IoT BASED DISEASE PREDICTION AND RECOMMENDATION SYSTEM FOR APPLE ORCHARDS IN HIMACHAL PRADESH

Thesis Submitted for the Award of the Degree of

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in

Computer Applications

By

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DECLARATION

I, hereby declared that the presented work in the thesis entitled **“IoT Based Diseases Prediction and Recommendation System for Apple Orchards of Himachal Pradesh”** in fulfilment of degree of **Doctor of Philosophy (Ph. D.)** is outcome of research work carried out by me under the supervision of **Dr. Anil Sharma**, working as Professor, in the **School of Computer Applications** of Lovely Professional University, Punjab, India. 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 **“IoT Based Diseases Prediction and Recommendation System for Apple Orchards of Himachal Pradesh”** submitted in fulfillment of the requirement for the award of degree of **Doctor of Philosophy (Ph.D.)** in the **School of Computer Applications**, is a research work carried out by **Karuna Sheel**, **41800846**, is bonafide record of 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

Agriculture remains one of the most vital sectors in India, both in terms of employment and economic contribution. The vast majority of India's population is dependent on agriculture, making it an essential segment of the country's GDP. With a rich variety of soils and climates, India produces an extensive range of fruits, among which apples are significant export products, especially from regions like Shimla. The integration of IoT in agriculture is revolutionizing traditional farming practices. By adopting a real-time framework for detecting factors that might lead to apple diseases, the yield and quality of apple production can be improved.

The work presents an Internet of Things (IoT) framework that is used to detect disease-causing environmental factors (DCEF) like temperature, humidity, light, rain, etc. for Apple Orchards. Moreover, this paper presented a real-time framework that is quite efficient in for identification of the factors that cause apple diseases. The real-time system design architecture is divided into three layers: the first is physical layer, the data transmission layer, and the application layer. The physical layer is deployed with sensors for identification of DCEF, then collected data is transmitted to the cloud server through the transmission layer and finally at the application layer automated monitoring is integrated with mobile application and for further analysis.

The methodology encompasses data collection from environmental variables like temperature, humidity, pressure, and light. Using the Mamdani fuzzy inference system (MFIS), the collected data is then employed to predict potential apple diseases. Initial tests conducted in an apple orchard in Shimla, India, demonstrated the system's effectiveness and efficiency, with minimal delays during various phases of the process. The research also provides a comparison with existing techniques used for disease detection.

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LIST OF ABBREVIATIONS

IoT	Internet of Things
WSNs	Wireless Sensor Networks
CAGR	Compound Annual Growth Rate
UAVs	Unmanned Aerial Vehicles
RFID	Radio Frequency Identification
GPS	Global Positioning System
FY	Fiscal Year
DCEF	Disease-Causing Environmental Factors
IoT	Internet of Things
NodeMCU	Node Microcontroller Unit
IC	Integrated Circuit
SoC	System-on-a-Chip
MFIS	Mamdani Fuzzy Inference System
RB	Rule Base
DB	Database

CHAPTER 1

Introduction

Overview

The Internet of Things (IoT) is revolutionizing various industries, including advanced agriculture, intelligent homes, wearable technology, progressive urban environments, digitally connected rural areas, health monitoring systems, vehicular communication, and drone integration. IoT enables data exchange and joint decision-making among everyday objects by facilitating seamless interconnection and interaction between devices. This transformation is driven by communication systems, internet protocols, and networks of sensors that turn traditional items into smart assets. As IoT continues to evolve, its applications are reshaping industries, with sectors like smart agriculture projected to experience significant growth, enhancing efficiency and sustainability worldwide.

Applications and Impact of IoT Across Various Sectors

The Internet of Things (IoT) application spans diverse sectors including advanced agriculture, intelligent homes, wearable tech, progressive urban settings, digitally connected rural environments, health monitoring systems, vehicular communication, drone integration, and more. Essentially, IoT facilitates the interconnection, interaction, and joint decision-making among tangible objects by exchanging data. By leveraging communication systems, internet procedures, applications, and networks of sensors, everyday items are revolutionized into smart assets. A notable trend is the growth of the smart agriculture sector, with projections estimating its worth to soar from \$5 billion in 2016 to a whopping \$18.0 billion by 2024[1].

Adoption of Smart Agriculture in Export-Driven Countriesand the Challenges of IoT Integration

Countries that primarily export agricultural products are witnessing a surge in the incorporation of smart agriculture as a vital IoT application. This involves utilizing wireless sensor networks (WSNs) in diverse ways, such as irrigation management, predicting catastrophic incidents, specialized soil treatments, blind entity recognition, advanced farming techniques, and precision-oriented agriculture. Nonetheless, creating a sustainable agricultural model powered by IoT comes with its set of challenges. These encompass hardware considerations, especially the selection and range of IoT devices and the diverse sensors available, like those detecting temperature, proximity, pressure, water purity, chemicals, gases, and humidity [2].

Challenges and Technological Solutions in IoT-Driven Ad- vanced Farming

Moreover, the field of data analytics in IoT underscores the significance of predictive mechanisms and the infusion of machine learning to derive effective solutions for advanced farming. Maintenance, too, is a hurdle as IoT gadgets are susceptible to damage in rugged farming terrains. Ensuring stable connections across expansive agricultural landscapes is a challenge due to the need to select appropriate wireless communication technologies. Options like “4G, 5G, Wi-Fi, 6LowPan, and LoRa” each have their advantages, but it's essential to choose the right one for specific farming needs. Lastly, developing a robust infrastructure demands innovative approaches, including the adoption of fog, edge, and cloud computing, along with network virtualization technologies[2].

Global Market Analysis of IoT in Agriculture: Components, Applications, and Regional Growth Trends

The international market for IoT in agriculture is classified based on its components, applications, and geographical regions. When looking at components, the market is broken down into software, systems, and services. The systems category is anticipated to dominate in terms of market size during the projected period, given that its costs often surpass those of software and services. Delving deeper into systems, we find subdivisions like sensing and monitoring mechanisms, fishery systems, intelligent greenhouse setups, animal monitoring, automation, and controls, among others. Notably, monitoring systems for livestock are forecasted to experience the steepest rise in the Compound Annual Growth Rate (CAGR), trailed by fishery and intelligent greenhouse systems. Sensing and monitoring platforms include tools like soil probes, water detection devices, climate monitoring, and yield trackers, among others. Fishery systems encompass GPS tech, various sensors, and more, while animal monitoring systems integrate RFID tech, control setups, GPS, and the like. Moreover, automation and control mechanisms can be further split into irrigation controllers, UAVs or drones, handheld tech devices, display systems, and so forth[3].

Focusing on applications, IoT's role in agriculture can be categorized into areas like animal surveillance, precision farming, indoor agriculture, aqua-farming, pest control, water management, and additional domains. Among these, precision farming is poised to hold the most significant market share in the coming years, largely due to its crucial role in overseeing soil conditions and plant health. This application also streamlines farm operations and amasses real-time insights, facilitating data-driven decision-making that maximizes both manpower and resources. Geographically, the market's scope spans North America, Europe, Asia-Pacific, the Middle East & Africa, and South America.

According to a report from Market Research Future that delves into the potential of IoT applications in the agriculture realm, the global market value for IoT in this sector is projected to surpass USD 34.88 Billion by 2025, growing at a

CAGR of 13.6%. This report also provides a visual representation of the market's trajectory from 2018 to 2025[3].

Figure 1.1: Global IOT market size in agriculture, 2018-2025

Global Significance, Cultivation, and Quality Attributes of Apples

The apple is a fruit of global importance, with production in 2014 surpassing 84 million tonnes. The contemporary apple, scientifically known as “Malus × domestica Borkh”, is believed to have originated from interspecific hybridization. This has resulted in the development of more than ten thousand cultivars, as recorded in the “European Apple Inventory”. The vast cultivar variety represents diverse quality traits. The term "fruit quality" evolves with changing consumer needs, which are shaped by sociocultural shifts. While consumers first judge apples by their appearance, eating quality ultimately influences repeat purchases. Notably, apples' high polyphenol content gives them noteworthy health benefits. Even though numerous apple varieties compete in the market, consistent repurchasing by consumers signifies true quality. It's crucial to note that environmental and agronomic factors throughout the growing season profoundly influence apple quality, including its health properties. Factors like temperature, light, orchard design, and irrigation can all affect the apple's external appearance, maturity, and chemical composition.

Apples thrive in various climates worldwide, including temperate, subtropical, and tropical zones. Their cultivation is primarily within the latitudinal range of 25° to 52°. They are cultivated in over 63 countries, each with diverse environmental conditions and apple varieties. In 2013, the average global consumption of apples was 9.2 kg per person. Ranking fourth in the world's fruit production, apples come after oranges, grapes, and bananas. China leads in apple production, contributing more than 48% of the global yield. The United States follows with 6.1%, then Poland (3.8%), India (2.9%), Turkey (2.9%), and Italy (2.9%).

The European Apple Collection boasts a staggering 10,000 apple cultivars. This vast diversity means there is a significant variation in their qualitative characteristics. For years, there's been a push in agriculture to enhance productivity to cater to the ever-growing food demand. As a result, numerous apple varieties have been developed to improve the fruit's attributes further[4].

The American/European dessert apples are known for their appealing shape, qualities, color, size, and balanced sweet-tart flavor. European pleasant apples offer improved texture and taste with predominantly one or two-toned skin. Asian dessert apples are notably sweet, have firm and juicy flesh, and minimal tartness, and are known for their long shelf-life. Lastly, the "Juicy Firm and Crisp (JFC) high-quality apples" are particularly esteemed for their texture and taste[4].

Nutritional Value, Quality Metrics, and Harvesting Impact on Apple Attributes

Apples are nutrient-rich, containing a significant amount of water, sugars, organic acids, vitamins, minerals, and dietary fibres. Notably, apples are a primary source of polyphenol antioxidants. The composition of these compounds can vary due to factors like environmental conditions, cultivation methods, maturity level, and storage duration[5]. In the realm of apple breeding, varieties with a lower allergic potential will likely be prioritized given the variation in allergenicity.

The idea of excellence is echoed by words like authenticity, typicality, and healthiness of the item. The term quality has multiple connotations. Quality, is "the aggregate of all features, traits, and aspects of an item or commodities that are intended to satisfy the specified or anticipated client needs”[6]. By dynamically synthesizing their physicochemical attributes and relating them to customer perceptions, Kyriacou and Rouphael have introduced a unique concept of fruit and vegetable freshness. Schuphan was the author of the first significant work on fruit freshness[7]. He wrote a book about the Caliber of the goods with an emphasis on the dangers of pesticide usage and nutritional considerations. Quality, according to Schuphan, is a collection of elements that includes outward features, technical attributes, inner traits, picture value, and sensory value. Based on where in the distribution network you are looking, assumptions apply. Fruit quality can be described in a variety of aspects, representing the biasness of the topic, including "extent of perfection," "extent of contentment of several circumstances that assess its acknowledgment by the customer," "fitness for a specific reason," or when the commodity satisfies the requirements for its particular usages. Fruit quality encompasses both visible and interior characteristics in general. Fruit's exterior integrity is determined by its color, form, size, and dearth of flaws, while its interior quality is determined by its flavour, consistency, fragrance, nutrient benefits, sweetness, tartness, storage stability, and flawlessness. Although the former might influence whether a user would buy the goods repeatedly, consumers first-rate a thing by its look before judging it for its eating qualities [4].

