\ (X, \Theta_F) \quad (2)$$

Further, N-Beats uses Basis expansion for the linear decomposition of the back cast and forecast outputs. This is done for the better mapping of the components of the time series components viz. patterns, trend and seasonality. The basis expansion is represented by eq. (3) and eq. (4)

$$\hat{X}^{t-H+1:t} = \sum_{i=1}^{Q} \beta_i\, b_i\ (.) \quad (3)$$

$$\hat{Y}^{t-H+1:t+F} = \sum_{i=1}^{P} \alpha_i\, f_i\ (.) \quad (4)$$

At the end, N-beats employ the stack architecture which is stack of various blocks where every block represents different aspect of the time series such as pattern, trend and seasonality. The output function is the aggregation of the output as demonstrated in eq. (5). The objective of the training function is to minimize the loss during the training round as demonstrated in eq. (6). The definition of the all the symbols used in the above equations are given in Table 3.1.

$$\hat{Y}_{final}^{t+1:t+F} = \sum_{k=1}^{K} \hat{Y}_{k}^{t+1:t+F} \tag{5}$$

$$L = \sum_{t=1}^{T} \sum_{n=1}^{N} (\hat{Y}_{n,t} - Y_{n,t})^2 \tag{6}$$

Table 3.1. Definition of Various Symbols used for N-Beats Architecture

Symbol	Explanation
$\hat{X}^{t-H+1:t}$	Back cast Output
$\hat{Y}^{t-H+1:F}$	Forecast Output
F	Forecast Horizon
f_i	Basis Function for Forecast
b_i	Basis Function for Backcast
α_i	Corresponding Weight for Forecast Basis Functions
β_i	Corresponding Weight for Backcast Basis Functions
K	Number of blocks

(b) Feature Decomposition: The model can decompose the poultry data into trend, seasonality, and any poultry-specific cycles, which would help in understanding and forecasting the data more effectively.

(c) Explanatory Variables: Since there are external factors that affect the poultry metrics, such as weather conditions or market prices, these can be incorporated into the N-BEATS model to improve the quality and explain ability of the forecasts. Custom blocks can be designed for specific patterns or cycles that are unique to poultry data, enhancing the model's ability to forecast and explain these patterns (Fig 3.5). BEATS provides a robust and flexible framework for forecasting time series data, and with appropriate adaptation, it can be an effective tool for making explainable forecasts in the context of multi-dimensional poultry data..

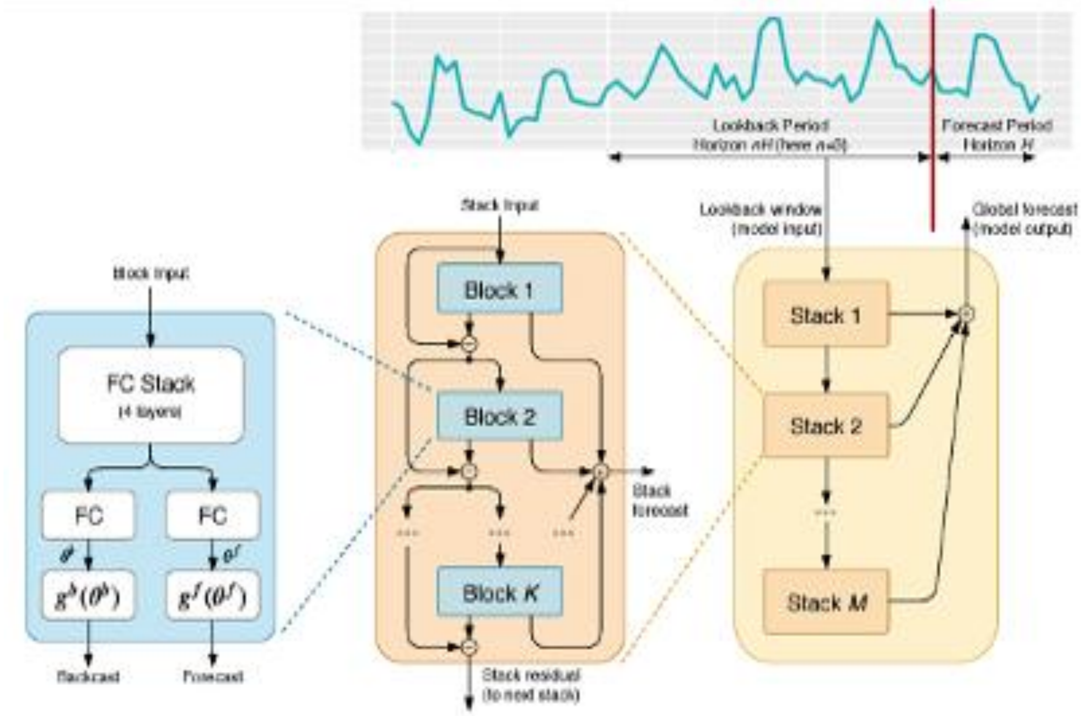


Fig. 3.5 : Architecture of N-Beats: Neural Basis Expansion Analysis for Interpretable Time Series Forecasting [16].

II. MATERIALS AND METHODS

The research employed utilizes several deep learning methods to check the applicability on multivariate dataset and to make the comparative performance analysis with respect to the proposed framework. The various deep learning models employed are explained as under:

(a) LSTM ((Long Short-Term Memory)

Three gates make up the framework of LSTMs: input, forget, and output gates. The cell state preserves long-term relationships in the model by allowing data to flow through the network unaltered with only small linear interactions. Because the gates regulate the information's entry and exit from the cell state, long-term support vector machines (LSTMs) can learn from data sequences. Through these gates, complicated nonlinear transformations are typically incorporated into LSTM units. The formula for these gates is as follows: tanh stands for the hyperbolic tangent function, and σ for the sigmoid function. Following equations demonstrate the working of various gates. Eq

(7) describes the forget gate that decides the information to be discarded from the cell state. Eq (8) represents the input gate that decides which information is to be updates. Eq (9) is the output gate which decides what next hidden state should be. Eq (10) & Eq (11) determines the cell candidate and cell state respectively. Eq (12) determines the hidden state.

$$\boldsymbol{f_t = \sigma\ (W_f.[h_{t-1}, x_t] + b_f} \tag{7}$$

$$\boldsymbol{i_t = \sigma\ (W_f.[h_{t-1}, x_t] + b_i} \tag{8}$$

$$\boldsymbol{o_t = \sigma\ (W_o.[h_{t-1}, x_t] + b_0} \tag{9}$$

$$\boldsymbol{\tilde{c}_t = tanh\ (W_c.[h_{t-1}, x_t] + b_c} \tag{10}$$

$$\boldsymbol{c_t = f_t * c_{t-1} + i_t * \tilde{c}_t} \tag{11}$$

$$\boldsymbol{h_t = o_t * \mathbf{tanh}\ (c_t)} \tag{12}$$

(b) GRU (Gated Recurrent Unit)

GRUs combine the forget and input gates into a single "update gate" and combine the hidden state and cell state, simplifying the LSTM design. This leads to a simpler model with fewer tensor operations, which may lessen training time and computational load. It consists of two gates; Update Gate to decide the amount of the past information that needs to be passed along to the future and secondly Reset Gate to determine the amount of the past information to forget.

$$\boldsymbol{z_t = \sigma\ (W_z.[h_{t-1}, x_t]} \tag{13}$$

$$\boldsymbol{r_t = \sigma\ (W_r.[h_{t-1}, x_t])} \tag{14}$$

$$\boldsymbol{h_t = \mathbf{tanh}\ (W.[r_t * h_{t-1}, x_t])} \tag{15}$$

$$h_t = (1 - z_t) * h_{t-1} + z_t * \tilde{h}_t \tag{16}$$

(c) Simple RNN

The various steps followed in the execution of the model architecture are elaborated below:

The most basic type of RNN, which has a gateless fundamental architecture and may cause problems with vanishing and exploding gradients. The input received at the present state and the hidden state from earlier are used to update the hidden state:

$$\boldsymbol{h_t} = \textbf{tanh}\,(\boldsymbol{W_h} * \boldsymbol{h_{t-1}} + \boldsymbol{W_x} * \boldsymbol{x_t} + \boldsymbol{b}) \tag{17}$$

(d) CNN (Convolutional Neural Network)

In order to capture temporal patterns in sequence data, 1D CNNs apply convolutional layers and slide filters throughout the sequence. Every convolutional layer uses a nonlinear activation function and the convolution process to alter the input data. To minimize dimensionality, pooling layers are frequently added afterward:

$$\boldsymbol{c_t} = \boldsymbol{Activation}\,(\boldsymbol{Conv1D}(\boldsymbol{filters}, \boldsymbol{kernel_{size}})(\boldsymbol{input_{sequence}})) \tag{18}$$

III. METHODOLOGY

The section demonstrates the steps followed in methodology of the framework.

1. **Dataset:** The dataset is a multivariate dataset representing four different time series of variables namely temperature, humidity, poultry feed, and disease outbreaks. The disease outbreak is the predictor variable based on three independent variables. The dataset contains 35126 rows and was collected hourly between January The visual representation of the dataset is provided in Figure 3.6.The dataset is attached in the annexure.

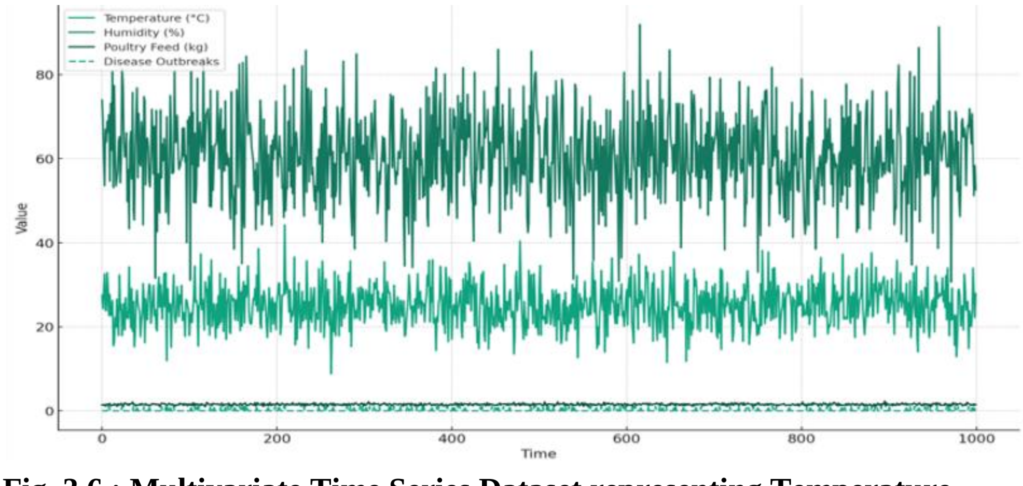


Fig. 3.6 : Multivariate Time Series Dataset representing Temperature, Humidity, Poultry Feed and Disease Outbreaks

2. **Data Preprocessing**: Observing the timeseries of the data, the first major issue is the lack of a uniformly sampled temporal space. Hence, the first step is to make the data uniform by taking into account a continuous temporal space and adding the values associated with the nearest day that is available, we may solve this problem. The second issue is that Fourier analysis is limited to stationary data, whereas this time series is obviously growing over time. To identify the best-fit polynomial function that fits the data, we will specifically employ polynomial regression as demonstrated in Figure 3.7. After that, we'll cut this line to get the stationary time-series as given in Figure 3.8.

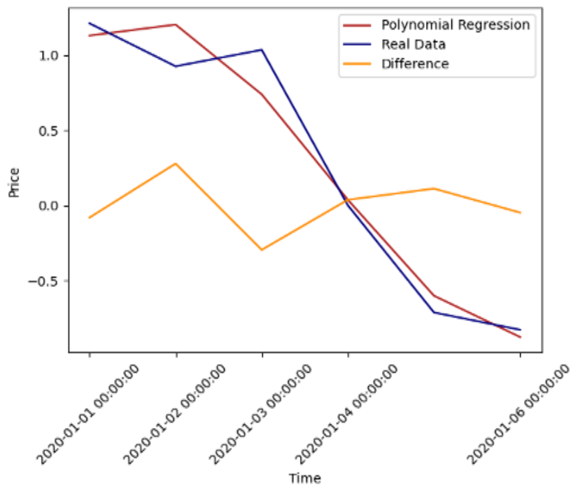


Fig. 3.7 : Stationarity using Polynomial Regression

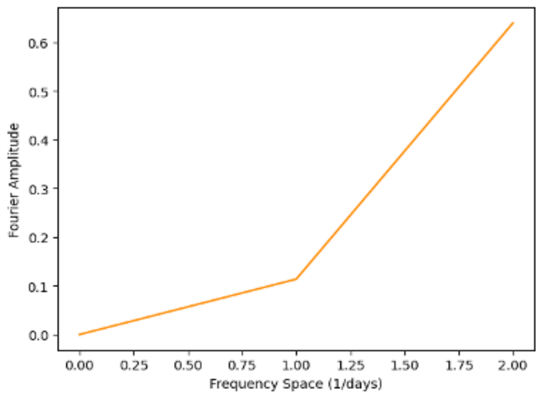


Fig. 3.8 : Amplitude Using Fourier Transform

Next step is to filter the data. All frequencies lower than a specific threshold are being eliminated. The maximum amplitude is utilized as a reference point to set this level. The result of filtering the data is given in Figure 3.9.

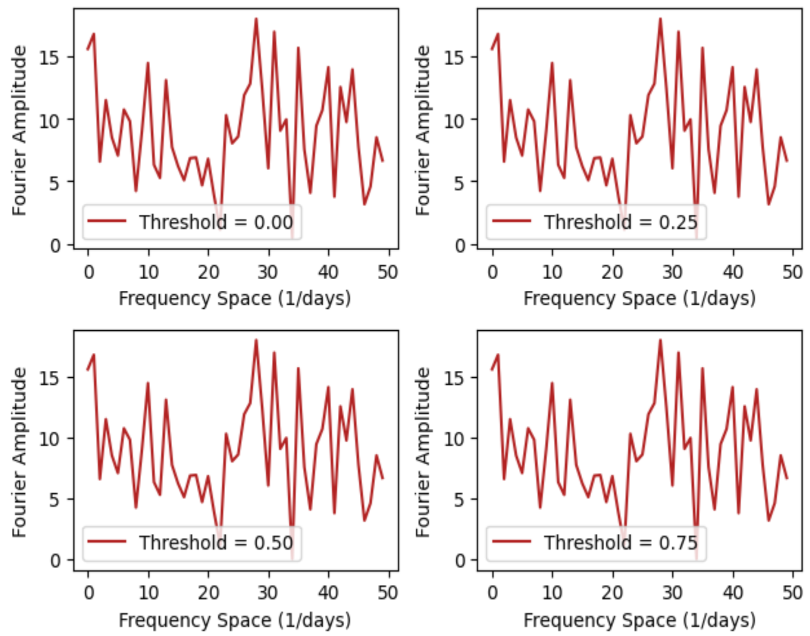


Fig. 3.9. Filtering of the Data below a Reference Threshold

If each filtered Fourier transform is inversed, the result is depicted in Figure 3.10. After denoising, After the data is scaled and divided into testing and training set. The next step is to apply the various techniques and explore the applicability of various methods for time series analysis and forecasting.

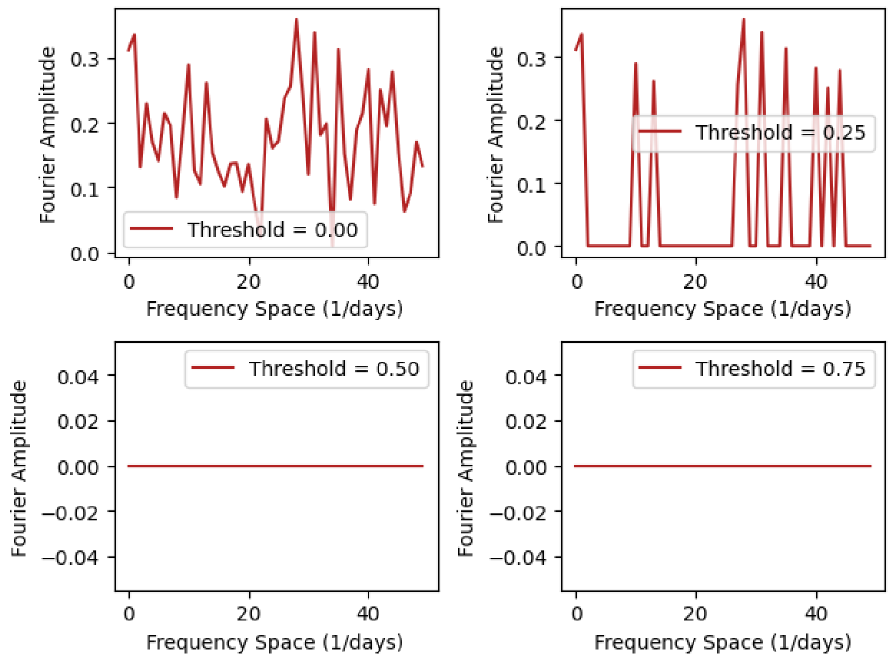


Fig. 3.10. Filtering of the Data below a Reference Threshold

Afterwards, N-BEATS architecture and the other deep learning models namely LSTM, GRU, RNN, CNN, Bi-LSTM are employed over the dataset. The results show that N-BEATS is the best model among tested deep learning architectures. The detailed discussion about the results is explained in chapter 4.

3.2.2 To develop an image processing-based approach to predict the abnormalities in the behavior of the poultry for diseases.

With 23 billion live chickens, the poultry industry is essential to global nutrition. India, a significant player with an industry valued at Rs. 80,000 crore in 2015–2016, has difficulties managing diseases. This sector is divided into an 80% organised and 20% unorganized sector. A crucial component of food security, 729 million chickens are reported in the 19th Livestock Census. The spread of disease is made simpler by large-scale production, which causes significant losses. It is essential to address these health issues if the chicken industry is to continue fulfilling nutritional needs.

The diseases that affect the health of birds, like chickens, turkeys, ducks, geese, and ostriches, come under poultry diseases. Such diseases result in decreased production, rapid spread of disease, and even death of these birds. The cause of the disease can be viruses, pathogens, bacteria, parasites, fungi, etc. Upon getting affected with such diseases, most of the birds start showing early symptoms like sneezing and gasping; the symptoms may vary according to the age of the bird and type of the disease. Usually, such diseases spread rapidly, and within days, all other birds in contact with the affected bird may start showing symptoms and cause high mortality. Some most common diseases observed in poultry are Coccidiosis, Salmonella, Newcastle, Mycoplasmosis, Fowl Typhoid, Botulism, and Infectious Coryza.

Coccidiosis is caused by protozoa of the phylum Apicomplexa, family Eimeriidae. The majority of species that infect chickens are found in the genus Eimeria and impact different intestinal locations. The disease course is fast (4–7 days) and is marked by parasite growth in host cells with significant destruction to the intestinal mucosa. Coccidia in chicken are generally host-specific, and the different species infect distinct regions of the gut. On the other hand, the coccidia may infect the entire digestive tract in game birds, such as quail. Coccidiosis affects game birds, wild birds, and poultry raised in captivity worldwide.

Newcastle disease (ND) is caused by the virulent Newcastle disease virus (NDV), which infects domestic chickens as well as other bird species. Newcastle disease poses little threat to public health or food safety. Viral NDV can cause a deadly illness in domestic poultry that has a significant impact on society and the economy. It is a global issue that mainly occurs as an acute respiratory illness, while the most common clinical form may be diarrhea, sadness, or nervous symptoms.

Around the world, salmonellosis, mostly caused by the Gram-negative bacterium Salmonella sp., is a major poultry disease. Salmonella gallinarum (S. gallinarum) and Salmonella pullorum (S. pullorum), which cause chicken typhoid and pullorum illness, respectively, are two salmonellae that are unexpected to avian hosts. Despite not having the same infectious potential as Salmonella typhimurium or Salmonella enteritidis, they can severely kill chickens, which can result in significant financial loss.

With the growth of technology, it is now possible to predict infectious diseases in poultry and obtain data that can be used to create predictive models. Deep learning algorithms like convolutional neural networks (CNN), based on fecal pictures, have been created to diagnose illnesses in poultry. It is really important to treat these diseases timely.

The primary objective of our initiative is to reduce the impact of poultry disease on birds' health. To solve this problem, we developed a mobile application called "HenScan" that will aid poultry farmersin the early detection of any poultry disease and suggest its prevention and treatment. We have trained several CNN models like SoloConvLayer Model, TriConvLayer Model, FiveConvLayer Model and MobileNetV2 model. We have integrated the model that gives the best accuracy with our mobile application.

I. Disease Overview

a) Coccidiosis

Coccidiosis is a disease caused by microscopic parasites called coccidia that infectthe intestinal tract of animals and humans. Coccidia are usually species-specific, meaning that they only affect one type of host. The most common human coccidiosis is toxoplasmosis, caused by Toxoplasma gondii, which can be transmitted by cats, dogs, or other animals. Toxoplasmosis can cause flu-like symptoms, brain damage, or birth defects in some cases. Other animals, such as chickens, cattle, goats, and rabbits, can also suffer from coccidiosis, which can cause diarrhea, weight loss, dehydration, or death. Coccidiosis can be prevented by good hygiene, sanitation, and medication. Coccidiosis can be diagnosed by microscopic examination of feces or tissue samples to detect the coccidia oocysts, which are the eggs of the parasites.

b) Newcastle Disease (NCD)

Newcastle disease is a viral infection that affects birds, especially domestic poultry. It is caused by avian paramyxovirus type 1 (APMV-1), which has different strains with varying degrees of virulence. The most severe form is called viscerotropic velogenic Newcastle disease (VVND) or exotic Newcastle disease, which can cause high mortality, respiratory distress, nervous signs, and drop in egg production. The disease is transmitted by direct contact, aerosols, or contaminated objects. It can be prevented by vaccination, biosecurity, and culling of infected birds. The disease is notifiable and may affect trade. Diagnosis is based on laboratory tests such as real-timeRT-PCR.

c) Salmonella

Salmonella is a type of bacteria that can cause foodborne illness in humans. In poultry, the bacteria can colonize the gut without causing any symptoms but can also cause infections that lead to poor growth, decreased egg production, and occasional mortality. Salmonella can be transmitted by direct contact, aerosols, or contaminated objects. Salmonella infections are classified as nonmotile serotypes (S. enterica Pullorum and S. enterica Gallinarum) and the many motile paratyphoid Salmonella. The nonmotile serotypes are highly host-adapted to chickens and turkeys and can cause high mortality in young birds. The paratyphoid Salmonella are not host-adapted and can affect almost all animals. They have public health significance because of contaminated poultry product consumption. Salmonella can be prevented by vaccination, biosecurity, and culling of infected birds. Salmonella can be diagnosed by laboratory tests such as real-time RT-PCR.

II. Convolutional Neural Networks

Convolutional Neural Networks (CNNs) are a type of deep learning algorithm that can learn features from data, especially images and videos, by applying filters or kernels to the input. The CNN's mimic how the brain works, enabling them to interpret images similar or more than humans can. CNNs consist of multiple layers, such as convolutional layers, pooling layers, and fully connected layers, that perform different operations on the input. Convolutional layers extract features by sliding filters over the input and applying a nonlinear activation function. Pooling layers reduce the size of the input by taking the maximum or average value in a region. Fully connected layers make the final prediction by applying a logistic function, such as sigmoid or softmax, to the output of the previous layer. CNNs are trained by minimizing a loss function, such as cross-entropy, using backpropagation and gradient descent. The Figure3.11 shows a schematic representation of a CNN architecture, consisting of multiple layers that perform different operations on the input. It also shows the input image, the output predictions, and the data flow direction through the network. CNNs are widely used for image recognition, classification, segmentation, and other computer vision tasks.

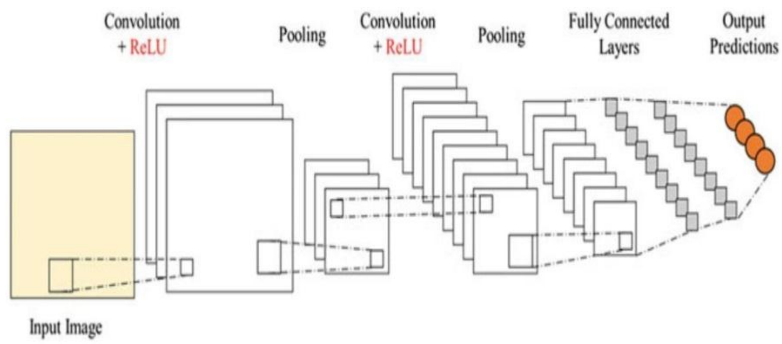


Figure 3.11: Basic CNN model architecture [16]

Based on the comparative study of various research papers focusing on the detection and classification of poultry diseases from fecal images using deep learning techniques, several research gaps are identified:

1) **Small Dataset Size:** Many of the studies mentioned in the comparative analysis utilized datasets consisting of a relatively small number of images.

While some studies attempted to address this by augmenting the dataset or balancing the classes, the overall size of the datasets remains limited. This small datasetsize could potentially limit the generalization of the developed models, as deep learning models typically require large amounts of data for effective training.

2) **Limited Data Preprocessing:** Several papers in the comparison did not extensively elaborate on the preprocessing steps applied to the raw image data before training the deep learning models. Proper data preprocessing techniques such as normalization, augmentation, and noise reduction are crucial for improving the quality of input data and enhancing the performance of deep learning models. The lack of emphasis on data preprocessing in some studies suggests a potential area for improvement and exploration in future research.

3) **Dependent on Pretrained Models:** Many of the research papers mentioned in the comparison relied solely on pretrained deep learning models such as VGG, ResNet, MobileNet, etc., without exploring the potential benefits of training models from scratch or fine-tuning pretrained models specifically for the task of poultry disease detection and classification. While pretrained models offer a convenient starting point and may provide good performance in many cases, customizing and fine-tuning models to the specific characteristics of the dataset and task at hand could lead to furtherimprovements in accuracy.

III. Novelty of Our Research

The novelty of the research lies in the comprehensive approach taken towards data preprocessing and model development for poultry disease detection. The following key aspectshighlight the contributions towards the study:

1) **Iterative Data Preprocessing Strategy:** Unlike previous studies that often overlooked the importance of data preprocessing or applied it in a limited manner, this research adopted an iterative approach to enhance the quality and quantity of the dataset. Three iterations of data preprocessing were conducted that can be referred in further sections.

2) **Development of Custom Models:** The custom CNN models were designed and trained specifically for the task of poultry disease detection and classification. Unlike relying solely on pretrained models, this novel approach involved constructing a baseline model with different architectures that will be described in later sections.

By integrating these novel approaches into the research methodology, the study aims to push the boundaries of current practices in poultry disease detection and classification. The iterative data preprocessing strategy, and development of custom baseline models collectively contribute to this research.

IV. Research Pipeline

This research project encompasses a comprehensive pipeline for the detection of major poultry diseases, namely Coccidiosis, Newcastle disease, and Salmonella. The Figure 3.12 shows the flowchart of the work done on this research.

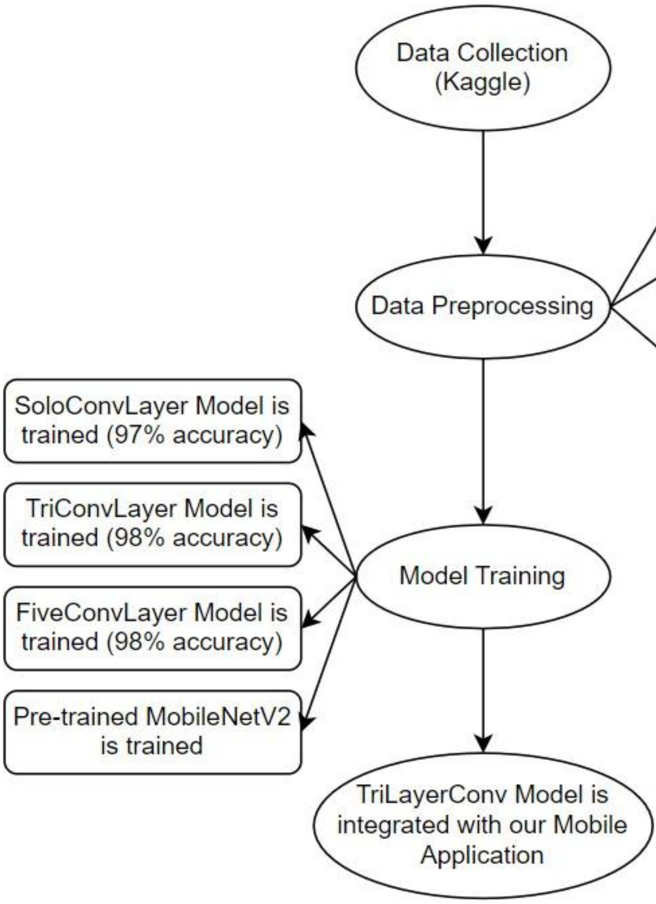


Figure 3.12: Research Pipeline

The dataset of 6812 fecal images was collected from Kaggle, which contains the three disease classes namely Coccidiosis, Newcastle disease, and Salmonella and one Healthy class. This dataset undergoes preprocessing to ensure the suitability for model training. In data preprocessing step, three iterations were performed and the basic CNN model of two layersof Conv2D and MaxPooling each, was compiled and trained to find the best preprocessing steps to be followed. In first iteration, the original dataset was divided into train, test and validation dataset, and later the class balancing was done in training dataset only, to ensure the generalization while training only. In the second iteration, the class balancing was done on the original dataset and later split into train, test, and validation dataset. This ensures the overall generalization and reducing oversampling or undersampling. In the third iteration, the steps that were followed are, class balancing, followed by increasing the size of dataset with the help of data augmentation and at last splitting the dataset. It ensures that dataset is both balanced and adequately sized for model training and evaluation. The third iteration data preprocessing was chosen for training all other models as well, as the accuracy obtained in third iteration is the best out of all other iterations. Three custom CNN models with different architecture were trained on this dataset for poultry disease detection: the FiveConvLayer model, the TriConvLayer model, and the SoloConvLayer model. The FiveConvLayer model, and the TriConvLayer model were trained with input shape of 224x224 RGB images, but with different architectures. The FiveConvLayer model comprises five sets of convolutional layers with max-pooling layers in between, followed by a flatten layer and fully connected layers. while the TriConvLayer model consists of three sets of convolutional layers with max-pooling layers, followed by a flatten layer and fully connected layers. The SoloConvLayer model is passed the input shape of 128x128 RGB images and is constructed with single set of convolutional layer and max-pooling layer, followed by a flatten layer and fully connected layers. These custom CNN models were then compared with pre-trained MobileNetV2 model. After, transfer learning, fine-tuning was also performed on MobileNetV2 and thus, all these models were compared on the basis of their metrices. The best model selected was further integrated with our mobile application “Henscan”.

The research pipeline culminates in the development of an effective and practical solution for poultry disease detection, leveraging custom CNN models and mobile technology.

V. Data Collection

The Data was collected for three diseases, namely- Coccidiosis, Salmonella, Newcastle disease from Kaggle, a widely recognized platform for sharing and discovering datasets. The dataset is available at Kaggle, that contains the folders of all the diseases and healthy fecal images. Sample images from the dataset are shown in Figure 3.13. The dataset contains the total of 6812 fecal images of poultry that are divided into 4 categories. There are 2103 images for "Coccidiosis", 2057 images for "Healthy",2276 images for "Salmonella" and 376 images for "New Castle Disease".

(a) (b) (c) (d)

Figure 3.13: Sample images from the faecal image dataset (a) Coccidiosis, (b) Salmonella, (c) Healthy, (d) Newcastle Disease

VI. Data Preprocessing

This procedure aims to achieve a balanced class distribution, enhance model generalization, andaddress challenges from limited data present in Kaggle. The process involves iterative steps to optimize the dataset for model training. The key strategy used is Image augmentation that creates new training images from existing ones by applying various transformations, such as rotation, cropping, flipping, brightness, contrast, etc. Image augmentation helps to increase the size and diversity of the training dataset, which can improve the performance and generalization of deep learning models. To ensure the effectiveness of the preprocessing pipeline, three iterations were undertaken, and tested on SoloConvLayer model, exploring different combinations of augmentation techniques. Through this iterative approach, we identified and selected the best-performing technique for subsequent model training which is discussed with results in chapter 4.