To ensure a good fruit grade for users, picking the right time to pick the fruits is crucial. Both early and late harvesting can have detrimental effects that lower fruit firmness [8]. The ultimate product's qualities may vary depending on the characteristics of the individual trees in an orchard. Particularly varied crop load amounts can have a significant impact on the flavor and maturation of the fruit. Zhang et al. have demonstrated variation in apples within the same tree [9]. In contrast to a relatively small tree, a big canopy offers a wide variety of quality attribute variations and increases variance [10]. Planting density has an impact on quality as well and is variety-based. The majority of factors affecting the freshness of the fruit can be quantified. Several fruit quality characteristics are typically identified using deleterious methods, but in the last ten years, the emergence of non-destructive approaches has expanded the prospects and possible outcomes for quality evaluation. This is because unique devices for estimating the quality of the fruit and maturity have been developed and made accessible to the fruit business sector and study segment.

IoT in Agriculture: Transforming Apple Disease Prediction and Prevention with Real-Time Monitoring

Integrating the Internet of Things (IoT) into agricultural research is transforming how we approach disease prediction systems, such as those for apple orchards. An IoT-based Apple disease prediction system leverages advanced sensors to monitor critical environmental factors, including temperature, humidity, light intensity, and altitude. These parameters directly influence the microclimate of an orchard, which in turn affects the likelihood of disease outbreaks. By continuously collecting real-time data, IoT sensors provide researchers and farmers with up-to-the-minute insights into the health and conditions of the orchard. This enables early detection of any potential triggers that may lead to disease development, such as an increase in humidity or a sharp drop in temperature, both of which can create an ideal environment for fungal growth or other pathogens.

IoT-based systems go beyond mere observation by enabling predictive analytics. The data collected from the sensors is processed through machine learning algorithms and disease models that can forecast the likelihood of an outbreak based on current and historical data. This proactive approach empowers farmers to implement preventive measures before visible symptoms emerge, significantly reducing crop losses and minimizing the use of chemical treatments. Additionally, the remote monitoring capabilities of IoT allow researchers and farmers to access real-time data from any location, enhancing decision-making without the need for physical presence in the orchard.

Furthermore, the scalability of IoT systems enables them to be deployed across multiple orchards or larger farming areas, providing a comprehensive view of environmental conditions and disease risks at a regional level. This holistic approach optimizes resource management and contributes to sustainable agricultural practices, making IoT an indispensable tool in modern agricultural research and disease prevention strategies.

National Impacts of Predominant Apple Diseases

In India, various apple cultivars are cultivated extensively Even though numerous modern apple strains display resilience to pests and diseases, the agricultural sector still encounters significant setbacks from these adverse elements. Both pre-harvest and post-harvest challenges mirror those faced by several major crops [11]. The emergence, progression, and intensity of afflictions in apple crops are largely dictated by climatic fluctuations, with meteorological inconsistencies being a chief contributor to apple diseases [12]. Diseases affecting apple crops can be categorized as [13]:

- Fungal: Conditions such as “apple scab, Alternaria leaf spot/blotch, collar rot, powdery mildew, Sooty blotch, fly peck, canker, and blue mold”.
- Bacterial: Ailments like “fire blight” and “gall formation”.
- Viroid-induced: Diseases like apple scar skin.
- Viral: Issues such as “apple mosaic, stem pitting, stem grooving, and chlorotic leaf spot”.

Diseases like scab, Alternaria Leaf Blotch (which can lead to early leaf fall), and powdery mildew have been estimated to cause approximately 30 to 40% of apple yield losses in the past three years. A sudden surge of the Alternaria ailment in 2013 wreaked havoc in Jammu and Kashmir [14]. As illustrated in Figure 1.2, the apple yield from 2014 to 2022, denoted in million metric tons, indicates that India harvested nearly two million metric tons in the fiscal year of 2022. This production level marked a rise from the previous year, with Jammu & Kashmir emerging as the primary apple-producing region in the nation [12].

Figure 1.2: Production volume of apples India FY 2014-2022

Economic Contribution:

Research in apple farming focused on predicting forthcoming diseases influenced by environmental factors such as temperature, humidity, sunlight intensity, and altitude offers substantial economic benefits. By accurately forecasting disease outbreaks, this research enables timely and targeted interventions, reducing crop losses and minimizing the need for costly broad-spectrum chemical treatments. This targeted approach not only lowers expenses associated with pest and disease management but also boosts overall yields by maintaining healthier apple trees. Additionally, optimized resource management, driven by predictive insights, leads to more efficient use of water and nutrients, further cutting costs. Improved crop quality and consistency can enhance market value, translating into higher revenues. Furthermore, such research supports sustainable farming practices, contributing to long-term economic resilience and stability by preserving soil health and reducing ecological impact. Collectively, these factors enhance the profitability and competitiveness of apple farming, demonstrating the significant economic contribution of advanced disease prediction research.

Apple Disease Management Policies Across Apple Growing States:

In **Himachal Pradesh**, disease management in apple farming focuses on Integrated Pest Management (IPM) and promoting bio-pesticides. The state provides subsidies for disease-resistant varieties and anti-hail nets, while also supporting weather-based crop insurance to mitigate climate-related diseases. Farmers are trained in modern disease control techniques and encouraged to adopt advanced technologies like weather prediction tools.

In **Jammu & Kashmir**, the focus is on high-density apple plantations that are more resistant to diseases. The state offers financial aid for spraying equipment and fungicides, alongside promoting IPM. Cold storage expansion is prioritized to minimize post-harvest losses, and farmers receive training on early disease detection and management methods.

In **Uttarakhand**, apple disease management is geared toward organic farming and sustainable practices. The government encourages the use of organic fertilizers and bio-pesticides, offering subsidies for disease-resistant varieties. Like other states, Uttarakhand promotes IPM and weather-based insurance, with training programs for farmers on disease prediction and prevention.

In **Arunachal Pradesh**, where apple farming is emerging, the focus is on introducing disease-resistant varieties and promoting IPM practices. The state supports the development of cold chain infrastructure and offers financial aid for disease control measures.

These state-specific policies aim to enhance disease management by combining modern techniques with traditional practices, ensuring higher productivity and sustainability in apple farming across India.

Influences of Environment and Agronomy on Apple Quality

To produce higher-quality fruits, orchards must be grown in places with high "environmental appropriateness": a difficult notion to grasp due to its both an environmental and an economic element. In most cases, varieties provided higher quality with less constructive effort in a significantly suited environment (i.e. pesticides). The ecological circumstances in which they grew had an impact on their development and grades. The interplay of the varietal mixture with the environmental parameters determines the difference in fruit freshness. Elevated concentrations of sunlight accessibility, temperature, and humidity, along with soil factors, can all have a significant impact on fruit freshness [15]. High-radiation conditions are much more prone to yield bigger fruit with nicer color and a greater dry matter content, yet too much light exposure can induce burns.

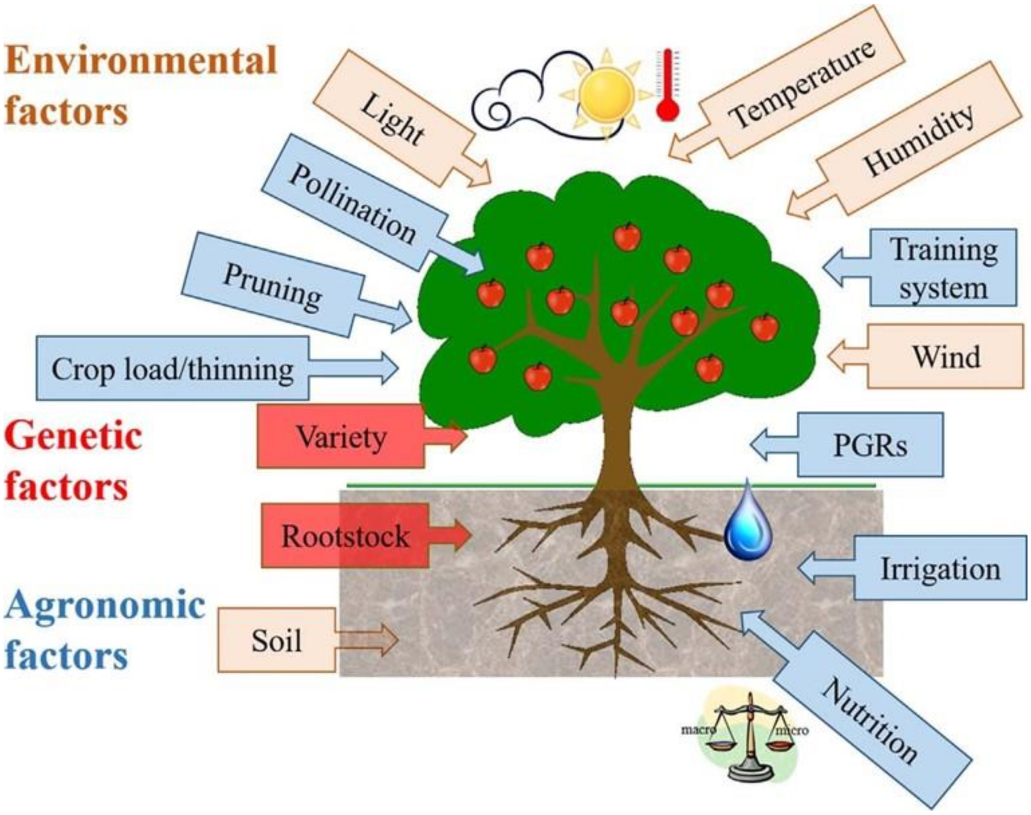

Figure 1.3: Influences on Apple Quality: Genetic, Environmental, and Agronomic Factors

Environmental Conditions

Climate significantly influences tree development and fruit quality. Although apples thrive in many regions, ideal conditions vary. Trees' physiological reactions, agricultural methods, and fruit preservation show stark differences between tropical and temperate settings. Faust outlined four distinct weather patterns impacting trees' vital physiological processes:

- Cold Days and Nights: Seen in places like England, Germany, Holland, northern France, and mountain areas like Italy's Bolzano Valley or Germany's Bodensee region. This chilly atmosphere restricts tree growth. Trees here grow slowly, and utilizing a vigorous rootstock might result in dwarfed trees. To balance potential yield reductions, increasing planting density might help. However, the fruit quality from these regions is exemplary.
- Warm Days and Cold Nights: Found in desert climates such as Washington State (USA), central Italy, and coastal regions of New Zealand, Tasmania,

and some Australian parts. Trees here are prolific. Cold winters and their effect on carbohydrate balance contribute to both fruit quality and consistent yields in subsequent years. This setting is optimal for high-quality yields, especially for apples and pears.

- Hot Days and Cooler Nights: Areas include the “Mediterranean, California, southern Australia, and central Chile”. Apple trees of medium stature are common here, and they bear numerous flower buds. The trees' regrowth post-pruning is modest.

Consistently Hot Days and Nights: Characteristic of the Mid Atlantic US, southern France, Japan, and certain Chinese regions. Among the four patterns, trees fare the worst in these conditions[16], partly because they might use up to 50% of their daily carbohydrate storage during nocturnal respiration.

In terms of precipitation, the four climates see annual rainfalls of 800mm, 400mm, 400mm, and 1000mm respectively. Apples require irrigation in the second and third climates [17]. Factors like increased CO2, greenhouse effects, and rising temperatures in recent times have profound effects on fruit quality and production. Such climate shifts can influence photosynthesis, fruit ripening, post-harvest preservation, and fruit nutrition. Addressing these challenges mandates further studies for future horticultural strategies [18].