VII. Model Architecture

a) SoloConvLayer Model Architecture

The SoloConvLayer model proposed in our research involves the combination of input layer, hidden layer and output layers. The input layer is made by a 2D convolutional operation (Conv2D) with 16 filters, each with a size of 3x3 pixels. Filters are the small matrices that capture specific patterns or features from the input image. ReLU activation function is applied to introduce non-linearity, allowing the model to learn complex features from the data. Following the convolutional layer, a max-pooling layer (MaxPooling2D) with a pool size of 2x2 is added to reduce the spatial dimensions of the feature maps. The feature maps obtained from the convolutional layers are flattened into a one-dimensional array using the Flatten layer, preparing them for input into the dense layers. A densely connected layer (Dense) with 64 neurons and ReLU activation function is added for feature extraction and representation. To prevent overfitting, a dropout layer with a dropout rate of 0.5 is applied after the dense layer. Dropout randomly sets a fraction of input units to zero during training, which helps in reducing overfitting by introducing redundancy. The output layer consists of 4 neurons corresponding to the number of classes in the classification task. It utilizes the softmax activation function, which normalizes the output into a probability distribution over the classes, ensuring that the sum of probabilities across all classes is 1. The model is compiled using categorical cross-entropy as the loss function, which is suitable for multi-class classification tasks. Adam optimizer is used for optimization with a learning rate of 0.001. The model's performance is evaluated during training using accuracy as the metric. This flowchart in Figure 3.14 illustrates the sequential flow of operations in the CNN architecture.

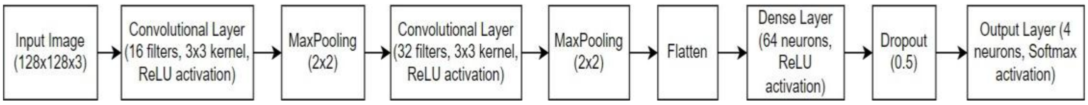


Figure 3.14: SoloConvLayer Model Architecture

b) TriConvLayer Model Architecture and Result

The TriConvLayer model proposed in our research involves the combination of input layer, hidden layer and output layers. The input layer that accepts images with dimensions of 224x224 pixels and three color channels (RGB). The model contains multiple convolutional layers, each followed by a rectified linear unit (ReLU) activation function to introduce non-linearity. The first convolutional layer has 16 filters with a kernel size of 3x3, and subsequent convolutional layers have 32 filters. All convolutional layers use the 'same' padding to ensure the output feature maps have the same spatial dimensions as the input. MaxPooling layers are inserted after each convolutional layer with a pool size of 2x2. These layers downsample the feature maps, reducing their spatial dimensions and extracting key features. After the final max-pooling layer, the feature maps are flattened into a one- dimensional array using the Flatten layer. This prepares the data for input into the dense layers. A fully connected Dense layer with 64 neurons and ReLU activation follows the flattening layer. This layer serves to further extract features and learn complex patterns from the flattened feature vectors. Dropout regularization with a dropout rate of 0.5 is applied to prevent overfitting by randomly dropping out a fraction of the neurons during training. The final layer is a Dense layer with four neurons, corresponding to the number of classes in the classification task. It utilizes the softmax activation function to output probabilities for each class, indicating the likelihood of an image belonging to each class. The model is compiled using categorical cross-entropy as the loss function, suitable for multi-class classification tasks. The Adam optimizer is used for optimization, with a learning rate set to 0.001. This model is more complex as compared to SoloConvLayer as it contains multiple conv2D and MaxPooling layer. This model contains total of four Convoluation layer. This flowchart in

Figure 3.15 illustrates the sequential flow of operations in the CNN architecture.

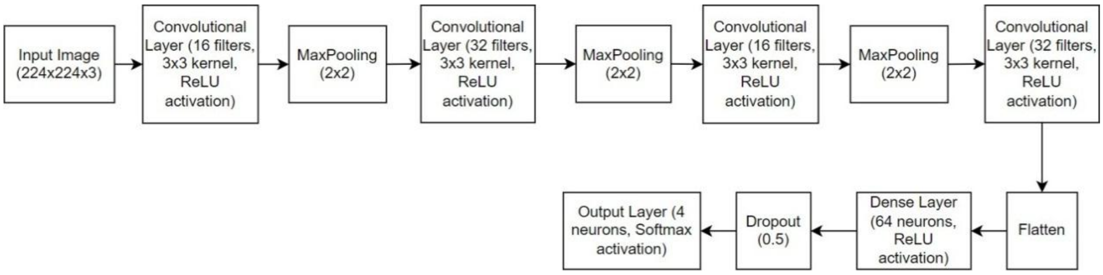


Figure 3.15: TriConvLayer model architecture

c) FiveConvLayer Model Architecture

The FiveConvLayer model proposed in our research involves the combination of input layer, hidden layer and output layers. The input layer Accepts images with dimensions of 224x224 pixels and three color channels (RGB). The model consists of multiple convolutional layers, each followed by a rectified linear unit (ReLU) activation function. MaxPooling layers with a pool size of 2x2 are inserted after each convolutional layer. The feature maps obtained from the convolutional layers are flattened into a one-dimensional array using the Flatten layer,preparing them for input into the dense layers. A densely connected layer (Dense) with 64 neurons and ReLU activation function is added. A dropout layer with a dropout rate of 0.5is applied after the dense layer. The output layer consists of 4 neurons. It utilizes the softmax activation function, which normalizes the output into a probability distribution over the classes, ensuring that the sum of probabilities across all classes is 1. The model is compiled using categorical cross-entropy as the loss function, which is suitable for multi-class classification tasks. Adam optimizer is used for optimization with a learning rate of 0.001. This model overall contains six Convolutional layer and is more complex than compared to other two models. This flowchart in Figure 3.16 illustrates the sequential flow of operations in the CNN architecture.

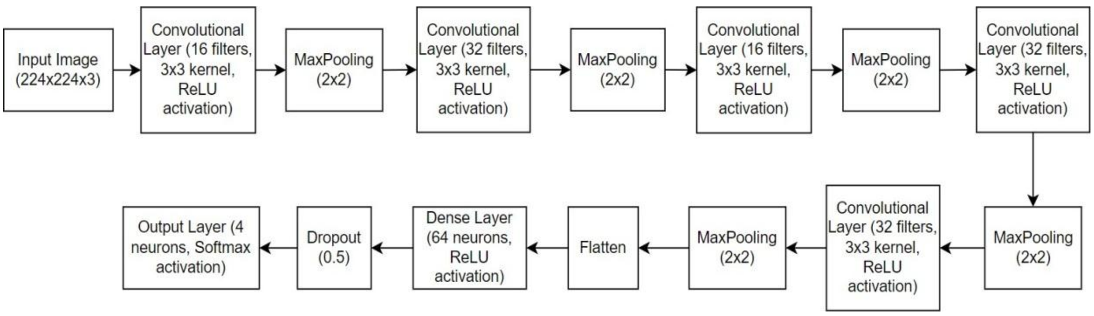


Figure 3.16: FiveConvLayer Model Architecture

d) MobileNetV2 Model Architecture

The pre-trained model of MobileNetV2 was trained. Initially, transfer learning was applied, followed by fine-tuning where the last 100 layers were trainable, and the rest were frozen. During the training, the input size was 128*128 and Adam optimizer is used for optimization with a learning rate of 0.001. The performance of the MobileNetV2 model was evaluated on training and validation dataset. In pre-trained MobileNetV2 model, some layers were frozen as described above in fine-tuning steps. So, after fine-tuning, again the model was evaluated which resulted in a slight improvement in accuracy. After the execution of all the above-mentioned models, comparative analysis is performed over the results obtained and the model with the best performance turns out to be TriConvLayer Model.Thus, this model is employed in the ‘HenScan’ mobile application which can be used by the farmers for the disease detection.

3.2.3 Mobile Application

The health and productivity of the birds are negatively impacted by poultry diseases, which represent a severe danger to the poultry industry. In order to stop outbreaks and reduce losses, it is essential to identify and diagnose poultry diseases early on. But many poultry farmers lack the knowledge and resources necessary to identify diseases accurately and quickly. To address this issue, we created HenScan, an mobile application that analyzes fecal samples to identify poultry diseases using deep learning model. HenScan gives researchers and poultry producers a reliable and practical tool to assess the health of their flocks and take necessary action. In the following section, we present the design, implementation, and evaluation of HenScan.

I. Mobile application framework

The detailed application framework is depicted below in the fig.3.17

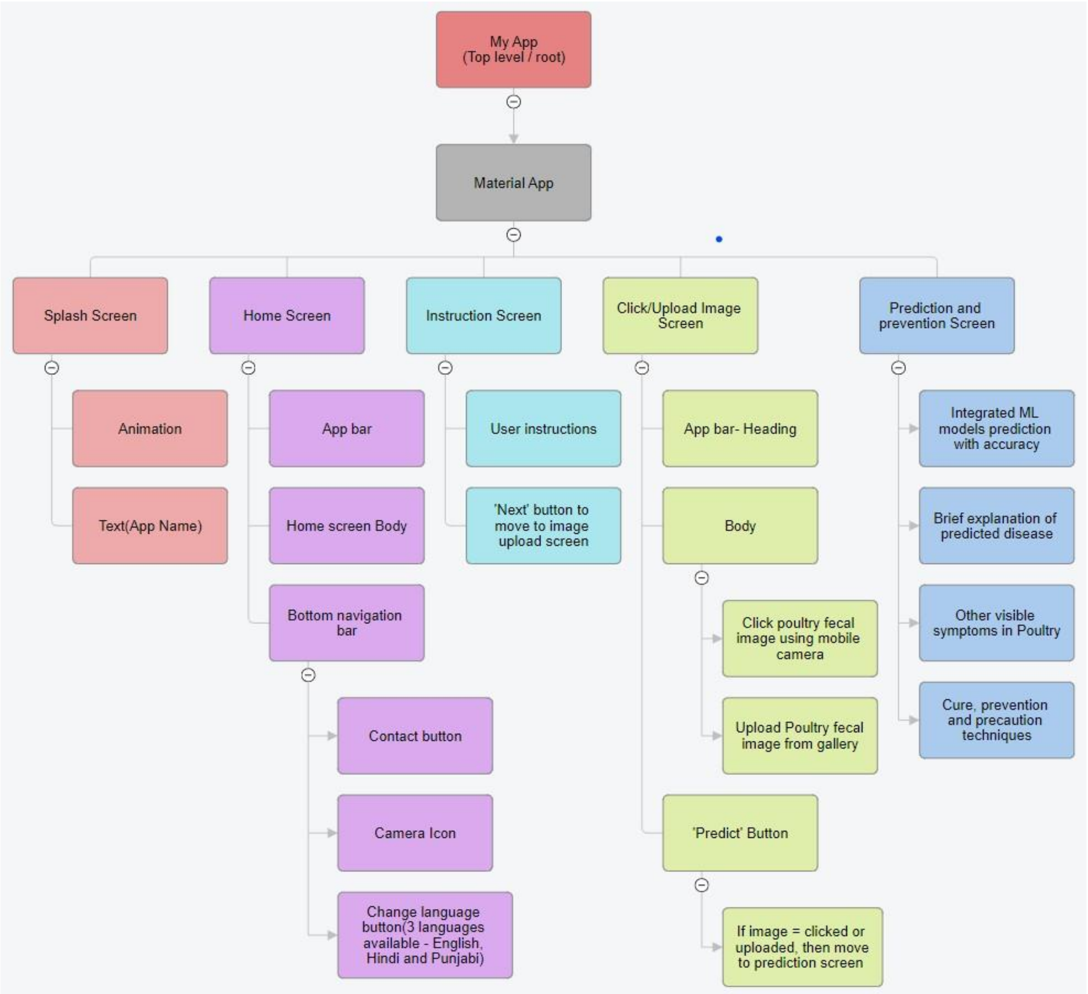


Figure 3.17: Mobile App Framework for Poultry Disease Detection

II. Flutter Framework

The app is built using Flutter, a cross-platform framework that allows creating native- like apps with a single codebase. Flutter offers several advantages, such as fast development, expressive UI, high performance, and hot reload and hot restart features. The app code is written in Dart, a modern and concise programming language that is easy to use.

III. App Structure and Organization

The app code and assets are organized into separate folders and files for clarity and maintainability. The assets folder contains subfolders for images and animations that are used in the app, as well as the machine learning model file in tflite format.

The lib folder contains the main.dart file, which is the entry point of the app execution, and two subfolders for screens and languages. The screens folder contains five dart files that correspond to the five screens of the app: splash screen, home screen, instruction screen, click/load image screen, and prediction screen. The languages folder contains the localization files for the three languages supported by the app: Hindi, English, and Punjabi. The app follows the naming conventions and coding standards recommended by Flutter.

IV. App Screens and Navigation

The app consists of five screens that provide the main functionalities and information–

1. The splash screen is the first screen that the user sees when opening the app. It displays a brief animation and the app name.

2. The home screen is the main screen that provides an overview of the app's purpose and features. It has an app bar that shows the app name, a body that shows the app description, and a bottom navigation bar that shows three icons/buttons: contact, camera, and language. The contact button allows the user to contact the app maintenance team in case of any issues or queries. The camera button directs the user to the instruction screen. The language button allows the user to choose their preferred language from the three options - Hindi, English and Punjabi.

3. The instruction screen provides the user with the guidelines on how to capture andupload the poultry fecal image for prediction. It has a next button that leads the userto the click/load image screen. The click/load image screen allows the user to eithertake a picture using their phone's camera or select an image from their gallery. It has a predict button that initiates the image analysis and prediction process.

4. The prediction screen shows the user the result of the image analysis and prediction. It displays the predicted disease, the accuracy, the other symptoms, and the cure andprevention measures.

V. Machine Learning Model and Prediction

The app uses a machine learning model that is trained to detect poultry diseases from fecalsamples. The model being used is the application is TriConvLayer model it outperforms various other models that we executed as discussed above.The model is stored in the assets folder as a tflite file, which is a compressed and optimized format for mobile devices. The app uses the tflite plugin to load and run the model on the device. The plugin provides an easy and efficient way to interact with the model and perform inference. The app takes the user's image as an input and preprocesses it to match the model's input format. The app then feeds the image to the model and obtains the output, whichis a probability distribution over the possible diseases. The app postprocesses the output to extract the most likely disease and its accuracy. The app also retrieves the other symptoms andthe cure and prevention measures from a local database that is based on research. The app displays the prediction result to the user on the prediction screen, along with the relevant information and advice.

VI. Methodology to Implement and Utilize the Poultry Disease Detection Mobile App

1. User Perspective:

(i) **Download and Installation:** Users can download the mobile application using the link.

(ii) **Usage:** Upon installation, users can seamlessly navigate through the application. Intuitive user interfaces guide users through capturing poultry fecal images and obtaining disease predictions effortlessly.

VII. Developer Perspective:

(i) **Pre-requisites:** Developers interested in exploring the codebase need to download Flutter and Android Studio.

(ii) **Setup:** Following the official Flutter documentation, developers can set up the necessary development environment.

(iii) **Codebase Exploration:** Developers can check out the organized Flutter app codebase in Android Studio. The codebase follows best practices for clarity, modularity, and maintainability.

(iv) **Plugin Import:** In the terminal, developers can run the command 'flutter pub get' to importthe required plugins added to the project.

(v) **Running the App:** Developers can initiate the app by running the command 'flutter run' inthe terminal. This launches the app on the connected emulator or physical device for testing and further development.

3.3 SUMMARY

This chapter proposes an intelligent approach to improve the production in the poultry farms of the Punjab as well as also provides an image processing-based approach to predict the abnormalities in the behaviour of the poultry for diseases. To achieve the first objective, we surveyed and gathered data from 111 farms in various districts of the Punjab.The questionnaire which was in English and Punjabi was used to gather the information from the farmers. To achieve the second objective, N-BEATS architecture was developed which is a deep learning model that can be used for the prediction of the diseases in the chicken using time series data. Additionally, the research uses the fecal dataset over which various deep learning models were trained and tested and their results were compared and the best model was used for the prediction of the chances of poultry birds prone to a certain disease. This fulfils the third and fourth objective of the study. Finally the best model obtained with higher accuracy for disease prediction is used in the mobile application named 'HenScan'.This application provides a practical approach that can be used by the poultry farmers in their fields to get help disease detection.