Temperature

Temperature undeniably impacts multiple facets of apple cultivation, from the thinning process and end fruit size to the intricate workings of growth inhibitors. Apple development follows a two-step trajectory: the early stage marked by swift cellular growth and division within the 1-4 weeks following full bloom, leading to a phase of cell enlargement for the season's remainder. Globally, apple farming regions typically experience milder temperatures during the initial cell growth period [20]. New Zealand-based research points to how diurnal temperature variances can dictate flowering and fruit maturation, resulting in cooler climes fostering tinier fruits. Especially within the first 40 DAFB, milder weather leans toward generating smaller apples[19]. Notably, higher solute concentrations were identified at 16/12°C than in hotter conditions. Bergh attributed brisker fruit growth during early-season warmth to amplified cell division in the fruit's cortex [20]. Warrington et al. illustrated that the growth trajectory revealed remarkable temperature sensitivity within the 40-day post-pollination window, with growth rates at 20°C surpassing those at 6°C by ten times[21]. Temperature also Molds apple coloration patterns. Saure theorized that chiller nights bolster the emergence of reddish shades [22]. For the 'McIntosh' strain, Creasy observed an inverse relationship between average temperatures and anthocyanin evolution [23]. Conversely, Yamada et al. documented enhanced anthocyanin levels in the skin of the 'Fuji' apple at 10°C, a figure that dwindled at temperatures above 24°C [24]. The thermal conditions in the run-up to harvesting critically shape the fruit's quality upon harvesting and its subsequent preservation traits, with cooler environments diminishing water-core manifestations and reducing the tendency for surface scald.

Light

Light is crucial for determining apple quality, with optimal sunlight exposure enhancing apple coloration. High-quality apples tend to develop on branches with significant sunlight, with a minimum of 30% of the total light needed for superior fruit quality. Too much sunlight, however, can cause physiological problems in apples. The process of apple skin coloration during maturation involves the production of secondary metabolites and the degradation of chlorophyll. Researchers have pinpointed genes responsible for this color development. Additionally, environmental factors such as UV light and temperature also play roles in apple coloration, with regions having pronounced UV-B radiation, like South Tyrol in Italy and Washington State in the USA, producing apples with vibrant coloring [24][25].To optimize light exposure, practices such as pruning and the use of reflective fabrics have been adopted [26]. Such techniques can influence fruit size and color. In Japan, a unique fruit wrapping technique is employed for certain apple varieties to enhance their coloration [27][28]. The production of anthocyanin, responsible for the red pigmentation in apples, is influenced by light processes and internal chemicals like gibberellins, ethylene, and abscisic acid [29]. Different environmental factors and cultivation practices can either suppress or enhance the anthocyanin formation in apples [30].

Sunburn

Sunlight exposure, especially in regions with intense light and heat, can have detrimental effects on apple crops. In temperate zones, it's estimated that sunlight-induced damages in exposed areas can cause agricultural losses of between 5 and 10%. Sunburn, which arises from excessive solar radiation or elevated temperatures on the fruit's surface, represents a significant economic challenge for apple producers worldwide[31]. The damages due to sun exposure are grouped into three categories:

- Sunburn Necrosis: This is a result of the fruit's surface temperature rising above 52°C for an extended period (around 10 minutes), leading to cellular damage [32].
- Sunburn Discoloration: This is the most frequently seen type of sunburn. It causes the apple's sun-exposed surface to turn yellow or bronze [31].
- Photooxidative Sunburn or Browning: This arises from prolonged solar exposure paired with high temperatures and UV-B radiation. While it changes the fruit's color, it doesn’t cause cellular damage.

Environmental factors such as low relative humidity, combined with high temperatures, can increase the likelihood of sunburn. Farmers and producers must weigh the pros and cons of each method and choose the one best suited to their environment, crop variety, and economic considerations[33].

Agronomic factors

Orchard Design

High-density planting (HDP) in orchards has developed due to a combination of various factors that have advanced simultaneously. Rootstocks and their interactions with specific apple varieties, canopy density, various training methods, tree height, and the overall structure and architectural style of the orchard all play a role in the evolution of HDP. Additionally, the efficiency of the whole tree and individual leaves in photosynthesis and sunlight interception is crucial in these systems. HDP orchards' success hinges significantly on maximizing tree efficiency and light interception. When there is a balance between the canopy and roots of the trees, the orchard can achieve optimal fruit yield without relying on pruning for corrections. However, while these systems might optimize production, achieving the best fruit quality often occurs at lower densities. Sansavini et al. noted that the ideal freshness in fruit is often found in orchards with fewer trees than those designed to maximize yield[6]. Wagenmakers and Callesen delved deeper into understanding the impacts of tree density [34]. They studied how tree density, the ratio of tree height to the space between rows, influenced light absorption, fruit yield, the color of the fruit, and the weight of individual fruits. Their findings showed that as tree density increased, so did yield, and this increase in yield was directly proportional to the amount of sunlight the orchard absorbed. However, there was a drawback: fruit coloration suffered. In conclusion, while HDP can maximize yield, it requires careful consideration of various factors to ensure that the quality of the fruit is not compromised. Balancing tree density, sunlight interception, and other orchard design elements is crucial for optimal results.

Row Orientation

Row alignment in orchards significantly impacts fruit freshness due to its role in sunlight interception. This difference becomes more pronounced in lower latitudes. Additionally, E-W row alignment can affect fruit thinning because of varying bloom times on each side of the trees. Such alignment also impacts fruit color, with the northern side of E-W rows often showing less color, as noted by Bergh et al. [20]. Therefore, orchards in the Northern Hemisphere generally prefer N-S row alignment, although fruits on the western end can still suffer from sunburn in the afternoons.

Pruning

Pruning plays a crucial role in determining fruit quality in high-density plantations (HDP). According to Sansavini et al. adjusting pruning to bud counts helps manage fruit bud integrity [6]. Larger flower buds have a higher fruit production capacity, making pruning based on their count essential for determining fruit quality. By eliminating a significant portion of flower buds, harvest quantity increases but may compromise fruit size. Another pruning technique is the Artificial Spur Extinction (ASE) which focuses on manually removing immature fruiting spurs to enhance fruit freshness and reblooming [35].In apple varieties like 'Modi,' fruits located at the top of the tree have a higher soluble solid content (SSC), as noted by Musacchi et al. [36]. However, apple quality isn't necessarily affected by different wood structures. High-density plantations, due to their design and smaller trees, are more prone to solar radiation damage compared to traditional low-density plantings[30]. Costa et al. found that fruit quality varied across different planting densities, with attributes like hardness and acidity increasing with spacing, while total soluble solids and color intensity decreased. Summer pruning affects fruit quality, especially color [37]. Miller noticed that aggressive summer pruning increased sunburn in fruits [38]. This type of pruning can also decrease the fruit's SSC due to reduced leaf coverage but can reduce issues like bitter pit. Another technique to consider is root trimming, which limits tree size and affects fruit quality by enhancing color and hardness and increasing SSC. Further research is needed to better understand the impact of root trimming on HDP apples.

Crop Load

Crop load refers to the measure of orchard production based on the number of fruits produced per tree or branching unit, as explained by Wünsche and Ferguson[39]. When associated with parameters like “canopy leaf area, trunk cross-sectional area, or light absorption”, it's often termed "output efficiency". Crop load has a direct influence on an orchard's photosynthesis and growth. Adjusting the fruit-to-leaf ratio through crop loading is crucial for fruit quality. Thinning, which changes carbohydrate availability, profoundly impacts fruit size, harvest quality, and future blooming. It modifies the balance of resources among competing fruitlets and shoots. Biennial bearing, associated with crop loading, can negatively influence fruit quality. Heavy seed production or high crop load can suppress flowering in the same year, though the exact physiological processes remain unclear [40].Autio noted that, although the correlation between crop volume and postponed ripening might fluctuate yearly, it consistently persists across different rootstocks [41]. Research by Serra et al. has shown that decreasing the crop volume can elevate fruit dry content, enhance its red hue, boost firmness, and increase acidity and soluble solid concentration. These effects are discernible both at the time of harvesting and following a half-year of storage(Figure 1.4).

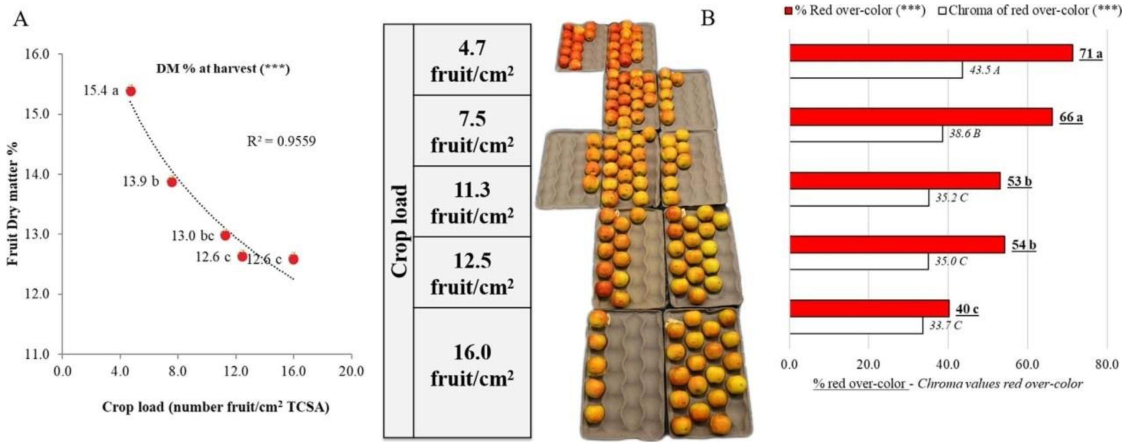

Figure 1.4: Impact of Crop Load on Apple Quality, Serra et al. (2016).

Figure 1.4 shows how crop loading affects apple quality using a "Honeycrisp" apple variety cultivated in Washington State, USA [42].

Thinning

Serra et al. found that 'Elstar' orchards with the least crop load produced apples with the highest weight, SSC, and likelihood of returning blossom[16]. Lower crop loads enhance fruit hardness, likely due to increased SSC, dry content, enhanced cell numbers in the cortex, and improved cell turgor [43]. Similar findings were noted for "Braeburn" and "Cox's Orange Pippin" [43]. Lighter cropping in "Stark Crimson Delicious" orchards resulted in apples with a more vivid yellow background and greater blush surface percentage [44]. Thinning is the act of removing excess fruitlets from apple trees to improve future blooming, reduce alternating bearing, and better fruit attributes at harvest. Dennis (2000) listed chemical, mechanical, and manual thinning methods, which can be used individually or together. The most cost-effective thinning method is chemical thinning. DeEll et al described several products usable for thinning, including caustic sprays, growth regulators, pesticidal carbamates, and photosynthesis inhibitors[44]. There are two primary categories of thinners: caustic and hormonal. Caustic thinners are used during bloom to damage flowers or inhibit pollen actions, ensuring that the primary (king) flower sets fruit while limiting other blossoms. Bergh[20] suggested that fruits thinned later develop smaller cells than early-thinned fruits. Chemical thinners likely function by either adjusting the carbohydrate availability for growing fruits or altering auxin production/movement within the fruit [45]. Chemical thinning can span a lengthy period, from blooming until the fruit is around 25mm in size. While blossom thinners are typically used in dry regions, they can harm the skin in humid climates. Hormonal thinners, on the other hand, induce stress in plants, disrupting physiological processes[38].