Chapter – 4

RESULT AND DISCUSSION

This chapter includes the results and discussion of Development of an Intelligent Approach to enhance the Poultry Production in the state of Punjab. Herein, the data collection of 111 poultry farms has been done and after that the collected data is analyzed to understand the existing problems being faced by the farmers and the various methods being used to tackle the problems. Furthermore, to develop an Intelligent approach to enhance the poultry production in Punjab by maintaining temperature and humidity, accurate forecasting of the poultry data is essential which is made possible by N-BEATS model that can be used to forecast many aspects of chicken disease diagnostics. Additionally, to develop an image processing-based approach to predict the abnormalities in the behavior of the poultry for diseases, various convolutional neural network (CNN) models are used and their results are discussed in this chapter in detail. Based on the comparison, we show that the TriConvLayer model outperforms all other models for all metrics used. This model is then integrated into a mobile application named "HenScan" for on-the-go disease detection. This innovative approach not only showcases advancements in poultry disease detection methodologies but also provides a practical solution for poultry farmers to manage and mitigate disease outbreaks effectively.

The proposed work is carried out for the improvement in the field of poultry farming basically in Punjab. In the poultry farming of Punjab there are many challenges which are faced by the farmers a few of which are discussed below:

- Routine Bird Monitoring
- Minimum Human Labor
- Enhance Animal Welfare
- Limit Disease Transmission
- Reduces Cost and Increases Availability
- To Locate Chickens

To Achieve the first object, the data is collected from the 111 farmers which gave us the information about various techniques being used in the farms of the Punjab to carry out poultry farming, various problems and issues being faced by the farmers, the various solutions they expect for all the problems being face by them. This data is collected manually and for the collection of the data a questionnaire was prepared. This questionnaire includes the basic questions on how the farmers are carrying out the various farming activities in their farms which could help relate to the major issues and problems being faced and what could be the possible solutions to tackle these issues.For instance, during the visit to the farms various questions were asked to the farmers to gather the information regarding the various methods used for the farm maintenance, farm monitoring, various kinds of methods used for maintain cleanliness in the farms, optimal temperature and humidity levels maintained in the farms, etc. The questionnaire consisted of thirty-five questions regarding the various aspects of the poultry farming and challenges being faced by the Punjab's poultry farmers. Thus, the dataset is prepared from the responses collected and the pre-processing is done over the gathered dataset. Finally, the in-depth analysis is done over the data and the graphs were generated representing the same. This analysis gives indication to the various methods used by the farmers for the maintenance of the farms and the problems being faced by the farmers that needs to be solved. Further, the results of this analysis can be used to develop methods for the better farm management and animal welfare in the farms and also for addressing the concerns of the farmers. After the analysis, for the accomplishment of the second objective, the N-BEATS architecture is developed for multi-dimensional poultry data explainable forecasting. N-BEATS is a deep learning model for predicting time series. The data related to forecasting is a multivariate dataset based on the environmental parameters of poultry. The methodology improves the process of making decisions for managing chicken farms by utilising the capabilities of the N-BEATS model and incorporating an explainable AI (XAI) framework to clarify the model's predictions. Afterwards, a comprehensive methodology was developed for poultry disease detection, focusing on the integration of convolutional neural network (CNN) models into a mobile application for practical deployment. The study begins with data acquisition from Kaggle, followed by meticulous preprocessing techniques, including data splitting and class balancing. Subsequently, various iterations of data augmentation are performed to enhance the dataset's size and balance, culminating in the creation of a robust final dataset. The core of the research involves model training, where three custom CNN models with single, three, and five convolutional layer sets achieve impressive accuracies of 97%, 98%, and 98% respectively. Additionally, a pre-trained MobileNetV2 model attains accuracies of 97% and 98% after fine-tuning. Based on the comparison, we show that the TriConvLayer model outperforms all other models for all metrics used. Thus, TriConvLayer model is used in the mobile application i.e. 'HenScan' to help the farmers in the detection of the possible disease from which the birds might be suffering.

4.1 Basic Data Analysis

The data is collected from 111 farmers to understand the methods and technologies used in poultry farms in Punjab. It has found that there are different crisis faced by the farmers. In order to view the cause of these crisis, this present study look into the questionnaire in which questions has been asked to the farmers to figure out the various issues faced by the farmers. These questions are enlisted below: -

1) What type of feed is being provided in poultry farms?
2) How many times the feed is given to the chickens?
3) What is the feeding regimen for the chickens (type of feed, frequency, quantity)?
4) List of the various medicines being given to the chickens?
5) Cost of the medicines provided to the chickens?
6) What are the various methods for the monitoring of the chickens to be free from the diseases?
7) What are the various vaccinations provided to the chickens?
8) What is the vaccination schedule for the chickens?
9) What are the various disease outbreaks the farm has suffered?
10) Are the birds suffering from cannibalism?
11) What are the methods being used to tackle the problem of cannibalism?
12) Are the chicken houses cage free or not?

13) Amount of the time given to the chickens for roaming outdoors per day (in case of caging)?
14) What are the various measures taken to maintain the cleanliness in the poultry farms?
15) At what intervals of the times the cleanliness measures are taken?
16) What are the optimal temperature values in the farms that is being maintained?
17) Any means of controlling the temperatures values in the farm?
18) What is the optimal humidity in the farms that is being maintained?
19) Any means of controlling the humidity in the farm?
20) What is the temperature, humidity, and ventilation system in the chicken houses?
21) Whether the quality of the water is being checked in the poultry farm?
22) What type of lighting is provided?
23) Are there any routine health checks or diagnostic tests performed?
24) How are diseases and health issues managed on the farm?
25) What is the type of the chicken breed being reared?
26) What is the average body mass of the chickens at various ages?
27) What is the productivity rate of the farm?
28) What is the death rate of the farm animals?
29) What is the average weight and growth rate of the chickens?
30) What is the egg production rate (if applicable)?
31) What are the major problems they are facing regarding the chicken farming?
32) What are the various equipment's/ tools (automated / manual) that are being used in the farm?
33) What advances in the computer systems are required for the better rearing of the chickens?
34) Are there any specific measures in place to control diseases and parasites?
35) Are there any specific management practices in place for different age groups or breeds?

Table 4.1 just represents the data set of collected data. This questionnaire is also attached in the Annexure.

Table 4.1: Snapshot of the Subset of the Data collected for Analysis

Name	District	State	What type of feed is being provided in Poultry Farms?	List of the various medicines being given to the chickens?			What are the methods being used to tackle the problem of cannibalism?	What are the various methods for the monitoring of the chickens to be free from the diseases?
Adamwal	Hoshiarpur	Punjab	Value Max Finisher	Bruton			No Issue Faced	Medicine, Properaring
Aima Mangat	Hoshiarpur	Punjab	Saguna feed	Sugi stress	Sugi electron		No Issue Faced	By Medicine time to time, spray every day
Arjanwal	Jalandhar	Punjab	Venky Feed	Figer	Himalaya	Oxymav	No Issue Faced	Seprated infected one
Arshkamal Poultry Farm	Hoshiarpur	Punjab	Venky Feed	Calcium	Liver tonic		No Issue Faced	Separated the infected one
Avtar singh Poultry Farm	Hoshiarpur	Punjab	Pre Starter, Starter, Finisher	Liver tonic	Bruton	Vitamin	No Issue Faced	By properhecking or Medicine
Baggu Farm	Amritsar	Punjab	Mesh feed	Gumboro	Coccidiostat	Oxymax B Antibiotic	Proper caring and cleaning	By security (with the help of medicine)
Bagroi	Hoshiarpur	Punjab	Value Max Finisher	Coccipro1 100g	Wormout Tablet		No Issue Faced	By Medicine (occiprol 100g, Worm out tablets)
Baldeve singh Poultry Farm	Hoshiarpur	Punjab	Mesh feed	Antibiotic	Vitamin		No Issue Faced	By doctor
Bana	Shaheed Bhagat Singh Nagar	Punjab	Pre starter, starter, finisher	Toxol	G-promin		No Issue Faced	Cleaning with chuna or white wash and medicine
Bana	Shaheed Bhagat Singh Nagar	Punjab	Pre starter, Starter, finisher	Antibiotic	Vitamin		No Issue Faced	By Medicine (Antibiotic, Vitamin)
Banga Rural	Hoshiarpur	Punjab	Saguna feed	Kilverm	Coccipro1 100 g		Remove any badly injured birds	By security and Byleaning

Based on the data collected from respondents, it is evident that majority of the farms in the Punjab allow the chickens to reside in a cage free environment as shown in Fig. 4.1 which enhances the animal wellbeing by providing them a natural habitat.

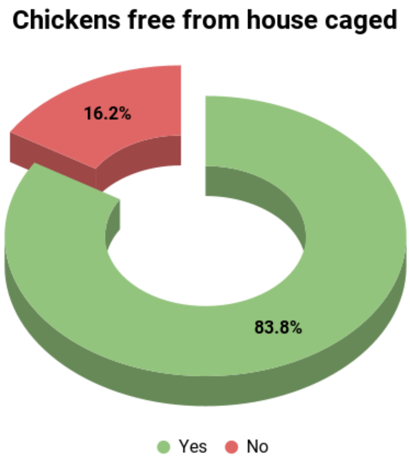


Fig. 4.1 : Analysis of House Caged Chickens

During interaction with farmers, different challenges have been unveiled as illustrated in Table 4.2.and the death rate in the various farms is depicted in the fig 4.2 These challenges primarily include changing weather conditions and the labour problems.

Table 4.2 : Major Challenges faced by Poultry farmers in Punjab

Challenge	Count of farmers
Weather Problem	66
Labor Problem	40
Electricity Problem	05
Humidity	02
Cleaning Problem	03
Market rate of Chickens	02
Problem of mouse	03
Problem of pollution	02
Temperature Handling	03
Viral Infection	02
No Problem	22

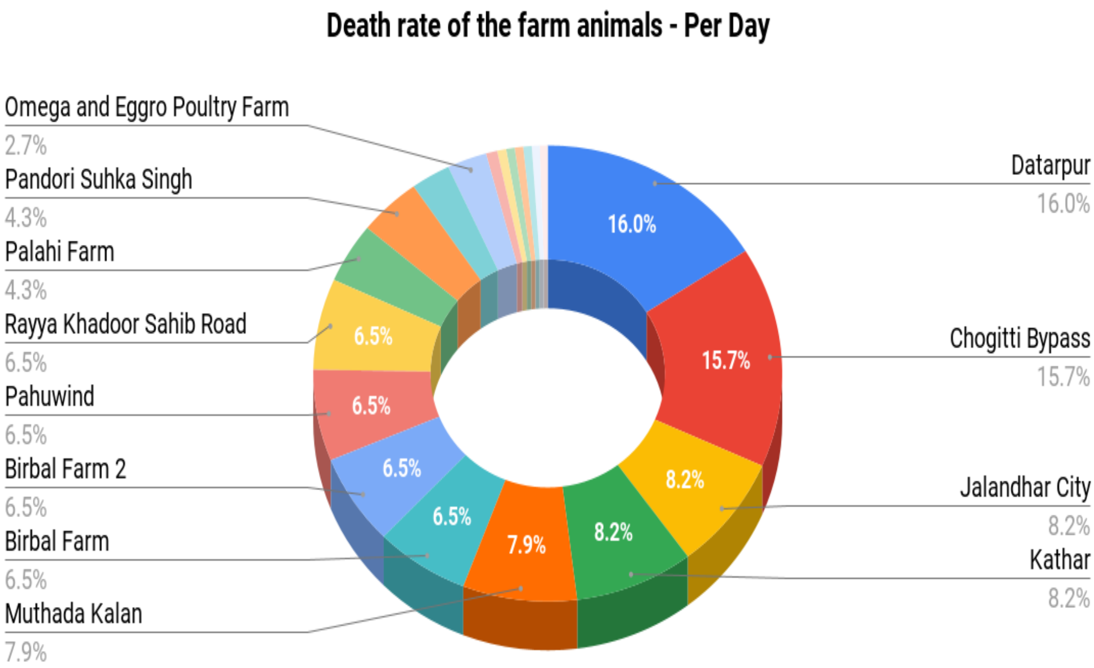


Fig 4.2 : Death Rate of the Farm Animals

The inability to maintain proper temperature or humidity levels leads to severe effect on the productivity of the animals. Also farmers discussed that some labours do not maintain proper cleanliness in the farms leading of spread of diseases. It was also mentioned that the farmers rarely face cannibalism issue because of the various preventive measures taken by them such as proper caring and cleaning of the farm animals, removal of injured birds from the rest of the flock and giving salt to the infected ones.

The health and production of chickens are greatly impacted by humidity levels. Wet litter can result from too much moisture in the air encouraging the development of dangerous germs and fungus. On the other hand, low humidity can cause dry air which causes respiratory irritation. Apart from humidity, the thermal environment has distinct effects on poultry animals. Because of the effects of climate change and the associated rise in climatic unpredictability, naturally produced chicken faces thermal problems that affect their capacity to produce and reproduce. As per the data gathered from the survey it is clear that average temperature range between 30 to 35 degree Celsius as shown in the Fig 4.3. And the humidity ranges are shown in the fig 4.4

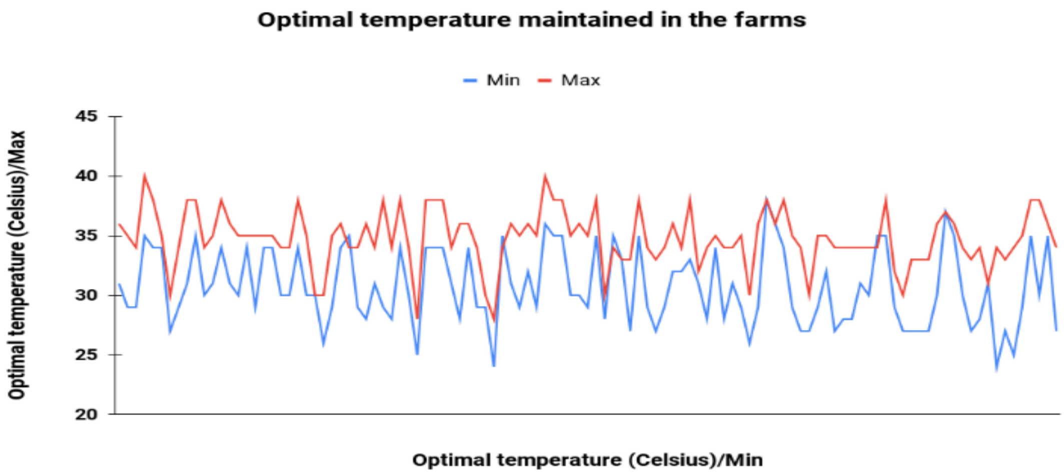


Fig. 4.3. Temperature Maintenance in Poultry

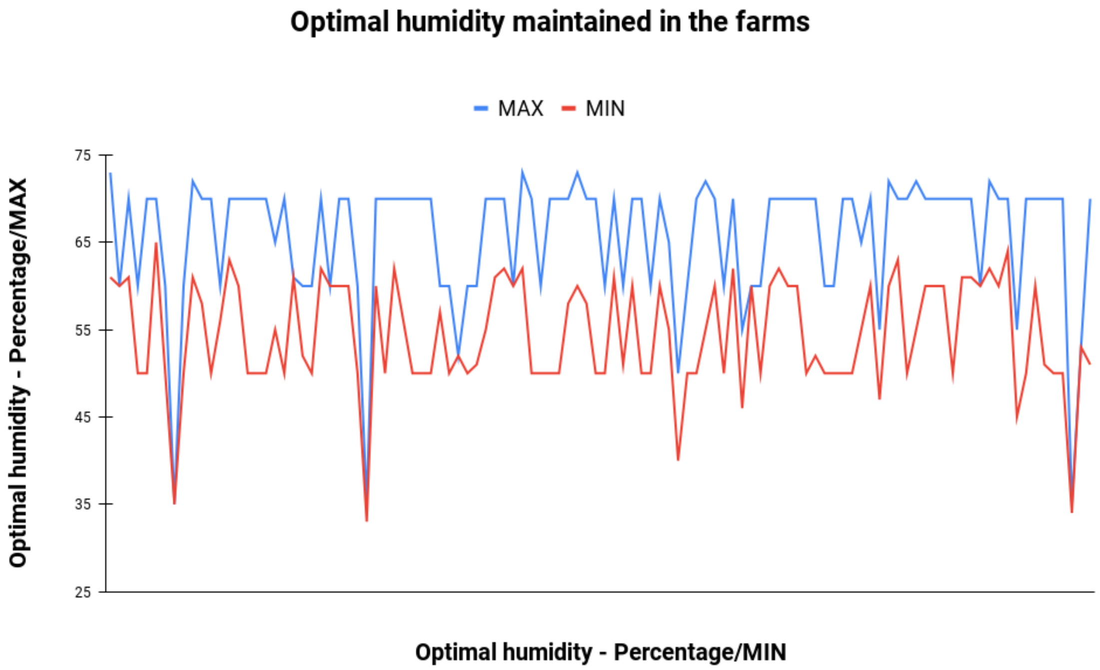


Fig. 4.4 : Optimal Humidity maintained in the Farms

The Cleanliness of the farms is an important factor for preventing various kinds of disease outbreaks in the farms. The best approach to take care of farm animals is to clean the chicken coop on a regular basis. One needs to get rid of any food or water that is left over each night to maintain the clean space and to avoid bug infestations. Picking up all the droppings once a week, then using fresh new bedding down within the coop, a deep clean 1-2 times each year is required. Fig. 4.5 illustrates the time intervals of the cleanliness measures taken by the poultry framers of the Punjab.

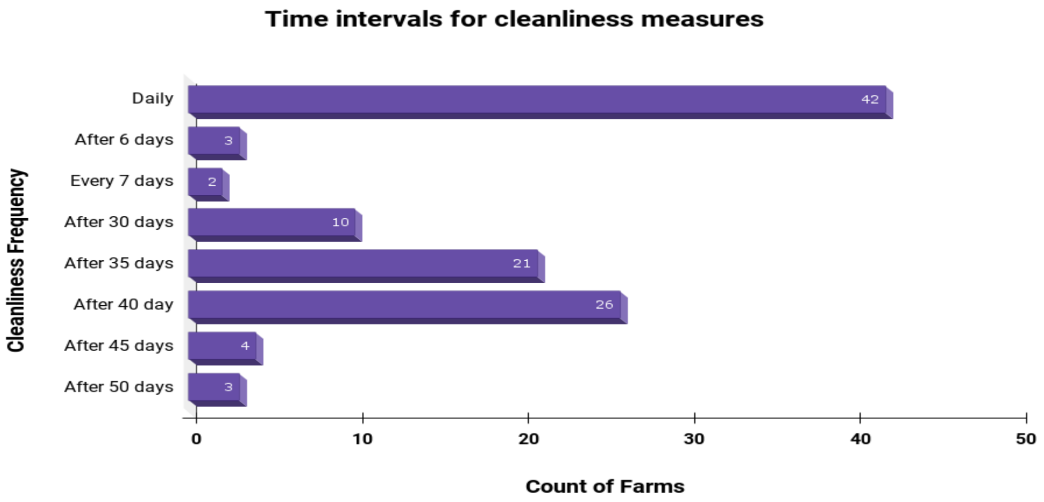


Fig. 4.5 : Time Intervals for Cleanliness Measures in Poultry

Feed gives chickens the energy and nutrients they need to grow bone, meat, feathers, and eggs. An optimal feed should consist of the Water, Carbohydrates, Fats, Proteins, Minerals, Vitamins. The lack of the proper feed can lead to various problems like health degradation, leg related issues, inadequate feathering, thinning of the egg shells, reduced egg production, easy vulnerability to infections. Thus, feed plays an important role in the growth of the animals so analysis of the various feeds being used in the farms of the Punjab is performed and the results are illustrated in the Fig. 4.6.

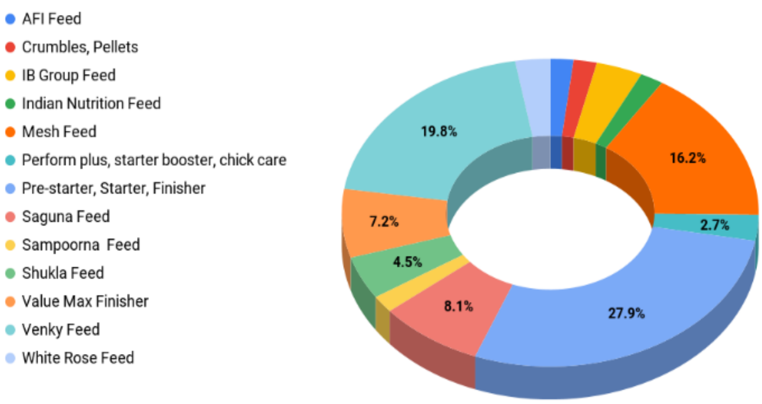


Fig. 4.6: Types of feed in Poultry Farms

Since healthy hens produce safe and nutritious food, different medicines and antibiotics are given to them to keep them healthy. By keeping hens healthy, it is ensured that minimum number of germs enters the food chain. Antibiotics and medicines also reduce the animal sufferings and promotes sustainable development. The different medicines administered in Punjab are graphically illustrated in Fig. 4.7.

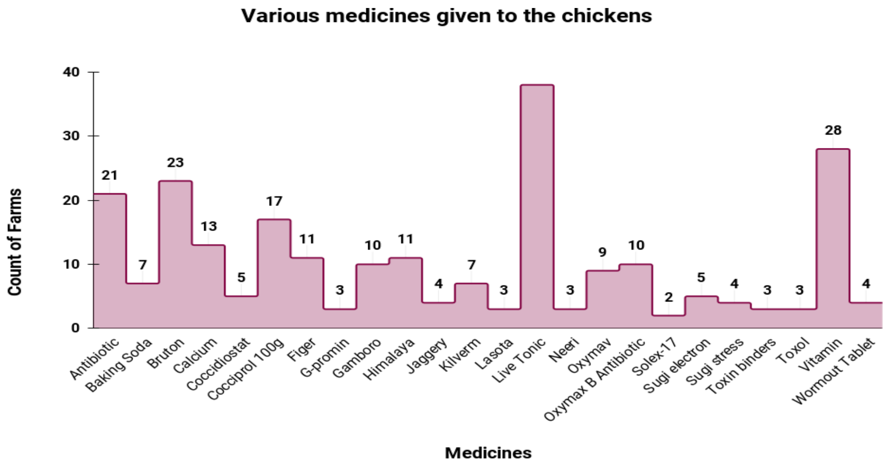


Fig. 4.7: Various Medicines given to Chickens

Following the establishment of a clean and hygienic environment through appropriate chicken farming techniques, routine preventative actions provide the next line of defence against disease. The farmers of Punjab use various methods for the preventing the outbreak of diseases in the farms as shown in the Fig. 4.8.

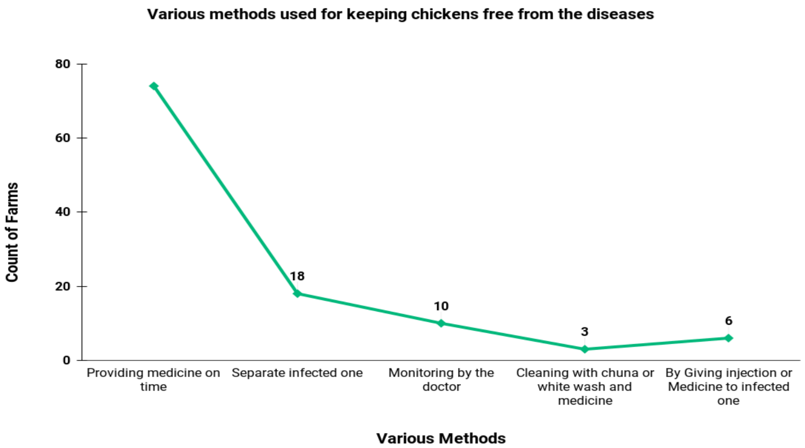


Fig. 4.8: Various Methods for disease-free Chickens

Further, to prevent and manage infectious poultry illnesses, different poultry vaccinations are also used extensively. In order to increase productivity, their usage in poultry production aims to prevent or minimize the occurrence of clinical illness at the farm level. Regarding a number of local characteristics (such as the method of manufacturing, the pattern of the illness locally, expenses, and possible losses), vaccines and vaccination programs differ greatly. The count of the different vaccines used in the Punjab is being depicted in the fig 4.9 and the productivity rate of the various poultry farms is depicted in the fig 4.10

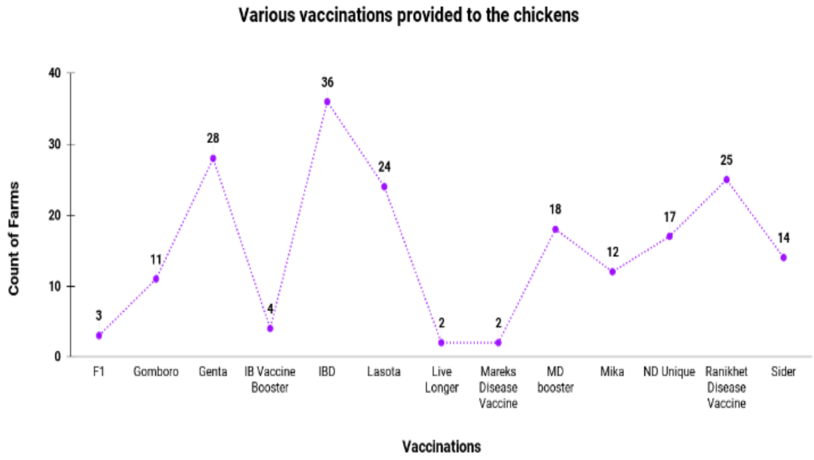


Fig. 4.9. Various Vaccinations Provided to the Chickens

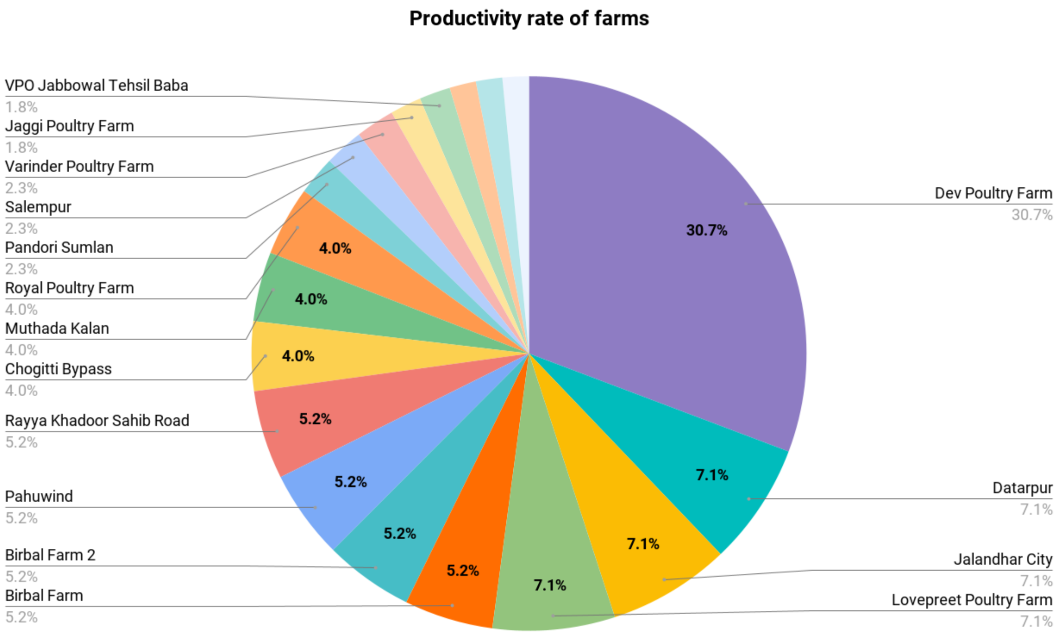


Fig 4.10: Productivity Rate of the Farms

In addition to all above safety measures, the temperature maintenance is crucial for the better growth of the farm animals. This is vital because if a chicken experiences heat stress, its core body temperature rises to lethal levels as a result of inadequate heat dissipation and inadequate coping mechanisms. Hence, various methods used for the temperature maintenance is illustrated in Fig. 4.11.

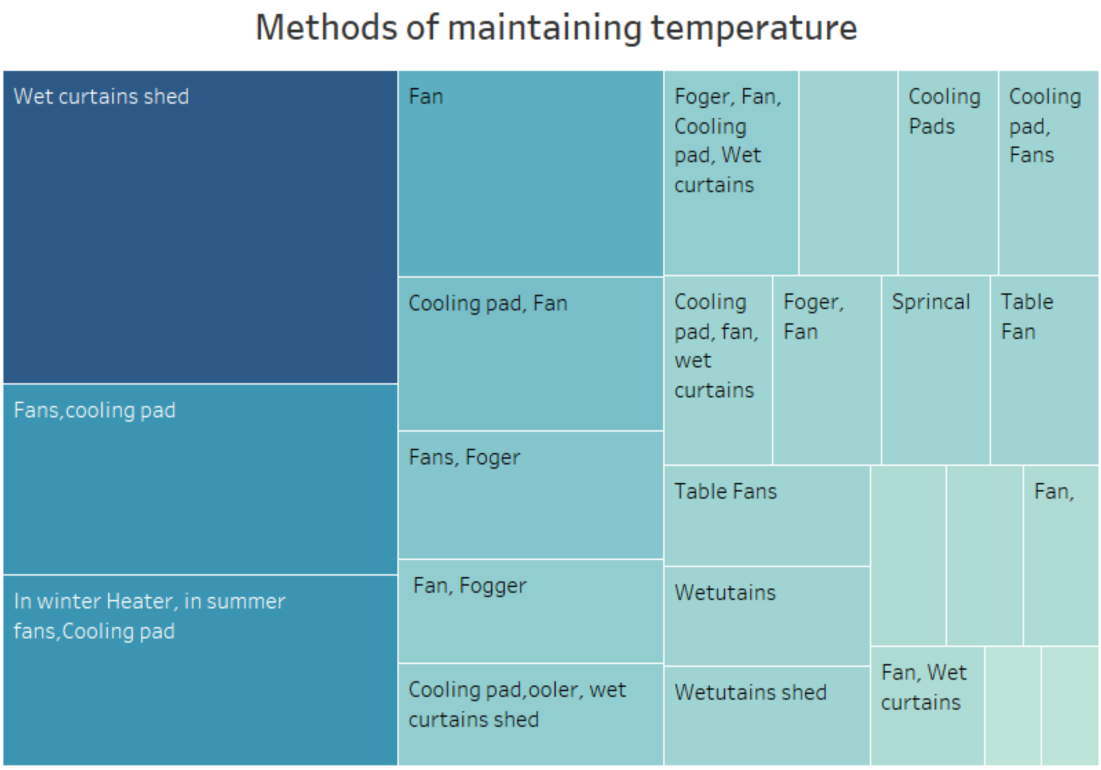


Fig.4.11: Types of feed in Poultry Farms

Thus, it is clear that poultry farmers in Punjab face numerous challenges which can be addressed by taking appropriate safety measures. The significance of adopting technological revolution in the domain of poultry farming becomes crucial owing to contribution of poultry farming towards economic growth of the state.

4.1.1 Analysis of Survey taken in Different Districts

With the view of this whole research, we are in concern to rectify the Poultry farming related issues in Punjab. As the literature reported that researchers around the globe are doing their well efforts but there is a very seldom study in the Punjab so in order to view this concern in the present study our center of attention is Punjab domicile. In the same state we have surveyed various farms in different districts. This table 4.3 describes the districts and the count of the farms covered in each district while collection of data. These areas include Hoshiarpur, Jalandhar, Ludhiana, Amritsar, Saheed Bhagat Singh Nagar, Kapurthala and Chandigarh. Figure 4.12 found that maximum collection of the data is from Hoshiarpur district followed by Kapurthala.