Pollination

Pollination is essential for fruit development and quality [38]. Although some varieties can self-pollinate, this typically results in only a 10% fruit set. Insect-mediated cross-pollination, primarily by honey bees, is vital for successful cultivation. Most apple blossom varieties have 10 ovules, necessitating 10 pollen grains to produce 10 seeds. Irregularly shaped apples, which command lower prices, were observed more frequently in 'Wealthy' and 'McIntosh' varieties when they contained only two to three seeds[38]. Despite "McIntosh" apples generally having more than two seeds, 2.6%–14.6% were found to be asymmetrical in a study by Brault and de Oliveira [46]. The number of seeds in each carpel can impact the form of an apple. Typically, the more carpels that have seeds, the fewer asymmetrical apples are produced. Such irregularities often result from inadequate pollination. Insufficient pollination in 'Breaburn' apples has been linked to reduced calcium content, leading to calcium-related disorders and malformed fruits. Growth near empty carpels is inhibited since auxins and other growth hormones mainly originate from fertilized ovules [44]. Apples with more seeds have been found to contain more IAA, a hormone that promotes ethylene production and fruit ripening. The "Granny Smith" variety also showed the influence of seed number on fruit shape. It is suggested that hormone production by fruit seeds, not pollen tubes, might play a crucial role in the irregular shaping of apples. Fruits with many seeds become nutritional sinks in trees due to the strong correlation of endogenous gibberellins in developing seeds with fruit growth. BA treatments can significantly reduce seed numbers even without fruit thinning.

Nutrition

Mineral nutrients are crucial for maintaining fruit freshness, with various diseases linked to nutritional imbalances. Often, fruit quality is influenced either by a deficiency or an excess of a particular mineral. One major condition associated with apple mineral nutrition is bitter pit, which was identified in 1936 as being related to low calcium levels. While calcium levels in apples remained stable from a month post-blooming to harvest, levels of nitrogen, phosphorus, magnesium, and sodium changed [35]. Nitrogen is essential for young trees' growth. However, excessive nitrogen can lead to larger, greener, softer apples that are prone to dropping and developing bitter pit. When the N/Ca ratio is low (around 10), apples can be stored longer without metabolic disorders, but a higher ratio (>30) can cause premature aging and other conditions[4]. Other minerals also impact fruit quality:

- Potassium: A deficiency can lead to less acidic fruits, poor coloration, smaller size, reduced organic acids, and a lack of vitamin C [47]. Excessive potassium can increase the risks of scald, bitter pit, and post-storage decay.
- Magnesium: A lack of magnesium can negatively affect both the yield and the freshness of the fruit. Certain apple varieties, such as 'Golden Delicious',

are especially prone to magnesium shortages, resulting in leaf drop. The combined ratio of potassium and magnesium to calcium (K+Mg)/Ca plays a more crucial role in the occurrence of bitter pit than either potassium or magnesium by themselves.

- Boron: Its deficiency can cause both internal and external corking in apples and is related to calcium deficiency[48]. Excessive boron can result in premature ripening and increased water core occurrence.

Irrigation

Deficit watering (DI) is a technique where trees receive less water than their typical requirements during certain growth periods. This was initially designed to control vegetative growth. While DI can negatively affect apple size, reduced crop loading can compensate for this. 'Breaburn' apples under DI showed improved qualities at harvest like flesh firmness and sugar content. 'Red Delicious' apples under DI were smaller but ripened faster. Water quality and shifts in soil moisture can impact apple appearance and content. For instance, water scarcity can reduce calcium transportation in apples leading to lower calcium levels in the fruit. Drought stress can also increase the chances of sunburn in apples. “Partial root-zone drying (PRD)” is a water-saving technique evolved from DI. It involves watering only half of a tree's roots while letting the other half dry, then alternating. This method can enhance water usage efficiency without compromising fruit production or quality. In studies, PRD-treated 'Pacific Rose' apples in New Zealand showed improved water usage efficiency and 'Fuji' apples in WA were firmer with higher sugar content after PRD. However, more research is needed to better understand PRD's impact on apple maturity and water usage efficiency [49][50].

Research Motivation

In the rapidly globalizing world of the 21st century, the significance of sustainable agriculture is unparalleled. It underpins numerous critical aspects of daily life, from food security and public health to economic vitality and environmental stewardship. Apples, a major agricultural commodity, not only contribute to the dietary needs of millions but also form the economic backbone of many regions worldwide, India being a prime example.

The increasing peril posed by diseases in apple orchards represents a serious challenge to this vital industry. Every year, apple crops suffer from significant losses due to an array of diseases, which, given traditional methods, often go undetected until too late or are too challenging to manage in difficult terrains. These diseases, many of which are influenced by environmental factors such as temperature, humidity, and altitude, lead to not only economic loss but also jeopardize the livelihood of millions who depend on apple farming.

In recent years, technological advancements, particularly in the realm of the Internet of Things (IoT), present a beacon of hope. Their potential to revolutionize disease detection in apple farming by harnessing real-time environmental data is both promising and exciting. However, despite the urgent need and available technology, there exists a gap between the two: a systematic methodology that bridges the power of IoT with the intricacies of apple farming, tailored to the unique needs and challenges of regions like India.

This research is motivated by the desire to address this very gap. By introducing a novel methodology for apple disease detection based on environmental factors, we seek to harness the capabilities of IoT to the fullest, making orchards smarter and more resilient. Our endeavour is rooted in the belief that with the right technology, informed by comprehensive research, we can ensure better yields, minimize losses, safeguard livelihoods, and guarantee a more sustainable future for apple farming.

Research Gaps

While recent advancements in the realm of apple disease detection provide promising avenues for apple farming sustainability, several gaps remain in the existing body of literature and practices. Herein, we highlight these research gaps, emphasizing opportunities for further exploration:

- In-depth Correlation Study: Most studies have superficially touched upon the influence of environmental factors on apple diseases. However, an exhaustive correlation study detailing how specific factors, in varied combinations, influence the onset of various apple diseases is lacking.
- Real-time Predictive Analysis: Although there's a growing body of literature on real-time data collection, predictive analysis – particularly in determining the imminent onset of apple diseases based on real-time environmental data – remains largely unexplored.
- Integration of Advanced Technologies: There's a lack of studies focusing on the integration of emerging technologies, such as artificial intelligence, and advanced sensors, for enhanced apple disease detection and prediction.
- Farmercentric Research: While technological advancements are crucial, they must be user-friendly and tailored to the needs and understanding of the primary users: the farmers. The gap exists in research that is both technologically advanced and user-friendly for growers without advanced technical know-how.
- Cost-Effective Solutions: Many current detection systems, though efficient, are economically prohibitive for smaller apple growers. Research focusing on budget-friendly yet effective solutions is limited.

Research Objectives

- To identify the different parameters affecting the yield of apple orchard using different case studies
- To develop an embedded system for monitoring the identified parameters using IoT devices.
- To propose a novel system for prediction of apple orchard diseases using fuzzy logic.
- To develop a GUI based mobile application for generating alerts and recommendations for disease prevention.
- To test and validate the proposed system.

Dissertation Organization

CHAPTER 1: Introduction, we will establish the context by highlighting the importance of apple farming in India and the pivotal role of disease detection. This will delve into the challenges apple farmers face due to the unpredictability and severity of various diseases. The main goals of this dissertation will be outlined, along with a brief discussion on the research boundaries and the approach taken to address the problem.

CHAPTER 2: Literature Review, the evolution of disease detection methods will be traced, starting from traditional practices and leading up to modern, technological methods. This chapter aims to create a foundational understanding of the topic and identify gaps in current methods.

CHAPTER 3: Factors Affecting Various Diseases in Apples and Its Possible Solution will delve deep into the diverse environmental and biological factors that lead to the onset of diseases in apple orchards. By understanding these factors, we will explore potential solutions to mitigate or prevent diseases, focusing on the role of technology and modern farming practices.

CHAPTER 4: Real-Time Application for Monitoring Apple Orchard Disease Causing Environmental Factors using Embedded System and Cloud Services will be a technical deep-dive into the Internet of Things (IoT) framework. This chapter will elucidate how the embedded system detects disease-causing environmental factors in real time and how cloud services aid in data transmission and analysis.

CHAPTER 5: Results and Discussions, the effectiveness of the proposed IoT system will be evaluated based on tests conducted in apple orchards. This chapter will discuss the system's performance, its advantages, and potential areas of improvement.

CHAPTER 6: Conclusion will summarize the findings and offer insights into future research directions, potential applications, and the broader implications for apple farming in India.

Conclusion: In this chapter a comprehensive understanding of the Internet of Things (IoT) in modern agriculture is presented giving particular emphasis on apple farming. The significant growth projections for the smart agriculture sector highlight the immense potential and economic viability of integrating IoT technologies into farming operations. Despite these promising advancements, the chapter also critically addresses the inherent challenges associated with IoT adoption in agriculture. Issues such as hardware selection, maintaining stable network connections in expansive and varied terrains, and the need for robust infrastructure solutions are identified as key obstacles that must be overcome to fully harness IoT's capabilities. Furthermore, the discussion on the global market dynamics and the specific case of apple cultivation illuminates the complex interaction between environmental conditions and agronomic practices. Focusing on India, the chapter highlights the national impacts of prevalent apple diseases and the region-specific policies aimed at mitigating these challenges.

CHAPTER 2

Literature Review Noteworthy Contributions

Sahu et al. [51] discussed that production serves as one of the most significant means of income on the Indian side of the Himalayan region[51]. The current research emphasizes the apple orchards in Himachal Pradesh, a state in the Himalayan Mountain range that is a significant apple grower in India. According to the report, the optimal apple-producing circumstances in the area have been continually moving, and producers are transferring their orchards to higher elevations. For instance, orchards have relocated to 1500-2500 meters in the 2000s, up from 1200-1500 meters in the 1980s. As of 2014, apples are being grown at elevations of much more than 3500 meters, such as in the recently created orchards of Leo hamlet in upper Kinnaur and the Keylong region of the Lahul and Spiti regions. Chilling hours for various districts are computed. Mann-Kendall and Sen's slope tests were used to examine the temperature trends throughout the growing phase, winter sessions, and annual precipitation. Statistics from various time spans show that the northernmost movement (towards higher elevation) is caused by variations in chilling hours, total yearly precipitation, and average surface temperature throughout the apple planting seasons. Between 2000 and 2014, the average surface temperature in all districts enhanced by over 0.5°C. These alterations are caused by global warming which is significantly impacting apple orchards in Himachal Pradesh, primarily through rising temperatures and increased humidity, which are fostering the emergence and spread of various diseases. One of the most notable effects is the proliferation of fungal diseases such as apple scab, caused by *Venturia inaequalis*, and powdery mildew, caused by *Podosphaera leucotricha*. These fungi thrive in warm, humid conditions, which accelerate their growth and increase their virulence, leading to widespread damage to apple crops. The rising temperatures also favor the spread of bacterial diseases like fire blight, caused by *Erwinia amylovora*. Fire blight is particularly devastating as it can rapidly spread through orchards, causing significant branch dieback and fruit loss. In summary, the combined effects of higher temperatures and humidity due to global warming are making disease management in apple orchards increasingly challenging, threatening both the yield and quality of the apples, and requiring growers to adapt with more resilient farming practices.

Sahu Whereas the shifting climate reduces apple productivity in the state's lower elevation districts, it creates unique chances for apple farming in higher elevations as circumstances improve for apple growing in those elevated areas. Regional producers are facing sociocultural difficulties as a result of the underlying socioeconomic developments.

Lin-Wang et al. [52] discussed about environmental circumstances influence the formation of anthocyanin in various plant species. Apple anthocyanin levels are less in warm climates. Researchers looked at the anthocyanin build-up in the peel of developing 'Mondial Gala' and 'Royal Gala' apples cultivated in both temperate and warm locations, as well as on-tree fruit artificially heated. Heat significantly reduced both peel anthocyanin concentrations and transcripts of anthocyanin biosynthesis pathway genes. Warming the fruit significantly lowered the expression of the R2R3 MYB transcription factor (MYB10), which is important for the coordinative maintenance of red color of skin, and also the production of all other genes in the transcriptional activation complex. A single night of cold temperatures is enough to cause a significant boost in transcription of MYB10 and, as a result, the biosynthetic pathways. Anthocyanin concentration declines did not seem to be caused by potential genes that could suppress anthocyanin production. Temperature-induced regulation of anthocyanin biosynthesis, researchers believe, is principally triggered by changes in the transcript quantities of the activation anthocyanin regulating complexes.

Latorre et al. [53] discussed about European canker is a serious apple illness in Chile, causing cankers on twigs and branches. Illness rate on 'Richard Red' apples has now been found to be more than 50% in Southern Chile. Conidial implantation of N. galligena was minimal in vitro at 6°C and 32°C, with an optimal implantation temperature predicted to be between 20°C and 25°C. Germination of ascospores was minimal at 5°C and significantly enhanced as the temperatures climbed from 5°C to 20°C. Germination rates were 2.3 times quicker for ascospores than conidia at 20°C, and germination percentage grew 2.6 times quicker for ascospores than conidia as temperature enhanced from 5°C to 20°C. The infections produced by N. galligena conidia via leaf scarring were strongly affected by temperatures and maximum moisture persistence. Nevertheless, no infections was detected at 5°C irrespective of the time of moisture. This is consistent with the absence of conidial germination observed in in vitro investigations conducted below 6°C. Temperatures ranging from 5 to 20°C enhanced illness occurrence in a linear fashion. According to our findings, at 20°C, a 2-h wetness duration was sufficient to induce a substantial infection, but at relatively low temperatures, lengthier humidity durations were required. Depending on climatic parameter research, an infection alert system was designed and deployed in the forecasting program Pat Frut. The monitoring system proved to be an excellent method for determining the requirement for fungicide forms of treatment against European canker across two seasons. Substantial variations in illness occurrence and intensity were seen, with illness occurrence decreasing from more than 24% in 1999 to 4.6% when interventions were scheduled based on the model approach. There were distinctions in intensity but not in illness occurrence between the prototype and regular programs. Conidia formed throughout leaf fall were deemed not to be a constraining feature in this forecasting system. It also expected that somewhere between March and July, vulnerable leaf scarring was always prevalent. The preventative fungicide treatments used during leaf fall dramatically diminished infections the next season, implying that leaf scars are crucial invasion sites for N. galligena on apples.

Rana et al. [54] examined the impact of recent climate changes on apple cultivation in Himachal Pradesh by analysing climate data and gathering local farmers' opinions. Their findings reveal that, Himachal Pradesh's apple-producing regions have witnessed a rise in temperature and a decrease in rainfall. The districts of Kullu and Shimla have observed a temperature increase ranging between 1.8 to 4.1°C over the past 20 years. This surge has caused a decrease in accumulated chill units (CU) hours, essential for apple growth. There has been a notable decrease in annual snowfall by 36.8 mm, and a decline in snowfall during both early and late winter periods suggests a shortened winter duration in the higher mountains.CU hours showed a decreasing trend up to an altitude of 2400 meters above mean sea level (amsl). This suggests a shift in optimal apple-growing conditions to higher altitudes. Local farmers confirm these findings, noting that apple cultivation is increasingly moving to higher elevations. While apple cultivation in Lahaul and Spiti has increased over the past decade, other apple-growing regions in Himachal Pradesh, like Kullu and Shimla, have seen a decrease. The financial data reinforces these observations. Compared to 1995, farmers in Lahaul and Spiti have seen their fruit-related income increase by more than 10%, while farmers in Kullu and Shimla have witnessed a decline of more than 27%.

Samajpati et al. [55] reviewed methods to detect apple diseases, segment the diseased parts of the fruit, and classify these diseases using image analysis. Various techniques related to color processing, texture analysis, segmentation, and classification are explored, outlining their respective pros and cons.

Kumar et al. [56] examined how abiotic factors, specifically temperature, relative humidity, and the duration of leaf dampness, affect the conidial development, germination, and infection of apple leaves by Marssonina coronaria, which causes Marssonina blotch. Key findings include, Conidia (asexual spores) grew across a broad temperature range of 5-30°C. The optimum temperature for their germination was 20°C.Conidia germinated successfully within a relative humidity range of 40-100%, achieving the best results when the humidity was close to saturation (>90%).The study found that the combination of 20°C temperature and 48 hours of leaf dampness was ideal for Marssonina blotch formation on apple leaves. Moreover, at least six hours of leaf wetness was essential for the pathogen to cause infections.Field experiments conducted in 2009 and 2010 revealed that of all climatic factors, relative humidity played the most significant role in disease manifestation. The severity of Marssonina blotch was closely associated with relative humidity levels.Regression equations developed for the years 2009 and 2010 had high coefficients of determination (R2) of 0.9161 and 0.9703, respectively, indicating a strong relationship between the examined climatic variables and the disease's occurrence.In essence, the research highlights the critical influence of climatic factors, particularly relative humidity, on the development and severity of Marssonina blotch in apple leaves.

Sheel et al. [57] presented a IoT based model for apple disease detection. Internet of Things (IoT) is a technology that connects computing devices, and it is now greatly influencing many different implementation fields. In terms of apple cultivation, Himachal Pradesh came in second position in India. The fastest-growing industry in the region is apple production. Apple farming is a major contributor to this state's economy. All year long, there is a lot of demand for Apple. The production and quality of apples are greatly impacted by climatic and meteorological variations. Climate and ecological factors like humidity and temperature have a big impact on how well apples are produced. Observing these environmental aspects of an orchard can aid in keeping apples healthy. Fuzzy logic can describe more than two states because of its use. The existing investigation focuses on designing an IoT-based system with a fuzzy logic implementation to forecast numerous illnesses and their effects on apples under distinct weather circumstances. In order to observe the information that can be analyzed for additional suggestions, a fuzzy logic implementation will be utilized in conjunction with certain well-known IoT boards, sensors, a Wi-Fi transceiver, and an android-based applications.

Feng et al. [58] presented a survillence system through the implementation of wireless sensing technologies, by applying Zigbee technology, GPRS technology, and IOT technology, on the premise of achieving apple orchard enviromental surveillance, it is possible to lower managerial prices of apple trees, enhance supplier reliability of apples, as well as provide thorough, exhaustive, and precise electronic data for planting works, pest warnings, and manufacturing quality surveillance of apples. Using the components of dynamic surveillance, agricultural recommendation, newly planted judgment creating, and data force in the framework as instances. this work offers a layout system of an apple orchard smart surveillance framework depending on IOT. It then goes into great depth to describe the particular techniques for implementing IOT to the revelation of apple orchard monitoring planning. This apple orchard smart surveillance systems delivers not only comprehensive surveillance information of apple growth for vegetable and fruits commercial organizations, but also decisions taking help for agribusiness. The system's investigation will be useful in supporting the expansion and implementation of IOT technologies in agricultural productivity.

Ahmadi et al. [59] demonstrated that the horticultural sector would be significantly impacted by climate change. In this study, data simulations from the HadGEM2-ES combined with results from the CMIP5 model series under both pessimistic (RCP8.5) and optimistic (RCP4.5) scenarios were utilized to depict potential impacts of climate change on apple farming areas in Iran. The results suggest that due to the increasing temperatures from climate change, cold regions of Iran that support deciduous trees face notable challenges, as there will be fewer suitable areas for fruit trees like apples. There will be shifts in agro-climatic indices pertinent to fruit trees because of climate change and evolving temperature patterns. According to the bleak prediction, average minimum and maximum temperatures during the apple tree growth period will escalate from 11.6 and 27.3 °C, respectively, to 16.7 and 33.4 °C by the 2090s. Changes in temperature indices and agroclimatic metrics exceeding the orchards' sensitivity threshold highlight the effects of climate change on fruit trees. The land in Iran suitable for apple cultivation will grow to an estimated 29,073,448 acres in the upcoming period. Shockingly, nearly 46.7% of the current apple cultivation areas could vanish. Given the climate change impact, apple cultivation in Iran is projected to shift to higher altitudes. The deciduous trees in colder Iranian regions are at risk with the expected increase in ambient temperatures.

The Shimla region in Himachal Pradesh, India, while not technically in temperate zones, can produce temperate crops such as apples due to its elevation (1900–2600 m ASL). Recently, inconsistent winter chilling in some apple-producing areas has raised concerns about the region's capability to maintain apple production. The potential for milder winters poses a challenge as apple trees might not meet their chilling requirements. Monitoring chill units during winter is essential to advise fruit producers on necessary adjustments. While methods to estimate chill units exist, they are not comprehensive. Pramanick et al. [60] introduced a "ready reckoner" for chill units specifically for Shimla's apple-growing region. The reckoner addresses previous models' limitations. The research found that bud burst took longer with fewer chill units but was quicker with more chill units. Despite concerns about apple production decline over the past 20 years due to various factors, an analysis of the last five years showed that chill units in Shimla were always above 1000, which is suitable for apple cultivation. However, annual fluctuations warrant caution, and more prolonged studies are essential to understand climate change's impact on the region fully.

Pollinators are pivotal not only for supporting human life but also for ensuring environmental diversity, positioning them as keystone species. Global warming might disrupt the phenological synchrony between mutualists, such as plants and their pollinators. This study examines the influence of climate change on the relationship between apple blossoming and its pollinators over a decade (2004-2013).Sharma et al.[61] found that apple blossoming can begin between March 16 and March 29, but no significant trend was observed when correlat- ing the blossom date with temperature changes. Through scan sampling and sweeping net methods, a consistent diversity in pollinator groups was noted, encompassing honey bees, bumble bees, wild bees, syrphids, drone flies, and other species. The number of pollinators remained stable over the years studied. The investigation further showed that apple orchards supplemented with honey bee colonies witnessed higher fruit yields. Fruit set in proximity to bee colonies was notably higher, with the best results observed in orchards close to bee colonies, while the least fruitful results were found in orchards distant from bee colonies.

Eisavi et al. [62] shows the significant impact of agricultural production operations on production of variety of fruits and cereals. A significant socioeconomic influence on people's lives is provided by the thousands of hectares of apple trees that are located in this area. The phenology of apple trees has been put in jeopardy by recent variations in climate and land cover (AOP). Current research has placed a strong emphasis on how temperature affects plant phenology, but it has ignored how variations in land coverage, like Lake Desiccation, might also have an impact. It is still unclear how the AOP will be impacted by Lake Desiccation and climate variability at this time. As a result, in this research, researchers retrieved the AOP occurrences using the Enhanced Vegetation Index (EVI) recovered from remotely sensed photos obtained by the MODIS sensor between 2003 and 2014. Moreover, they examined the association between temperature variations/ lake Desiccation and AOP using a randomized forest regression (RFR).

In a study conducted by Argenta et al. [63], the researchers analysed the influence of different growth sites and their environmental aspects on the quality of apple fruits. They set up experimental orchards in Southern Brazil's subtropical humid environment to study 'Gala' and 'Fuji' apple varieties. The findings showed clear variances in fruit attributes based on the temperature profiles of the cultivation sites. While fruit size and coloration were superior in cooler environments,certain quality aspects like titratable acidity and soluble solids were pronounced in warmer climates. Notably, the study highlighted that pre-harvest conditions play a pivotal role in fruit quality, suggesting adaptive cultivation strategies.

Dong et al. [64] focused on Southern blight, a detrimental apple disease prevalent in China and beyond. Their research was dedicated to understanding the conditions facilitating the germination of Sclerotium rolfsii Sacc., the fungus behind this disease. The study showed that certain environmental conditions, such as temperature, soil water concentration, and substrate type, play a significant role in the propagation of the fungus.

Sun et al. [72] explored an innovative approach to irrigation, integrating rainwater collection with smart photovoltaic systems. Their high-efficiency rainwater irrigation (HRI) system, when used for dryland apple trees, showed promising results in soil moisture regulation and apple yield. The study also emphasizes the importance of precision rainwater irrigation as a sustainable approach for the future of apple cultivation, especially in drought-prone regions.