Table 4.3: Major Challenges faced by Poultry Farmers in Punjab

District	Count
Jalandhar	13
Hoshiarpur	35
Amritsar	14
Shaheed Bhagat Singh Nagar	19
Kapurthala	25
Ludhiana	4
Chandigarh	1

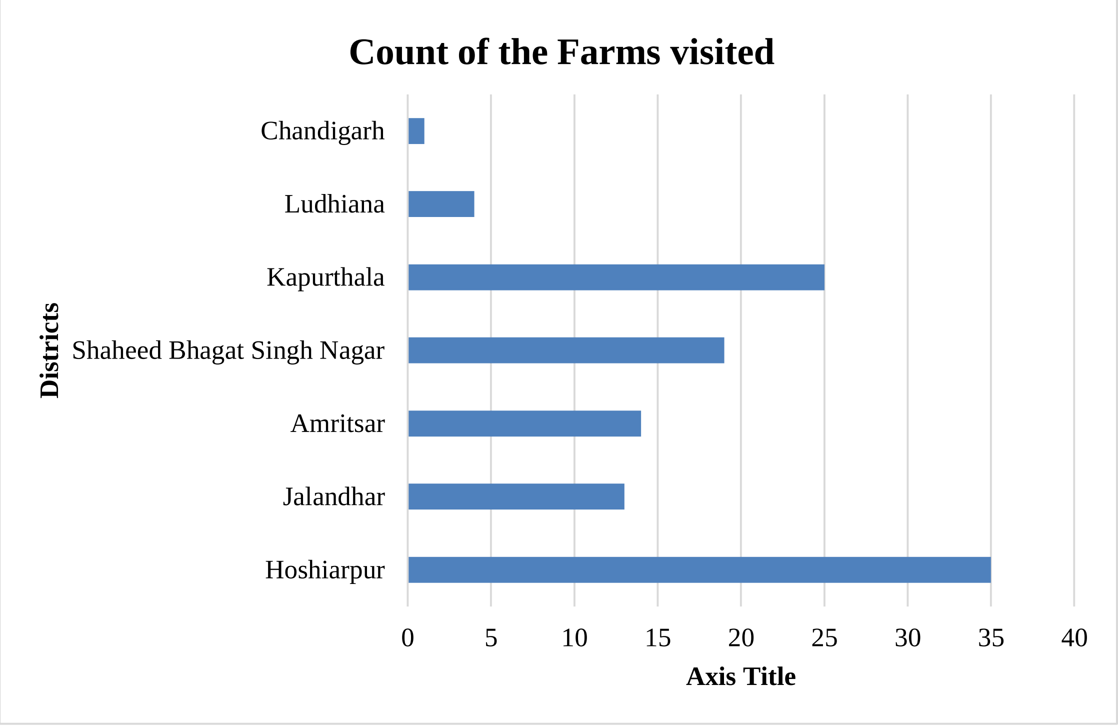


Fig.4.12 : Count of the Farms visited in various Districts

4.2 INTRODUCING AI SOLUTIONS FOR ENHANCING POULTRY PRODUCTION

After the analysis done from the above dataset it is observed that temperature and humidity variations heavily impact the poultry production. In order to enhance the poultry production N-BEATS architecture is developed. The N-BEATS (Neural Basis Expansion Analysis for Time Series Forecasting) architecture is a state-of-the-art framework in time series forecasting, with specific use cases that emphasize the assessment and forecasting of Early-Age Incidence (EAI) metrics. Due to the complex temporal connections and dynamic nature of the underlying processes, time series forecasting is a considerable challenge, particularly in the context of poultry data. Through the use of stacked, fully connected blocks that can be adjusted to various EAI forecasting scenarios, N-BEATS addresses this issue and improves predicted accuracy and robustness. The forecasting of EAI indicators, which include crucial elements like mortality rates, growth patterns, and disease outbreaks, temperature, humidity among others, is extremely important to the poultry business. The optimization of production techniques, resource distribution, and protecting the general health and welfare of the poultry population all depend on accurate forecasts in this area. By utilizing deep neural networks to recognize complex patterns and dependencies within time series data for the poultry industry, N-BEATS provides a strong foundation to meet these forecasting requirements This research delves into the N-BEATS architecture, specifically focusing on its application in forecasting poultry EAI data. The study involves a thorough examination of the various components that make up the N-BEATS architecture, such as the stacked FC-Blocks, considerations regarding width and horizon, and the ensemble learning capabilities. This exposition endeavours to offer a comprehensive understanding to stakeholders in the poultry industry, data scientists, and researchers regarding the utilization of N-BEATS as an advanced solution to improve the accuracy and dependability of EAI forecasts in the poultry sector. The subsequent section compares the performance of the N-BEATS architecture with that of other deep learning models namely LSTM, GRU, RNN, CNN, Bi-LSTM on various prediction steps in this experiment. N-BEATS is the best model among tested deep learning architectures for both a prediction step of one hour and eight hours, despite the fact that GRU outperforms LSTM based on results given below. Additionally, as the prediction step increases, the errors observed in all models also increase, which is consistent with our intuition that the more uncertain about the future, the greater errors models are likely to make.

1. **Evaluation of Training and Validation Loss:** This evaluation demonstrates the visual depiction of learning process of how the accuracy improves for classification issues and the loss lowers with each epoch in these plots. A model is said to be learning the training set if its loss decreases, and it is said to be well-generalizing to new data if its loss decreases on the validation set. From the Fig.4.13, it can be easily concluded that LSTM, GRU and CNN are underfitting as their training and validation losses remain at high levels where as Simple RNN shows overfitting as its training loss keeps on decreasing whereas its validation loss keeps on increasing. Looking at the Fig. 4.13, it can be safely concluded that N-beats generalizes well with the data.

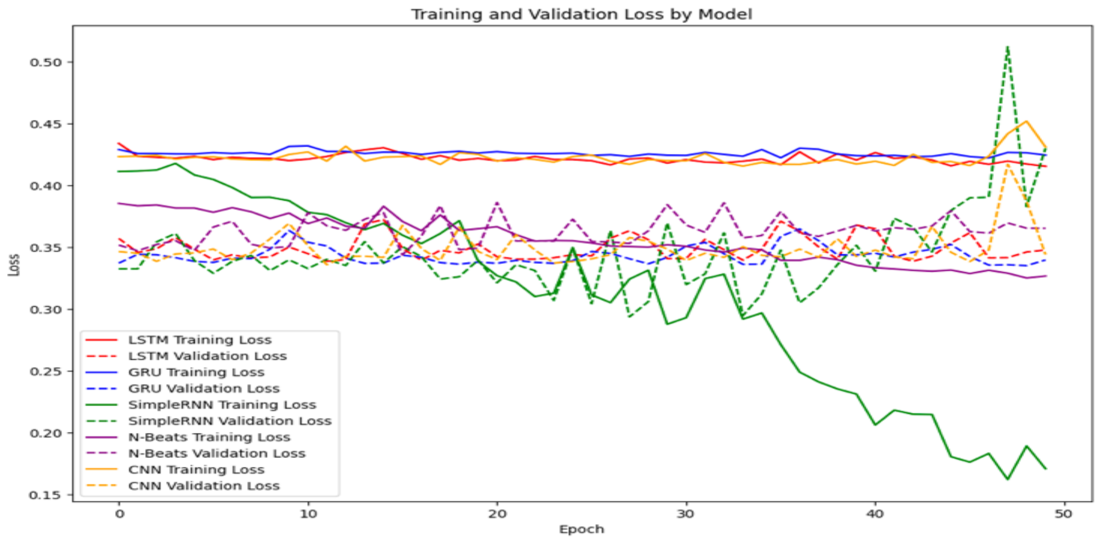


Fig. 4.13. Visualization of Training and Validation Loss of various Deep Learning Models

2. **Evaluation of Forecasting on Training and Testing Data:** In order to evaluate the performance of deep learning models on the multi-variate dataset, it is essential to take into account both test and training performance when assessing the models. When a model fits training data well but does not

perform well on test data, it can be overfitting, meaning it has picked up noise instead of the underlying pattern. In contrast, a model that exhibits middling performance on both training and test data may be underfitting or overly basic in order to fail to capture the complexity of the data. For our poultry dataset, the disease outbreaks in the poultry dataset are probably complex, non-linear effects of the input variables. There may be threshold effects for temperature and humidity, whereby extreme values markedly raise the risk of illness. A more direct linear association between the feed variable and disease rates resulting from malnutrition may exist, with lower feed levels being associated with greater disease rates. The graph in Fig. 4.14 implies that all the models were able to capture some patterns in the data. However, the variations in generalization are indicated by the variability in test predictions.

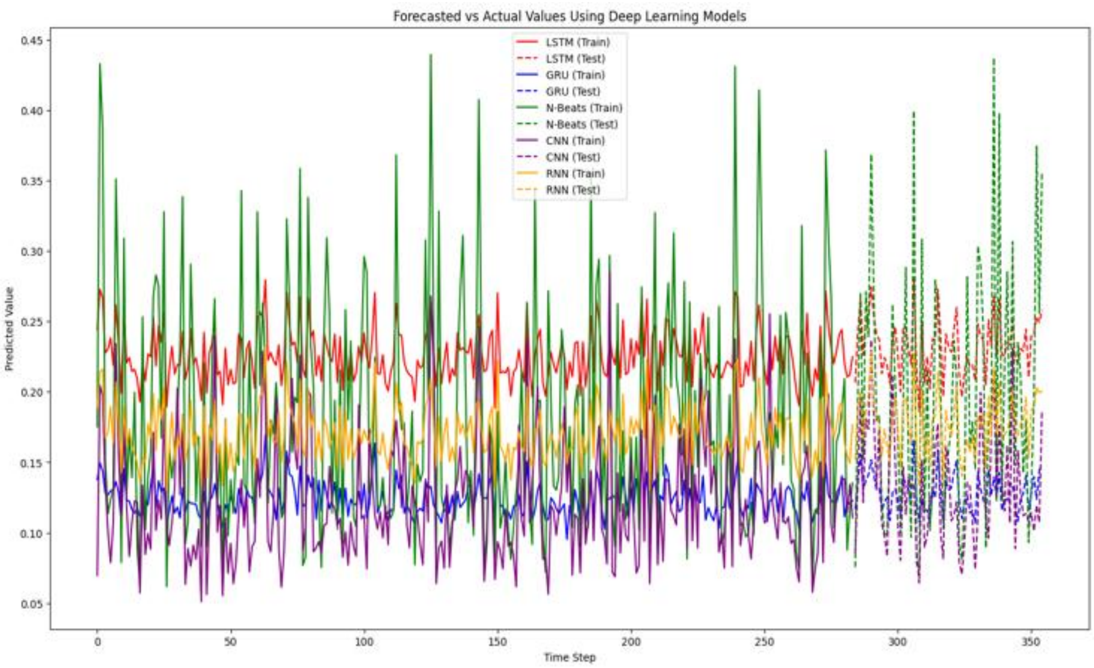


Fig. 4.14: Visualization of Forecasting Accuracy of the employed Models on the Multivariate Poultry dataset

N-BEATs model represented by green colour demonstrates good fit and generalization without overfitting indicating test and training predictions that are well matched with each other and with the real data. The result of the N-beats individually is being depicted in the Fig. 4.15, demonstrating the well analysis of the patterns.

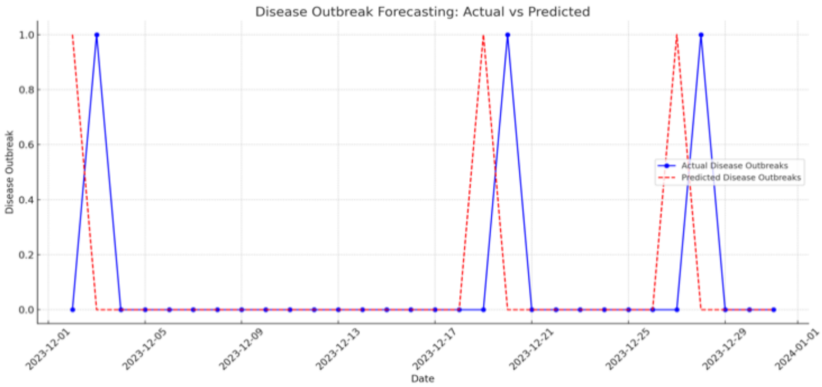


Fig. 4.15. Visualization of N-Beats Model with the Ground Truth Data

3. **Analysis of Performance Metrics of various Models:** Various performance metrics are analyzed in order to understand the applicability of the models on the dataset. The metrics utilized are mean absolute error (MAE), root mean squared error (RMSE), Mean Squared Logarithmic Error (MSLE), the coefficient of determination (R-squared), Root Mean Squared Logarithmic Error (RMSLE). MAE calculates the average magnitude of mistakes in a series of predictions without taking direction into account. It is the average of each forecast error's absolute value. RMSE is the square root of the average squared discrepancies between the actual observation and the prediction. Larger errors are assigned a higher weight. The ratio between the true and anticipated values is measured by the MSLE (. More so than overestimating, MSLE will penalize underestimating R-Squared measures how well the model replicates observed outcomes based on the percentage of total outcomes variance that the model explains. RMSLE, favours underestimates over overestimates in terms of penalty. The results of various models are given in table 4.4.

Tables 4.4. Analysis of various Performance Metrics

Model	MAE	RMSE	MSLE	R-Squared	RMSLE
LSTM	0.285	0.313	0.062	-0.209	0.250
GRU	0.201	0.310	0.045	-0.011	0.213
CNN	0.203	0.310	0.046	-0.229	0.248
N-Beats	0.176	0.296	0.034	0.046	0.211
RNN	0.260	0.311	0.052	-0.023	0.228

4. **Visual Discussion of the Results of Deep Learning Models for Multivariate Dataset:** A visual description of the results provided in table 4.4 is provided in Fig. 4.16. LSTM has shown moderate errors. However, the R-squared value of the LSTM model is negative, which means that the LSTM may be performing worse than a horizontal line at the mean of the actual values and hence it can be easily seen that model is not effectively capturing the variation of the dataset. Further, looking at the performance of GRU, it is seen that the GRU model outperforms the LSTM, indicating improved error and prediction ratio management. But the R-squared value is still negative, though, suggesting that there might be a problem with how well the model fits the data. The performance of CNN model is almost similar to LSTM. N-beats is the best-performing model among the employed models as it has the positive R-squared and the lowest errors across all metrics. It appears to be the best at capturing the patterns in the dataset without overfitting to noise or outliers. The performance of RNN is also not preferable as it has negative R-squared value and higher value of other performance metrics.

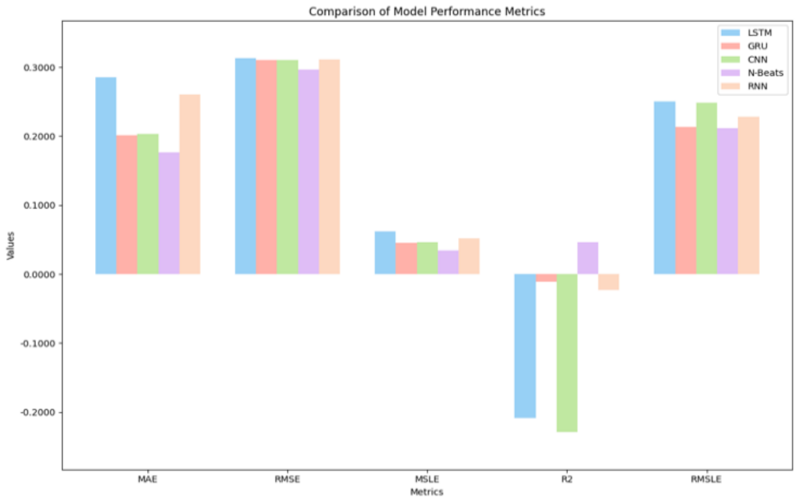


Fig. 4.16. Visualization of Performance Metrics of the employed Models on the Multivariate Poultry dataset

To conclude,this section focuses on the applicability of various deep learning models for capturing the patterns in multi-variate poultry dataset. The dataset consists of three independent variables and the predictor variable i.e. disease incidence is modelled on the basis of independent variables. After the pre-processing step which includes removing of nose, smoothening of data, and filtration, various models are employed. Based on the results achieved, the N-Beats model is clearly the most applicable for this specific forecasting task. The lesser value of error metrics of the N-Beats model indicates that it is less susceptible to noise and possible outliers, making it more effective at capturing the trend and volatility in the data. This can be easily attributed to its architecture, which is made to efficiently handle a range of data patterns. For all other models, the negative R-squared values raise a concern as it suggests that that none of the models fits the data well indicating that the models are underfitting. Further, with the exception of N-Beats, all of the models' RMSE values indicates that none of them performs noticeably worse or better at managing huge errors, which are highly penalised in RMSE and this metric also proves the competency of N-beats for the dataset**.**

4.3 IMAGE PROCESSING FOR PREDICTING POULTRY DISEASE ABNORMALITIES

Every year, a significant number of birds suffer from various poultry diseases, causing substantial losses for poultry farmers. In order to predict the poultry Diseases three custom CNN models were implemented over the fecal dataset taken from Kaggle. The dataset consisted of the 4 classes representing the three main diseases i.e. Coccidiosis, Salmonella, Newcastle as three classes and the fourth class is the Healthy class. As discussed earlier, the dataset contains 6812 fecal images. The tabular representation of dataset is shown in Table 4.5.