Dong, Xiang-li et al. [64] undertook a detailed analysis of ozone therapy's effects on various apple varieties. Their findings indicated that ozone treatment could influence the epicuticular wax on apples' skin, potentially accelerating its natural maturation. Interestingly, the effect of ozone on the preservation quality varied across apple varieties. While some varieties benefited from ozone treatment, others saw accelerated decay. The study underscores the potential of ozone treatment for long-term apple storage but suggests it should be tailored to individual apple varieties for optimum results.

Sun, Miao, et al. [65] discussed about hail nets to protect vegetation from hail storm destruction. There are now more apple trees in southern Brazil than ever before that are protected against hail by nets. There is, nevertheless, little information available regarding potential impacts on the microenvironment and, as a result, on growth of plants, crop productivity, and fruit freshness. This report's assumption was that storm nets in apple trees encourage microclimate and production adjustments. The goal was to describe the microclimate and agricultural output of apple orchards grown in hail nets and, as a result, to produce numerical variables for apple orchard administration and agricultural simulation.

The investigation was carried out in commercial orchards that were grown in the open and protected from hail storm. The amount of photosynthesis-active radiation (PAR), atmospheric temperature and humidity levels the wind velocity, and the amount of precipitation were all continuously measured. The quantity and weight of fruits per plant were used to measure productivity. The hailstorm nets decreased wind velocity and PAR by 30% and 32.8%, respectively. The ambient temperature, moisture, or precipitation, in comparison, were unaffected by coverage. When a hailstorm event occurs, the production of apples likely to be higher when protected from hail, and this effect is more apparent. These findings are crucial for investigators and apple producers to develop criteria for deciding whether to employ hail net protection and to create suitable managerial techniques for safeguarding orchards in order to make sure and enhance fruit yield. In general, it is crucial to estimate the impact of long-term local meteorological influences on agricultural output.

Bertolino et al. [66] examined the factors influencing Savi's pine vole populations in Italian apple orchards, focusing on ecological, agricultural, and population density parameters. The study found that the presence of voles in nearby locations and the proximity of kiwi fruit trees, which are typically not treated with rodenticides, affected vole densities. Irrigation methods played a crucial role, with flood-irrigated areas having fewer voles than drip-irrigated regions. Additionally, the age of apple trees and tilling practices influenced vole densities. The study concluded that farming practices and the variety and distribution of fruit trees significantly impact vole populations. Effective vole management in apple orchards requires a combined approach that includes chemical treatments, reviewing irrigation methods, and regular soil tilling checks.

Jiang et al. [67] introduced an IoT-driven agricultural system that leverages various technological advancements to aid the Agri-sector in monitoring and mitigating fruit diseases. This approach heavily relies on machine learning and image processing technologies to devise efficient strategies for disease detection and prevention in crops. The study proposed a method using deep learning for the detection and classification of apple diseases, benefiting from deep learning's proven proficiency in image analysis. Different deep neural network structures, consisting of varying convolution layers and neuron numbers, were tested and evaluated. The results were gauged based on accuracy, sensitivity, selectivity, and the ROC curve. The proposed method's effectiveness was highlighted by comparing it with previously established apple image classification studies.

Nabi et al. [68] presented the comparative analysis of several research to offer a greater understanding of these kind of implemented technologies. It comprises a review of various kinds of illnesses seen in apple orchards, a comparative assessment of various sensors application scenarios in precise agriculture such as environmental surveillance, precise watering, and so on, and a research of plant illness diagnosis approaches for application in prediction models. They also give a complete review of apple illness prediction methods that have been created thus far, highlighting their important advantages and shortcomings in this research article. The effectiveness of these devices was compared by taking crucial criteria into account. The results of this research will be utilized to identify acceptable techniques for constructing optimum WSN-based systems for the precise agriculture of apples, which will assist producers in avoiding the carnage induced by illness breakouts.

Wani et al. [69] focuses on diseases and infections in four key crops: tomato, rice, potato, and apple. An extensive exploration of possible diseases in these crops, the origins of these diseases, and their identification markers form the core of this study. The paper provides a deep dive into various methodologies employed for plant disease identification and classification using both Machine Learning and Deep Learning techniques. Moreover, they introduce several online databases dedicated to plant disease identification. The research thoroughly examines a range of Machine Learning and Deep Learning classification approaches in terms of their performance metrics, datasets used, and feature extraction methods related to the four specified crops. The article concludes by addressing present obstacles in utilizing machine and deep learning for plant disease detection and suggests possible avenues for future research.

Nowadays, various abnormally operating identifiers in plants and animals have demolished agriculture productivity in the domain of agriculture. Bacteria, fungus, microorganisms, and viruses, in general, have a negative impact on the fruits and their leaves. To accomplish amazing work in leaf illness recognition is an important contribution to effective plant illness administration, and its presentation to the constant surveillance of bacteria, fungi, and microorganisms viruses endures as an important work that is conducted or tried by the Department of Agriculture. Pandiyan et al. [70] introduced an Advanced Segmented Dimension Extraction (ASDE) using Heterogeneous Internet of Things procedure (HIoT) characteristics to efficiently identify leaf illness. IoT methodological characteristics were found as a recurring and continuous region in the leaf picture. This is also utilized to determine the effect gesture of a leaf image, which is negligible to the recognition duration to a reasonable amount. This research proposes a Signs-based plant illness recognition method for real-time detection of leaf illness organisms, fungi, microorganisms, and viruses. Signs-based plant illness recognition, especially heterogeneous IoT monitoring, is used to sustain diagnostics and separation approaches. The tests reveal that the targeted architecture separates a diagnosis of performing plant illness diagnosis efficiently attaining 97.35% with a high-detection ratio. Furthermore, the presented article illustrates the need of algorithms for automatic identification of finely tailored illness nodes in solitary leaf images. On parsing, localization, normalization, and separation processes are used for automatic identification.

Sangeetha et al. [71] proposed a deep learning framework to identify and classify illnesses. Models relying on Convolution Neural Networks (CNN) are utilized to identify apple leaf illnesses. The VGG16 infrastructure is an easy-to-implement CNN-based framework that is commonly utilized in various deep-learning classifiers. VGG16 is utilized in this case to diagnose and categorize apple leaf illnesses. Techniques and modules such as Kaggle Notebook, Tensor flow, and Keras were utilized to develop the infrastructure. The VGG16 model has been deployed to the apple leaf diseases datasets from the Kaggle library. Utilizing deep learning, the presented approach tries to reduce complication in diagnosing apple leaf illness. On the apple leaf illness database, the suggested method has the best validation precision of 93.3%. This approach surpasses certain existing state-of-the-art methods. Every photograph takes an average of 14 seconds to process. As a result, the presented approach could be utilized by producers to ease the apple leaf illness categorization procedure and aid in early identification and therapeutic interventions of the illness.

The emergence of apple illnesses has had a significant impact on apple freshness and productivity. Illness surveillance is an essential step in ensuring the apple firm's long-term viability. Yu et al. [72] presented an MSO-ResNet (multistep optimization ResNet) apple leaf illness identification system cantered on a remnant network (ResNet50). The recognition precision and pace of the models are enhanced, and the amount of model factors is lowered, by deconstructing the convolution kernel, upgrading the identity mapping approach, decreasing the number of leftover modules, and substituting the batch normalizing layers. The empirical findings demonstrate that the presented model's average accuracy, recollection, and F1-score for identifying leaf diseases are 0.957, 0.958, and 0.957, correspondingly. The parameters storage is 14.77 MB, and the identification period for every picture is only 25.84 ms. The aggregate effectiveness of the presented method outperformed the other models. The presented approach in this study has great identification performance and good resilience, and it could give essential technological assistance for the automated identification of apple leaf illnesses.

Li et al. [73] proposed ConvViT, a compact apple leaf disease identification system founded on Vision Transformers to retrieve useful aspects of crop illness patches to diagnose crop illnesses. Convolutional structures and Transformer structures are employed in this ConvViT. The patched encapsulation approach has been modified to sustain more picture edge data and to encourage data sharing across patches in the Transformers. The model's variables and FLOPs (Floating Point Procedures) are greatly lowered by utilizing depth wise differentiated convolution and linear-complexity multi-head attentive processes. Empirical results from a self-constructed apple leaf disease dataset show that ConvViT matches the recognition performance (96.85%) of the state-of-the-art Swin-Tiny, even against a complex background. Notably, ConvViT's parameters and FLOPs are only 32.7% and 21.7% of Swin-Tiny's, respectively. Furthermore, its performance surpasses that of MobilenetV3, Efficientnet-b0, and other systems. This suggests that ConvViT is a promising framework for disease identification, offering genuine practical application potential.

Storey et al. [74] discussed about the importance of adopting sustainable farming practices, specifically minimizing pesticide use due to associated health and environmental hazards. They propose the use of intelligent sprinklers that can accurately identify and target issues like weeds or crop diseases, allowing for more precise and reduced chemical application. The study harnesses the power of artificial intelligence and computer vision for precise crop identification and monitoring. Specifically, they delve into the identification of rot and leaf diseases in apple trees using Mask R-CNN for object recognition, segmentation, and disease detection. They utilized three different Mask R-CNN architectures for this purpose. Segmental masks from the Plant Pathology Challenge 2020 dataset informed the retraining and evaluation of these architectures. Their findings highlight the efficiency of a “Mask R-CN’ Nmodel with a “ResNet-50” backbone, especially in detecting subtle rust-infected areas on apple leaves.

Fan et al. [75] presented a broad approach for identifying plant illnesses in this research. In order to establish high-level latent characteristic representations, researchers initially presented a deep feature descriptor built on transfer learning. Then, using feature fusion, researchers combined the deep characteristics with more conventional hand-crafted features to extract the local texture data from plant leaf photos. Center degradation is also added to the fused characteristic to improve its capacity for discrimination. The centre loss learns both compact and distinct characteristics by concurrently minimizing intra-class distance and maximizing inter-class distances. To verify the efficacy of the suggested strategy, comprehensive studies have been carried out on three publically accessible databases (two Apple Leaf databases and one Coffee Leaf datasets). On thethree databases, the proposed approach achieved categorization accuracy rates of 99.79%, 92.59%, and 97.12%, correspondingly. The findings of the experiments show that the suggested strategy successfully encapsulates the representations of the exclusionary features for differentiating plant leaf disorders.

Wang et al. [76] investigated the relationships between the prevalence of ARD and the richness and content of the AM fungal communities in the soil of perennial apple trees. In Bohai Bay, China, 27 soil specimen in total were gathered. A negative correlation was found between the degree of ARD and the organic soil carbon, pH, and comparative density of Archespore. Societies in AMF can be impacted by soil characteristics. The primary initiators of AMF communities in the soil of perennial apple trees were total nitrogen and accessible phosphorus. By altering the diversification of AMF, the aggregate nitrogen, aggregate phosphorus, and accessible phosphorus might inadvertently influence the intensity of ARD. The link between AM fungal populations, soil characteristics, and ARD intensity is shown by these data, which offer a theoretical foundation for ARD regulation and the use of favourable soil microorganisms to increase apple orchard yield.

Garg et al. [77] discussed about autonomous approaches for image based disease categorization. In the agricultural sector, these approaches are used for weed recognition, fruit categorization, and illness identification in plants and trees. Convolutional neural networks (CNN) have achieved outstanding outcomes in the categorization of images, but one of their limitations is their inability to retrieve certain important picture elements from the input picture. However, the correlation between picture characteristics can be completely utilized by the reoccurring neural network (RNN). In this study, significant picture characteristics from photos of infected apple leaves are extracted in order to assess the performances of integrated CNN and RNN systems. This work suggests combining a specific kind of RNN called LSTM with a pre-trained CNN network. Transfer learning was used to separate the deep characteristics from the Xception, VGG16, and InceptionV3 pre-trained deep models' numerous completely interconnected layers. To help the presented framework be more concentrated on identifying pertinent information in the input information, the recovered deep characteristics from the CNN layer and RNN layer were combined and sent into the completely interconnected layer. Eventually, the combined framework for apple foliar illness categorization determines the category labels of the pictures of the illness. Experiments show that the presented technique works better than separate pre-trained systems.

Longa et al. [78] conducted a study to understand how the composition of microbiota evolved from the time of orchard planting to the commencement of fruit production. The research examined changes in bacterial and fungal communities on various aboveground parts of apple trees, including the leaf, bark, blossoms, and fruits across three apple crop varieties. The dominant bacterial phyla across all samples were Proteobacteria, Bacteroidetes, Actinobacteria, and Firmicutes. For fungi, Ascomycota and Basidiomycota were predominant. Notable members of the aboveground microbiota included fungal species like Aureobasidium and Filo basidium, and bacterial genera like Pseudomonas and Sphingomonas. The findings revealed that apple plants harbor diverse microorganisms, with plant organs having a more pronounced effect on the taxonomic structures of bacteria and fungi than the sampling time or plant genotypes. The research underscores the unique microbiota associated with apple tree aboveground parts, the changes in microbiota composition through the vegetation's growth, and the minimal impact of apple varieties on this composition.

Yadav et al. [79] proposed for the detection and classification of various leaf diseases in orchards. The datasets for this study were obtained from the Cornell Initiative for Digital Agriculture and from Kaggle competitions held in 2020 and 2021. When the AFD-Net's performance was benchmarked against other prominent deep learning models, it excelled by achieving an accuracy rate of 98.7% on the Plant Pathology 2020 dataset and 92.6% on the Plant Pathology 2021 dataset.

Jiang et al. [80] introduced a deep learning approach which centered on augmented convolutional neural networks for real-time diagnosis of apple leaf diseases. For this purpose, the Apple Leaf Diseases dataset (ALDD) was constructed, comprising of intricate images from field studies and labs. The study also presented a unique deep-CNN-based model using the Google Net Inception architecture and Rainbow concatenation. The INAR-SSD system was then trained on this model to recognize five prevalent apple leaf diseases using a dataset of 26,377 images of affected apple leaves. Experimental outcomes showed that the INAR-SSD model achieved a 78.80% mAP with a commendable identification speed of 23.13 FPS.

This suggests that INAR-SSD offers an efficient solution for early diagnosis of apple leaf diseases, outpacing other real-time systems in terms of accuracy and speed.

Orchards are among the most prominent plants to cultivate in both huge farms and backyard gardens. At the very same moment, apple trees are one of the most susceptible to illness. Even the professional's eyesight finds it difficult to identify diseases at an initial phase and prohibit them from migrating to other sections of the tree. As a result, a sufficient approach is needed to diagnose plant illness in stages. Baranwal et al. [81] demonstrated the ability of Convolutional Neural Networks to recognize and solve a problem autonomously. Images of Apple leaves from the Garden Town database, representing numerous illnesses as well as healthier specimens, are utilized to verify outcomes. Picture screening, compaction, and generating approaches are utilized to obtain a huge train-set of pictures and fine-tune the framework. The skilled framework gets high precision ratings in all categories, with a total precision of 98.54% on the complete database, selected and created from 2561 annotated pictures.

The apple is widely recognized and consumed globally for its delicious taste and myriad of health benefits, containing nutrients such as Vitamins A, B1, B2, B6, C, and folic acid. However, the presence of rotten apples not only poses health risks but also results in significant economic losses in agriculture and the food industry. Consequently, there's an increasing research interest in detecting rotten apples. Singh et al.[82] focused on distinguishing between rotten and fresh apples in their study. To achieve this, they extracted various texture features of apples such as the discrete wavelet feature, histogram of oriented gradients (HOG), Law's Texture Energy (LTE), Gray level co-occurrence matrix (GLCM), and Tamura features. For the classification task, they employed several classifiers like SVM, k-NN, logistic regression, and Linear Discriminant. Their proposed method, which employs the Classification model, achieved an impressive accuracy rate of 98.9%, outperforming the other classification techniques in the study.

Bansal et al. [83] discussed about efficient and early detection of plant diseases to mitigate potential economic losses due to decreased yield. Traditional methods of disease detection, which involve experts physically inspecting large fields, are both time-consuming and ineffective. Bansal and colleagues propose an automated system to identify diseases in apple orchard leaves. Their approach uses a combination of pre-trained models, namely DenseNet121, EfficientNetB7, and EfficientNet NoisyStudent. These models analyse photographs of the leaves and categorize them into one of four categories: healthy, apple scab, apple cedar rust, or multiple diseases. To enhance the dataset size and subsequently the accuracy of their model, they employed several Image Enhancement techniques. In tests, their system achieved an accuracy rate of 96.25% on validation datasets. Impressively, the system could identify leaves with multiple diseases at a 90% accuracy rate. The model's promising performance across various parameters suggests its potential utility in the agriculture sector for rapid and reliable assessment of plant health.

The coloration of fruit, specifically the red hue of apples, plays a pivotal role in determining its market appeal and competitiveness. The redness in apples is mainly attributed to the accumulation of anthocyanins. Gao et al. [84] delve into understanding the factors influencing anthocyanin formation, focusing on the roles of hormones and environmental conditions. They also explore how internal gene responses and anthocyanin levels change when apples face different environmental stresses. Their study offers insights that can guide future research into apple anthocyanin production and sets a reference point for similar studies in other organisms.

Sottocornola et al. [85] described a case analysis of a knowledge-based recommendation systems that can detect post-harvest illnesses in apples. It outlines the method of eliciting information and building a Bayesian Network argumentation framework, in addition to its assessment using three various kinds of research with infected apples. Genome sequencing in a laboratory has proved the veracity of illness occurrences. The article illustrates the operational distinctions of knowledge-based rationalization processes as a result of various consumers communicating with the framework under various circumstances, and it recommends techniques for improving effectiveness using possibility indications acquired from the approximated agreement of consumer and specialist's conversations.

Chao et al. [86] aimed for the swift and accurate diagnosis of apple leaf diseases and introduced an improved network structure for apple leaf disease categorization, tailored especially for mobile terminal use. The researchers introduced the SE-DEEP block which combined the Squeeze-and-Excitation (SE) modules with the Xception network, resulting in the SE Xception network. The placement of the SE modules between the depth-wise convolution and point-wise convolution of the depth-wise separating convolutional layer allows for weighting of the feature channels from the base layer. This makes the model more sensitive to pivotal features of the classification task. The authors further compacted the SE Xception network to create the SE miniXception, which has a reduced depth and width. Empirical data showed that SE Xception had a classification average precision of 99.40%, which is 1.99% higher than the original Xception. Moreover, even with fewer parameters than MobileNetV1 and ShuffleNet, SE miniXception achieved a mean classification accuracy of 97.01% – surpassing the other two models by 1.60% and 1.22%, respectively. The streamlined SE miniXception also boosted the identification speed, cutting it down from 15 milliseconds to 7 milliseconds per image, and reduced both storage needs and FLOPs.

Apple tree disorders such as rot, scab, and blotch are responsible for significant economic losses worldwide. Traditional methods of identifying these disorders rely heavily on human labour and hand selection processes. Moreover, classic machine learning techniques for categorizing apple diseases depend on handcrafted features which often turn out to be unreliable and intricate. Although these techniques need a massive amount of samples, advanced methods like Convolutional Neural Networks (CNNs) have emerged as a promising alternative, offering superior accuracy. In this study, Ayaz, Hamail et al.[87] explored the application of various Deep CNN architectures for apple disease categorization, aiming to achieve enhanced accuracy by using deep learning-generated images. The researchers optimized a basic model and introduced an end-to-end trained DCNN framework. This proposed model had fewer parameters and exhibited higher identification accuracy compared to previous models. To validate the efficacy of their approach, they carried out an extensive comparison between the state-of-the-art CNN models and traditional techniques available in the market. The comparison results affirmed the dominance of their introduced model, suggesting its potential benefits for apple disease detection in the agricultural sector.

Apple trees can face challenges when grown continuously in the same location. This phenomenon, known as Apple Replant Disorder (ARD), results in stunted growth and a decline in fruit production and quality. While the exact cause of ARD is yet to be pinpointed, soil microorganisms are believed to be involved. A study by Mahnkopp-Dirks et al.[88] delved into the endophytic root bacteria of apple trees in soils affected by ARD compared to untouched soils. The team utilized a specific DNA barcoding method across three distinct areas. They discovered that the original bacterial community of the rootstock did not significantly alter the diversity and richness of bacteria in the trees, even after two months of growth in different soil conditions. Most of the bacteria from the starting substrate didn't settle in the apple roots, with Proteobacteria being the most prevalent in all samples. Notably, the number and diversity of bacterial strains were similar in both ARD-affected and unaffected soils. However, the frequent detection of the bacterium Streptomyces spp. in ARD-impacted soils stood out. Its presence inversely related to the growth indicators in all locations. Therefore, the role of specific strains of this bacterium needs further exploration to determine if they contribute to ARD. This investigation is pivotal in deepening our understanding of bacterial communities in ARD soils, revealing potential treatments.

In another study by Jams et al. [89], a Hybrid Neural Clustering (HNC) system was introduced to identify various apple fruit diseases. This two-phase method initially uses K Means Clustering to preprocess images by grouping vector points. The refined data is then classified using the Feed Forward Back propagation neural network (FFBP). This led to the categorization of multiple apple diseases such as Alternaria Rot, Black Rot, and others. When judged on accuracy, memory usage, and F Measures, this method surpassed other existing techniques, achieving a staggering 98% superiority rate.

When anticipating the evolution of apples and assisting fruit growers in their agricultural activities, the location of the apple growth phase is crucial. The manual placement of the apple growth phase is a time-honoured approach, although it has shortcomings including low efficiency and poor precision. Throughout the development of the apple, patterns identification supports continual and quick placement. The captured apple pictures are much more complicated in the orchard because of the vast variations in the colours of the specific apples throughout the growing phase and the impact of elements like lighting variations. This makes it extremely challenging to identify and divide the apples. Li et al. [90] utilized the sequence detection to autonomously recognize and retrieve the growing phases of apples. A hue concentration (HI) color segmentation algorithm centred on a Gaussian dispersion framework cantered on previous understanding is researched, and then an active shape framework (ASM) is utilized to recognise every time frame of apple advancement premised on sequence identification. Following a number of empirical validations, the ASM-based autonomous recognition approach suggested in this study is viable and can detect the different development stages of apples, hence enabling automated apple farming.

Zang et al [91] proposed an Internet of Things (IoT) systems for apple illness diagnosis based on a deep multi-scale dual-channel convolutional neural network (DMCNN). Initially, the photograph was color space translated into HSV and RGB color subgraphs, from which the color and texture aspects of apple illnesses were retrieved. The Color Assessment Subnet of the HSV color subdomain was then presented to retrieve color characteristics. (2) To retrieve texture characteristics, the Texture Assessment Subnet of the RGB color subspace was presented. The attention technique enhanced by double-factor weight was applied to significantly increase this subnet's textured characteristic retrieval capabilities. (3) DMCNN was built utilizing a homologous characteristic cross-fusing process. It may combine the characteristics gathered by color and textural assessment subnets to improve its expressiveness. Eventually, by merging hardware and detecting models, an IoT detecting method was created.

Raman et al. [92] presented a real-time technique for categorizing and segmenting the illness simultaneously, which greatly increases forecasting rate. To improve functionality, they have added a number of bypass links to UNet (using ResNet as the backbone). Outcomes from experiments using the presented approach show that it can categorize diseases with a precision of 94.29% and segregate infected body parts with a dice score of 90.01%. In order to improve the usage of the presented infrastructure and to show the purposes, they have also designed mobile applications.