Table 4.5: Dataset Class Distribution

Class	Image in each class
Coccidiosis	2103
Healthy	2057
Salmonella	2276
New Castle Disease	376
Total Images	6812

4.3.1 Data Preprocessing

Data preprocessing improves model generalization, attain a balanced class distribution, and handle issues arising from the limited images available in one class. The primary technique used is picture augmentation, which uses a variety of transformations—such as rotation, cropping, flipping, brightness, contrast, etc.—to produce new training images from preexisting ones. Three iterations investigating various combinations of augmentation approaches are conducted and evaluated on the SoloConvLayer model in order to verify the efficacy of the preprocessing pipeline which is discussed below

4.3.2 SoloConvLayer Model

The SoloConvLayer model proposed in our research is already discussed in the previous chapter and the following sections discuss the results of the various preprocessing steps and the three iterations performed on the dataset in detail.

4.3.3. First Iteration

The dataset was divided into 3 sets, Training (80%), Validation (10%), and Test (10%). There were 376 images of NCD in Training dataset, that caused class imbalancing in the training dataset. To overcome this problem, we implemented targeted image augmentation techniques during the training set preprocessing. Specifically, we applied horizontal and vertical flipping, random shifts, and noise to augment the dataset. After augmentation, the number of files in NCD increased from 300 to 1200 images, ensuring class balancing in training dataset. The data distribution is shown in Table 4.6.

Table 4.6: Dataset Distribution in First Iteration

Class	Image in eachclass	Training	Validation	Testing	Training after augmentation
Healthy	2057	1645	206	206	1645
Coccidiosis	2103	1682	210	211	1682
Salmonella	2276	1820	228	228	1820
New Castle	376	300	38	38	1200

After using this dataset in training of our proposed model i.e. SoloConvLayer model, some results were observed that are as follows:-

- Overfitting observed between training and validation datasets that suggests the model is learning training data too well, potentially including noise or outliers that may not generalize to unseen data.
- Achieved highest training accuracy of 97.21% at epoch 23.
- Highest validation accuracy reached was 92.82% at epoch 21.
- Lowest training loss observed was 7.06% at epoch 23.
- Lowest validation loss recorded was 26.2% at epoch 7.

Figure 4.17 shows the history graph that was obtained while training the model that showsthe loss and accuracy graphs.

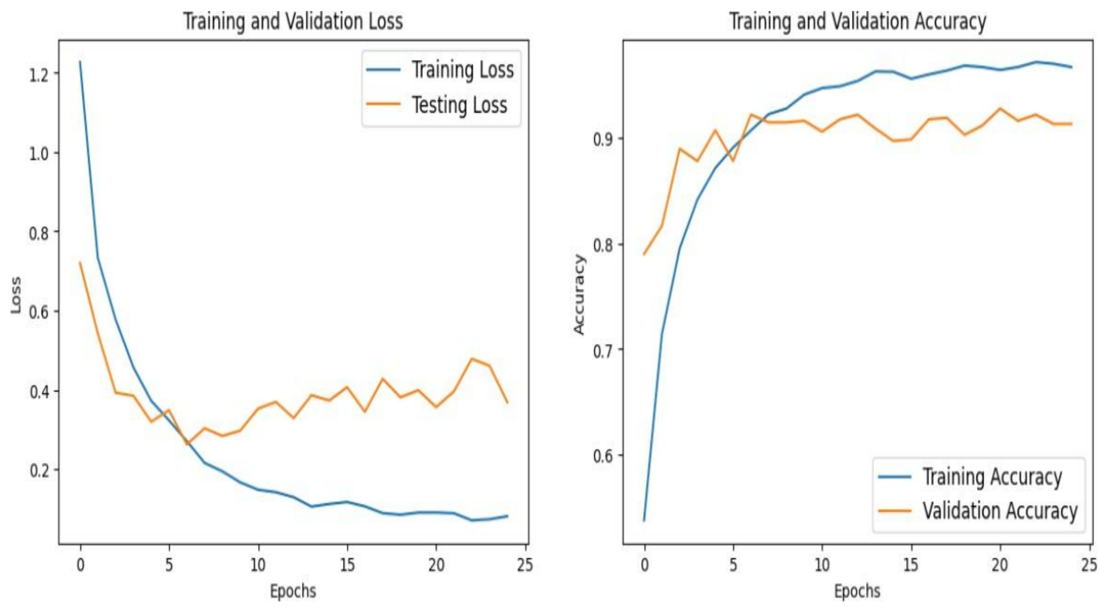


Figure 4.17: Training plot for SoloConvLayer model in first iteration

The classification report in Table 4.7 shows the overall accuracy of model is 92%. From the report we can see the precision score for NCD is low due to class imbalancing, so in future iterations we will undergo the process of class balancing to obtain better accuracy.

Table 4.7: Classification report of SoloConvLayer model in first iteration

	Precision	Recall	F1-score	Support
Healthy	0.93	0.91	0.92	228
Coccidiosis	0.99	0.95	0.97	210
Salmonella	0.91	0.91	0.91	206
New Castle	0.60	0.82	0.69	38
Accuracy	0.92			
F1 Score	0.87			

4.3.4 Second Iteration

In second iteration, the main focus was on class balancing in NCD of original dataset. So, to achieve this some image augmentation techniques were applied like horizontal and vertical flipping, random shifts, noise, and zoom. This targeted augmentation increased the original NCD images from 376 to 2256 images, that resulted in class balancing. Then the dataset was divided into 3 sets, Training (80%), Validation (10%), and Test (10%) which were further used in training of the model. The data distributionis shown in Table 4.8.

Table 4.8: Dataset distribution in second iteration

Class	Original Dataset	Dataset after augmentation	Training	Validation	Testing
Healthy	2057	2057	1645	206	206
Coccidiosis	2103	2103	1682	210	211
Salmonella	2276	2276	1820	228	228
New Castle	376	2256	1804	226	226

After using this dataset in training of our proposed model i.e. SoloConvLayer model,some results were observed that are as follows:-

- No overfitting was observed between training and validation datasets,suggesting good generalization to unseen data.
- Achieved highest training accuracy of 91.43% at epoch 25.
- Highest validation accuracy reached was 94.83% at epoch 15.
- Lowest training loss observed was 20.46% at epoch 25.
- Lowest validation loss recorded was 20% at epoch 16.

Figure 4.18 shows the history graph that was obtained while training the model that showsthe loss and accuracy graphs.

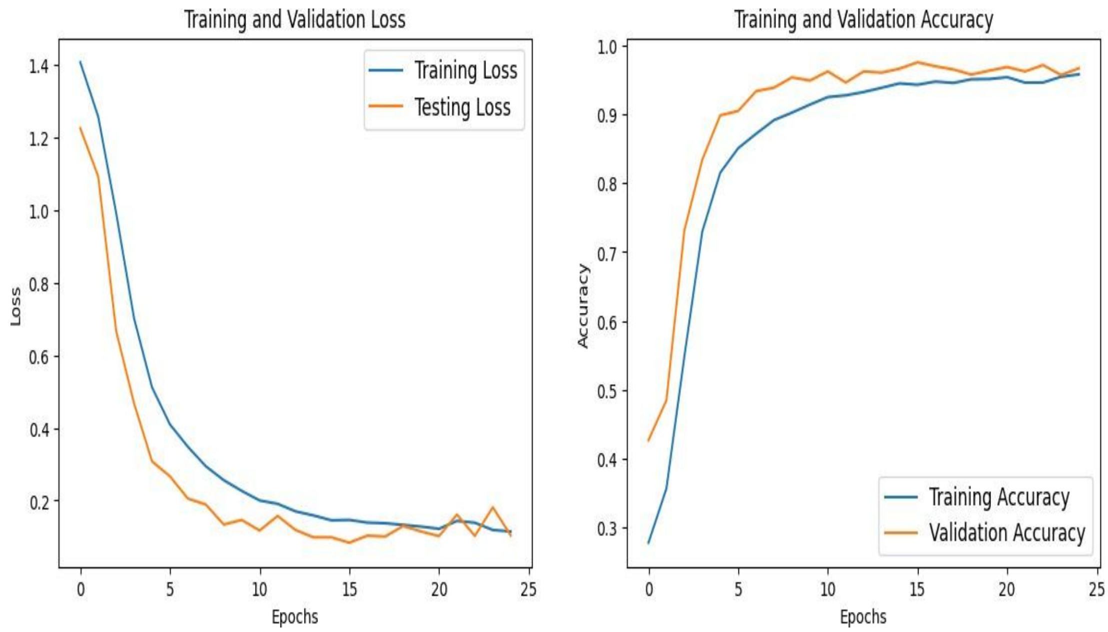


Figure 4.18: Training plot for SoloConvLayer model in second iteration

The classification report in Table 4.9 shows the overall accuracy of model is 94%. From the report we can see that all classes are showing good accuracy with dataset having 8692images. So in future iterations we will increase the size of dataset to help the model withgeneralization.

Table 4.9: Classification report of SoloConvLayer model in second iteration

	Precision	Recall	F1-score	Support
Healthy	0.91	0.93	0.92	228
Coccidiosis	0.96	0.96	0.96	210
Salmonella	0.92	0.92	0.92	206
New Castle	0.95	0.93	0.94	226
Accuracy	0.94			
F1 Score	0.94			

4.3.5 Third Iteration

In third iteration, the aim is to increase the size of the dataset with the help of image augmentation. So, at first targeted augmentation was applied in NCD class for class balancing. The images increased from 376 to 2256 in NCD. To increase the size of dataset again we used image augmentation and applied techniques like noise to all the classes to double the images [12]. Then the dataset was divided into 3 sets, Training (80%), Validation (10%), and Test (10%) which were further used in training of the model. The data distribution is shown in Table 4.10.

Table 4.10: Dataset distribution in third iteration

Class	Original Dataset	Dataset after class balancing	Dataset after increasing size	Training	Validation	Testing
Healthy	2057	2057	4114	3291	411	412
Coccidiosis	2103	2103	4206	3364	421	421
Salmonella	2276	2276	4552	3641	455	456
New Castle	376	2256	4512	3607	451	452

After using this dataset in training of our proposed model i.e. SoloConvLayer model,some results were observed that are as follows:-

4.3.6 No overfitting was observed between training and validation datasets, suggesting good generalization to unseen data.

4.3.7 Achieved highest training accuracy of 95.84% at epoch 25.

4.3.8 Highest validation accuracy reached was 97.58% at epoch 16.

4.3.9 Lowest training loss observed was 11.46% at epoch 25.

4.3.10 Lowest validation loss recorded was 8.36% at epoch 16.

Figure 4.19 shows the history graph that was obtained while training the model that showsthe loss and accuracy graphs.

Figure 4.19: Training plot for SoloConvLayer model in third iteration

The classification report in Table 4.11 shows the overall accuracy of model is 97% that is the best accuracy attained out of all three iterations. From the report we can see that all classes are showing very good accuracy with dataset having 17384 images. So, we conclude that this iteration where class balancing and increase in size of dataset was done, gives best accuracy. In future we will be using this dataset for training all other model.

Table 4.11: Classification report of SoloConvLayer model in third iteration

	Precision	Recall	F1-score	Support
Healthy	0.98	0.97	0.97	455
Coccidiosis	0.99	0.97	0.98	421
Salmonella	0.94	1.00	0.97	411
New Castle	0.96	0.94	0.95	451
Accuracy	0.97			
F1 Score	0.97			

So, the dataset obtained in third iteration is the best out of all other iterations as it gives the bestaccuracy among all others.

4.3.6 CNN Model Results

In this section, the results of all three custom made CNN models: SoloConvLayer Model, TriConvLayer Model, FiveConvLayer Model and predefined MobileNetV2 model along with its fine-tuning will be discussed.

4.3.7 SoloConvLayer Model Result

The results obtained are also mentioned in Figure 4.19 and Table 4.11, where this model achieved the accuracy of 97%.

4.3.8 TriConvLayer Model Result

In order to further improve the performance TriConvLayer Model is used which has three hidden layers..This model was compiled and trained using the training dataset. The accuracy obtained on evaluation of this model is 98%. The training graph can be shown in Figure 4.20. The classificationreport, showing the overall accuracy and accuracy for each class is also shown in Table 4.12.

Figure 4.20: Training plot of TriConvLayer model

Table 4.12: Classification report of TriConvLayer model

	Precision	**Recall**	**F1-score**	**Support**
Healthy	0.98	0.97	0.98	455
Coccidiosis	0.99	0.99	0.99	421
Salmonella	0.97	0.97	0.97	411
New Castle	0.96	0.98	0.97	451
Accuracy	0.98			
F1 Score	0.98			

4.3.9 FiveConvLayer Model Result

The FiveConvLayer is even more complex convolutional architecture. The accuracy obtained after training and compiling this model is 97%, which can be seen in Table 4.13. The training plot shown in Figure 4.21 shows the graph obtained while training the model.

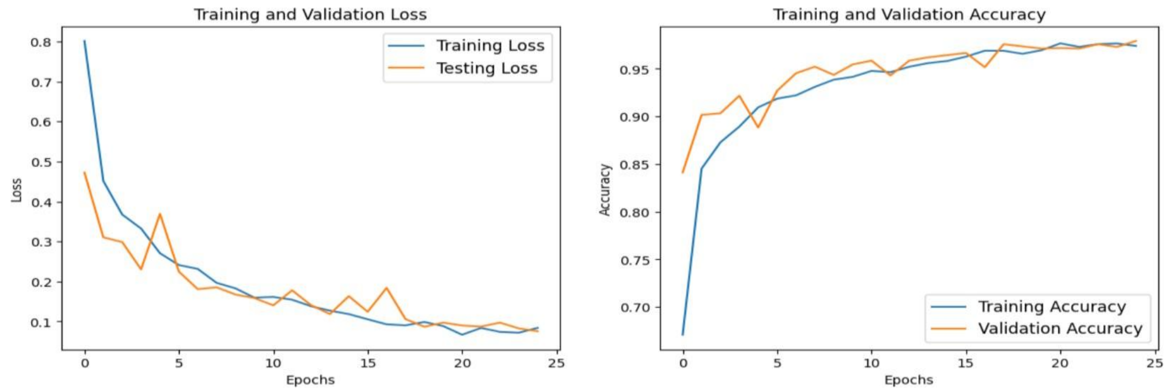


Figure 4.21: Training plot of FiveConvLayer model

Table 4.13: Classification report of FiveConvLayer Model

	Precision	Recall	F1-score	Support
Healthy	0.97	0.97	0.97	455
Coccidiosis	1.00	0.98	0.99	421
Salmonella	0.97	0.95	0.96	411
New Castle	0.95	0.99	0.97	451
Accuracy	0.97			
F1 Score	0.97			

4.3.10 MobileNetV2 Model Architecture and Result

The pre-trained model of MobileNetV2 was trained. Initially, transfer learning was applied, followed by fine-tuning where the last 100 layers were trainable, and the rest were frozen. Table4.14 summarizes the shared hyperparameters used during both transfer learning and fine-tuning.

Table 4.14: Hyperparameters used while training MobileNetV2 model

Parameter	Value
Input size	128*128
Optimizer	Adam
Learning rate	0.001

The performance of the MobileNetV2 model was evaluated on training and validation dataset. The history training graph is shown in Figure 4.22. The model attained the accuracyof 97%, that can be shown in classification report in Table 4.15.

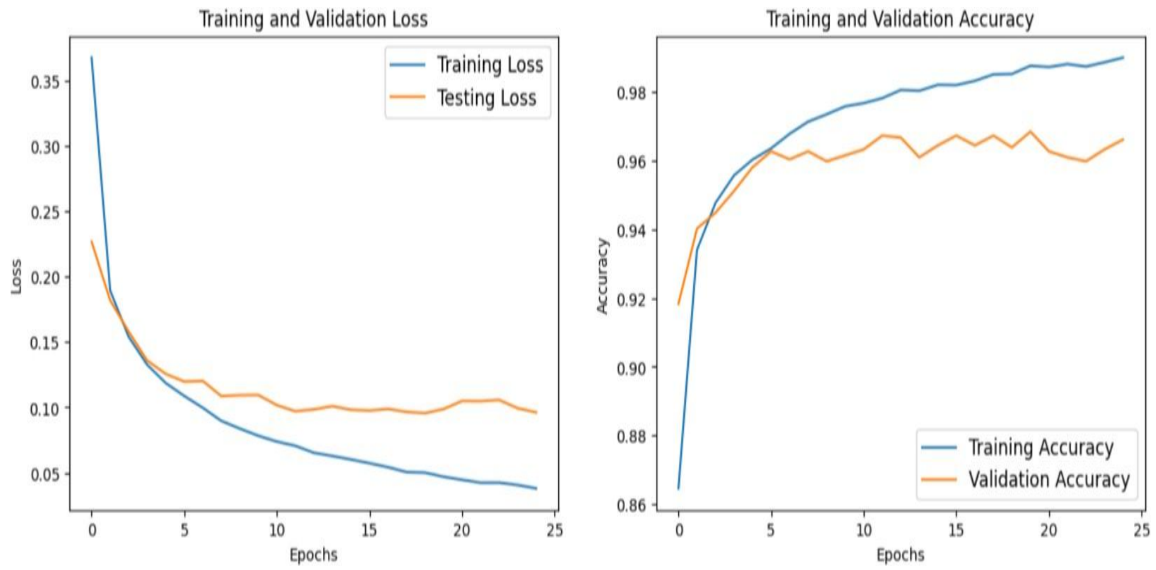


Figure 4.22: Training plot for MobileNetV2

Table 4.15: Classification report of MobileNetV2

	Precision	Recall	F1-score	Support
Healthy	0.97	0.96	0.96	455
Coccidiosis	0.99	0.97	0.98	421
Salmonella	0.95	0.96	0.96	411
New Castle	0.96	0.98	0.97	451
Accuracy	0.97			
F1 Score	0.97			

In pre-trained MobileNetV2 model [18], some layers were frozen as described above in fine-tuning steps. So, after fine-tuning model attained the accuracy of 98% which can be shown in classification report in Table 4.16. The training plot is shown in Figure 4.23.

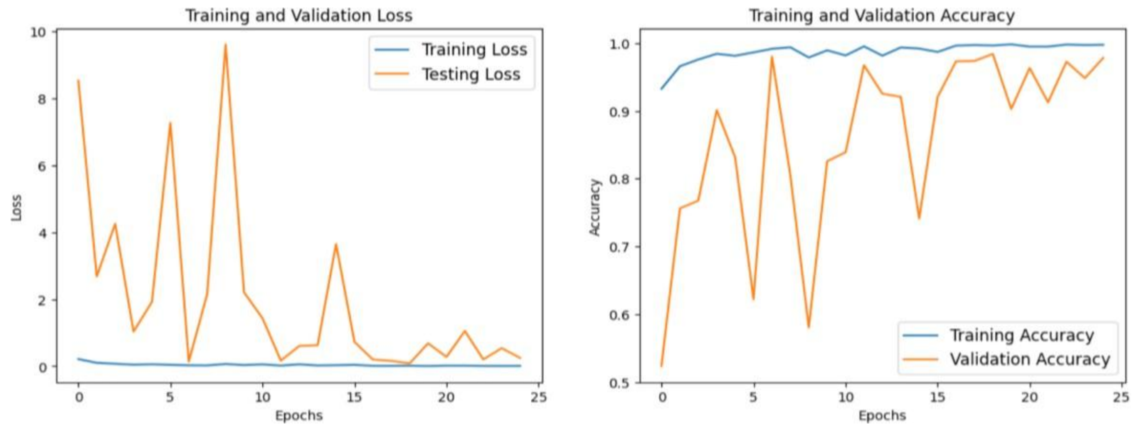


Figure 4.23: Training plot for MobileNet after Fine-tuning

Table 4.16: Classification report of MobileNetV2 after fine-tuning

	Precision	Recall	F1-score	Support
Healthy	0.98	0.98	0.98	455
Coccidiosis	1.00	1.00	1.00	421
Salmonella	0.94	1.00	0.97	411
New Castle	1.00	0.95	0.97	451
Accuracy	0.98			
F1 Score	0.98			

4.3.11 Discussion

The study starts with finding the best approach for data preprocessing, in which the third iteration where first class balancing was performed, then dataset size was increased, was selected. Then three custom made CNN models were trained: SoloConvLayer model, TriConvLayer model and FiveConvLayer model were trained and the accuracy obtained were97%, 98%, 98% respectively. The pre-trained model MobileNetV2 was also trained and it attained the accuracy of 97% and further it was fine-tuned and on evaluation the accuracy obtained was 98%. Based on the metrics used and accuracies obtained by all the models used in this study, the comparison is done in Table 4.17.

Table 4.17: Comparison of Models

	SoloConvLayer model	TriConvLayer model	FiveConvLayer model	MobileNetV2 model	MobileNetV2 model (FT)
Accuracy	97%	98%	98%	97%	98%
F1-Score	0.97	0.98	0.98	0.97	0.98
Size (mb)	24.10	4.82	0.66	9.15	23.46
Input shape	128x128	224x224	224x224	128x128	128x128
Coccidiosis accuracy	97%	99%	98%	97%	100%
Salmonella accuracy	100%	97%	95%	96%	100%
Newcastle accuracy	94%	98%	99%	98%	95%
Healthy Accuracy	97%	97%	97%	96%	98%

From Table 4.17 it is clear that MobileNetV2 after fine tuning is giving best overall accuracyas well as good accuracy in all other classes as well. But the only drawback is it is larger in size, so while integrating this model in mobile application, it will take a lot of time to load and make the whole process slower. It takes input size of 128X128 which may also cause problem in mobile application because picture quality will decrease. So rather than that we have selected our proposed model TriConvLayer as its accuracy is also outstanding and the size of the model is very small, making it compatible with out mobile application.

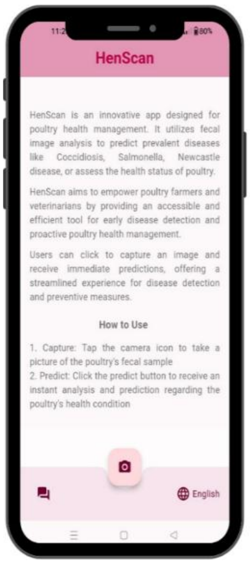
So, based on the matrices the TriConvLayer model is selected with accuracy of 98%.

4.3.12 Mobile Application

Poultry diseases pose a serious threat to the poultry industry, affecting the well-being and productivity of the birds. Early detection and diagnosis of poultry diseases are vitalfor preventing epidemics and minimizing losses. However, many poultry farmers lack the access and expertise to perform accurate and prompt disease detection. To solve this problem, we have developed HenScan, an android mobile application that uses deep learning to detect poultry diseases from fecal samples. HenScan provides a handy and trustworthy tool for poultry farmers and researchers to check the health of their flocks and take appropriate actions. A brief overview of working of mobile application is given below:

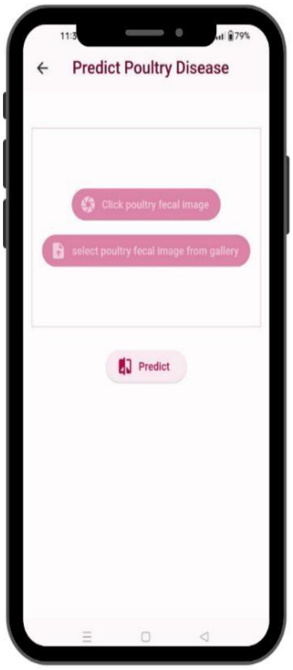
1. Splash Screen:

On opening the HenScan app, users are greeted with a brief splash screen that lasts for a few milliseconds, creating a visually engaging introduction.



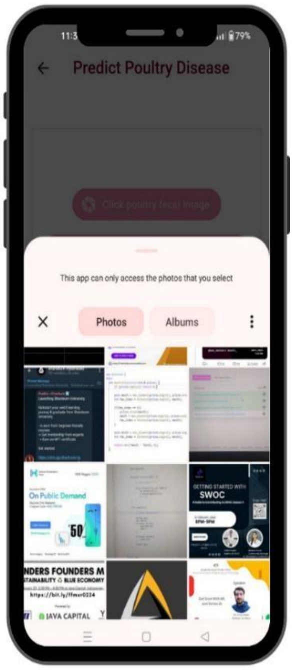
2. Home Page: After the splash screen, users land on the home page. Here, they can select their preferred language from the available options: Hindi, English, or Punjabi. The home page provides a concise overview of the application's purpose.

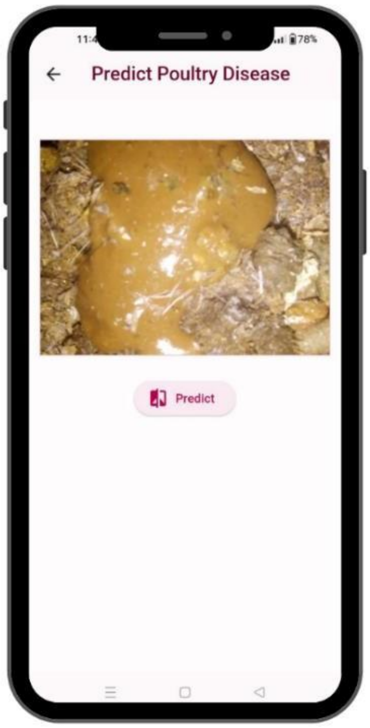
Bottom Navigation Bar: The main screen has a navigation bar at the bottom, which contains a camera icon that directs users to the poultry fecal image capture function. The navigation bar also has language options for user convenience.



3. Image Capture:

By clicking the camera icon of home screen , users are navigated to another screen dedicated to capturing fecal images for prediction. Here, they have two options: Upload from Gallery: Users can select a pre-clicked image from their phone's gallery. Instant Image Capture: Users can utilize their phone's camera to capture an instant image.





4. Prediction Process:

After selecting or capturing an image, users proceed to the next step by pressing the "Predict" button. This action activates the application's machine learning model, which thoroughly analyzes the image to identify potential diseases.

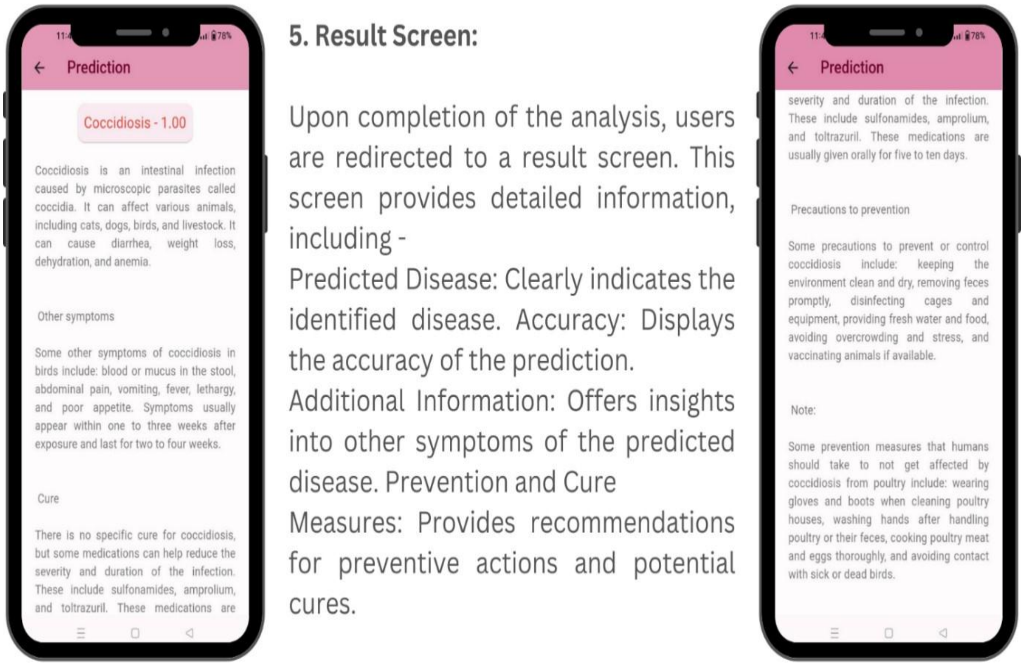


Figure 4.24: Working of mobile application

The above images shows the step by step user manual of Mobile application “HenScan”. These steps must be followed to access the application.

4.4 SUMMARY

In this chapter we have discussed about the various inferences that we found from the dataset. To achieve the observations, we have divided the data set into trained dataset and tested dataset. In the training set, 70% of the data is chosen for usage while the remaining 30% is utilized as a test dataset. To achieve first objective, collection of data of 111 farmers was done. The analysis of these effected parameters has been discussed. After the analysis, time series data is utilized to construct a deep learning model called N-BEATS architecture, which can be used to forecast chicken diseases. Furthermore, the study makes use of the fecal dataset, which is utilized to train and test different deep learning models. The outcomes of these tests are compared, and the optimal model is employed to forecast the likelihood that chicken birds would contract a particular disease. Ultimately, the "HenScan" mobile application makes use of the best suited model named TriConvLayer Model.

Chapter – 5

CONCLUSION AND FUTURE SCOPE

This chapter includes the summary of the work accomplished in the thesis and the future perspective of the work. The first objective of this work was to survey the farmers of Punjab from different districts. Herein, 111 farmers were surveyed from different districts of Punjab. A deep analysis of the survey made us draw several inferences and among the various issues identified, the major challenges which were being faced by the farm owners were maintenance of the temperature and humidity in the farms and the requirement of the labor to perform day to day tasks and diagnose disease prone chickens in the poultry farms. Maintaining the accurate weather conditions in the farms is essential for increasing the productivity of the farms and reducing the death rate of the farm animals. For this, the farm workers need to be aware about the optimal weather conditions and require to maintain it on daily basis which is a challenging task. Another issue being faced is the failure to identify the infected birds or the birds suspected of some disease as it requires skilled workers and continuous vigilance from them.Otherwise this again can lead to the spread of the disease among the entire farm animals if the suspect is not isolated on time and treated.

To address these critical issues, the present study focuses on the applicability of various deep learning models for capturing the patterns in multi-variate poultry dataset. The dataset consists of three independent variables and the predictor variable i.e. disease incidence is modelled on the basis of independent variables. After the pre-processing step which includes removing of nose, smoothening of data, and filtration, various models are employed. Based on the results achieved, the N-Beats model is clearly the most applicable for this specific forecasting task. The lesser value of error metrics of the N-Beats model indicates that it is less susceptible to noise and possible outliers, making it more effective at capturing the trend and volatility in the data. This can be easily attributed to its architecture, which is made to efficiently handle a range of data patterns. For all other models, the negative R-squared values raise a concern as it suggests that that none of the models fits the data well indicating that the models are underfitting. Further, with the exception of N-Beats, all of the models' RMSE values indicates that none of them performs noticeably worse or better at managing huge errors, which are highly penalised in RMSE and this metric also proves the competency of N-beats for the dataset. The future scope of the proposed work includes exploring various strategies for handling negative R-squared values which include feature engineering, hyperparameter tuning, or a detailed data pre-processing steps.

Additionally, the study also presents a comprehensive methodology for poultry disease detection, culminating in the development of an innovative mobile application named "HenScan" for on the-go disease detection [1]. Through meticulous data preprocessing, including data acquisition, splitting, class balancing, and augmentation, a robust final dataset was constructed, laying the foundation for accurate disease detection models. The core of the study involved the training and evaluation of various convolutional neural network (CNN) models, including custom-made models like SoloConvlayer, TriConvLayer and FiveConvLayer model, as well as a pre-trained MobileNetV2 model. These models exhibited impressive accuracies, with the TriConvLayer model emerging as the top performer with an accuracy of 98%. While MobileNetV2 showed promising results after fine-tuning, its larger size and input size constraints rendered it less suitable for integration into the mobile application. Through thorough analysis and comparison, the TriConvLayer model was selected for integration into the "HenScan" mobile application due to its outstanding accuracy, compact size, and compatibility with mobile devices. By leveraging this model, poultry farmers can effectively detect and manage disease outbreaks, leading to improved disease management and ultimately contributing to the welfare of poultry populations worldwide. Overall, this study highlights the significant advancements in poultry disease detection methodologies enabled by deep learning techniques and mobile technology integration. The findings offer practical solutions for poultry farmers to combat disease outbreaks efficiently, ultimately benefiting the poultry industry and enhancing the welfare of poultry populations globally. Further research and development in this area hold promise for continued improvements in disease management and overall poultry health.

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