Sheel et al. [93] show the impact of IoT in a variety of implementation sectors. Mobile apps are regarded as the greatest method for digitally commercializing any project or organization in a fast-evolving environment. The utilization of intelligent mobile apps with IoT is the main emphasis of the current work. Mobile apps working on smart gadgets play a significant role in advancing the internet of things. The research emphasizes the connectivity of tangible items with third-party facilities such as Google Firebase for database and applications administration. The approach is intended to connect IoT services with smart smartphone applications capable of detecting and predicting illness outbreaks in apples.

Pandiyan et al. [94] developed an Advanced Segmented Dimension Extraction (ASDE) technique using Heterogeneous Internet of Things (HIoT) characteristics. In the leaf picture, IoT methodological elements were recognized as a repeating and continuous region. This is also utilized to determine the impact gestures of a leaf picture, which is rather negligible to the recognition duration. This research proposes a Signs-based plant illness diagnosis method for detecting leaf illnesses caused by bacteria, fungus, microorganisms, and viruses in real time. Signs-based plant illness recognition, i.e. heterogeneous IoT identification, is used to sustain diagnostics and isolating approaches. The tests reveal that the proposed structure effectively differentiates recognition of performing plant illness diagnosis of 97.35% with a high-detection threshold. Furthermore, the presented work demonstrates the need of algorithms for autonomous identification of finely tailored illness nodes in solitary leaf images.

IoT is a technique that is making a significant impact in a variety of implementation domains. The apple, a cash crop, is one of the fruits that is in significant need all year. Himachal Pradesh is India's second largest apple producer. This state's economy is primarily based on apple farming. Weather and climatic factors have a substantial influence on apple and plant output and health. The success of apple harvest is heavily dependent on climatic and ecological factors such as temperature and humidity. Sheel et al. [95] developed an IoT-based system that can forecast numerous illnesses and their effects on apples under varied weather circumstances. To accomplish this, various common IoT boards equipped with sensors and a Wi-Fi transceiver will be utilized to collect information that can be analysed for additional specific suggestions.

Botryosphaeria dothidea is a fungal disease that causes canker, dieback, and fruit decay in apple orchards all over the world. In China, ascospores are a significant source of Botryosphaeria canker inoculum. Xue et al. [96] carried out under both regulated and natural situations to investigate the production of perithecium in response to atmospheric factors. Under environmental circumstances, perithecia of B. dothidea were discovered on cankered lesions everywhere in the apple producing period apart from in July and in certain years, which include August. The first perithecium was found on freshly developed canker lesions as soon as August, around a week after rainfall. Perithecia developed in stages, from early August through June of the following year, with a maximum in later September or earlier October. Temperature and precipitation are two important ecological elements that influence perithecium development. Perithecia were only formed under regulated settings on cankered shoots maintained at experimental temperatures of 20 and 25°C and moistened by more than 3 days of simulating precipitation each week. The frequency of perithecia formed on canker lesions rose as precipitation period enhanced. Perithecia developed on canker stems only when they were subjected to precipitation in June, July, and August, but not in September. Precipitation of more than three days per week could be utilized to anticipate the start establishment of perithecia in China's primary apple producing regions, assisting illness control.

Ariadi et al. [97] discussed about climate change and its influence on agricultural productivity. The purpose of this research is to determine producers' understanding of climate changes and their conduct in apple farming, in addition to investigate the influence of changing climate on apple production, ecological harm, and apple costs. Interview questions with apple producers were used to acquire main information. The Structural Equation Model (SEM) is used to investigate the impact of climate variation on productivity, the environment, and cost variations. The findings revealed that peasants have awareness about changing climate based on data primarily obtained from broadcast and their observed experiences. Higher air temperatures, droughts, and the demand for item infrastructures such as fertilizers and insecticides are all caused by climatic variation. It does, although, result in a decline in apple yield. Apple production and the price of apples as a commodity are significantly impacted negatively by climate variation. Apple yield is negatively impacted by the atmosphere as well, though less significantly. Apple production throughout changing climate has a detrimental impact on apple pricing, which indicates that the greater the production of apples, the lesser the cost of apples would be. Therefore, the commercial worth of the regional apple agribusiness in Malang Raya decreased as a result of climate variation.

Trichothecium roseum, a key postharvest pathogen for apples, belongs to an infection group that releases ammonia during fungal growth and colonization, altering pH levels. This pH adjustment by the fungus is believed to boost its gene expression, thereby increasing its virulence. Han et al. [98] delved into how inoculating apples with T. roseum spores at varying pH levels (from 3 to 7) impacts the production and neutralization of reactive oxygen species (ROS) in the host, suggesting a link between fungal pH regulation and host responses. The results highlight that spore inoculation at pH 3 led to minimal cell membrane penetration and ROS generation in the apples. By day nine post- inoculation at this pH level, there was a significant reduction in the production of ROS compared to inoculation at pH 7. Conversely, apple tissues exposed to a pH 3 solution after spore inoculation exhibited heightened antioxidant enzyme activities, demonstrating better defence responses. By the ninth day, these antioxidant activities, associated with the ascorbate-glutathione cycle, were significantly higher at pH 3 compared to pH 7, with similar trends observed in the storage of certain antioxidants. The findings imply that pH regulation by pathogens influences host defence mechanisms and can impact colonization success.

Grab S et al. [99] presented modifications in the average flowers bloomed timeframes for one pear and three apple cultivars in the southwest Cape of South Africa. Between 1973 and 2009, these morphological and physiological modification in the very same area were associated with variations in rainfall and temperature. Over the past 37 years, there have been notable initial spring temperature rises of +0.45 °C/decade, which are related with an average flower bloomed ahead of time of 1.6 d/decade. Golden Granny Smith apple trees are the least sensitive to climate alteration in the area, while Scrumptious apple trees are most sensitive. However, precipitation in the wintertime and the earlier spring has also reduced throughout this timeframe, these reductions are not substantial. It is suggested that both factors act together to affect average flowers bloomed dates in the southwestern Cape since they show substantial relationships with both temperature and precipitation when compared with mean flowers bloomed periods.

Aalum et al. [100] employed by McLean and Cook (1941) was utilized to examine the influence of relative humidity on spore propagation whereas the slide germination techniques published by Wellman and McCallan (1943) was utilized to determine the impact of temperature on fungal spores. At all temperatures between 10 and 40ºC, spores grew, but 30ºC had the highest germination rate (98.50 percent). There was a reduction in germination rate at temperatures below 20ºC and beyond 40ºC, even though 90% to 93.75% of spores propagated within a spectrum of 25 to 35ºC. The Alternaria mali spores also started growing at all of the experimental humidity concentrations, which ranged from 46.8 to 100 percent, but the highest spore germination rate (97.9%) was noted at 100 percent relative humidity, accompanied by 92.0 percent R.H. (92.17%), which were statistically equal to each other, and then 82.0 (71.31%), 75.6 (64.40), 66.8 (52.41), and 46.8 percent (18.8%). At 36.8% relative humidity, no spore growth and development were seen.

Nautiyal et al. [101]discussed about negative impact of climatic adversities on the growth and productivity of temperate plants like apples. Climate change specifically poses a threat to traditional apple farming in the mountains of Uttarakhand. These climatic variations can influence an apple tree's life cycle, from its budding phase to the fruit's final quality. One key issue is the increasing temperatures which affect the apple fruit's essential chilling requirement for flowering. Insufficient chilling causes poor fruit setting, while spring hailstorms can lead to frost damage, thus reducing fruit quality. Due to these deteriorating conditions, there's a noticeable shift from apple cultivation to other fruits like kiwi and pomegranate. A potential solution lies in the development and promotion of apple varieties that require minimal chilling and possess a higher adaptability to these climatic challenges. The Anna apple variety, for instance, can thrive in such conditions and is well-suited for the lower altitudes of Uttarakhand, where there's reduced cold exposure.

In the Himalayan region of Himachal Pradesh, India, apple cultivation is not just a primary agricultural activity but also a crucial source of livelihood for the local residents. However, this traditional farming practice is now under threat due to changing climatic conditions. Basannagari et al. [102] aimed to gauge farmers' perceptions of how climate change is affecting apple cultivation across different elevational terrains in the region. To gather insights, a questionnaire-based survey was conducted among apple farmers residing in the lower, middle, and higher elevational zones of Himachal Pradesh. The findings reveal that the majority of farmers across all elevations noticed a rise in ambient temperatures. Specifically, 72% of farmers at lower elevations attributed this temperature increase to the reduction in fruit size and quality. Farmers' primary concerns differed based on their location. 24% of farmers in the lower hills saw thunderstorms as the major hurdle to apple cultivation. In contrast, frost was considered a significant detriment by 35% of farmers in the higher hills and 30% in the mid-hills. Reduced snowfall was another common observation among farmers, with 92% in higher hills, 79% in middle hills, and 83% in lower hills noting the decrease. There was a marked difference in production perceptions based on elevation. While 71% of farmers in the higher elevational areas didn't observe a drop in apple production, the majority at the lower and middle elevations reported a decrease. Farmers also reported a delay in apple harvesting ranging between 73% to 83%. As signs of changing climate, farmers from lower elevations highlighted pest infestations in apple orchards, while those from middle elevations reported apple scab incidents. Climate change has also influenced farmers to alter their land use patterns, with many transitioning from apple cultivation to growing coarse grains, seasonal vegetables, and other horticultural crops.

Lee et al. [103] discussed that the type of illness and parasite is thought to be detrimental to vegetation and to have a significant negative impact on agricultural production. Pesticides and fungicides, which harm the ecosystem and reduce the health of the vegetation and output, are necessary to eradicate illnesses and parasites. In attempt to lessen the presence of pests, the IoT infrastructure is created to decrease the recurring application of insecticides and fungicides and to anticipate when infestations will come. In order to study the relationship between pests and meteorological information that had a significant impact on pests, monitoring stations have been put close to the orchards. The correlation data was used to generate the forecasting algorithms. In other terms, researchers suggested a framework that gives producers data about illness and pest forecasts so they can swiftly manage them.

Singh et al. [104] discussed the climate change that refers to a substantial alteration in the average condition of the climatic conditions or to its fluctuations that persist for a long time. It could result from internal natural phenomena, outside forces, or chronic manmade alterations to the atmosphere's chemical composition. The heating of the earth's crust is caused by greenhouse gases such CO_2, CH_4, N_2, ozone, water vapor, and CO_2. These gases also reflect some solar energy back into space. The planet would become frigid (approximately - 18°C) and unable to sustain life if they did not fulfil this beneficial purpose, allowing the majority of the thermal energy to escape. Moreover, man-made operations have significantly increased the amount of GHGs in the atmosphere since the beginning of the Industrial Revolution, which was around 150 years ago. Between 1750 and 2000, the atmospheric levels of CO_2, CH_4, and N_2O increased by approximately 31%, 151%, and 17%, respectively. In the higher mountains of Himachal Pradesh, snowfall was a common occurrence twenty years ago, but in the last two decades, just a few occurrences of snowfall have been noted. Between 1963 and 2007, the average highest temperature increased by 0.58°C, while the average lowest temperature increased by 2.75°C. Although Kullu in northern Himachal Pradesh is very well recognized for its apple farming, the area's apple agriculture has been negatively impacted by insufficient snowfall and inappropriate chilling hours. According to chilling's qualitative and quantitative effects on blooming and following fruit setting, Starking Excellent' erratic yielding pattern is greatly impacted by environmental factors. The fruit production is negatively impacted by rainfall and hailstorm throughout blossoming, but a medium temperature of 20°C combined with minimal rainfall throughout flowering produces adequate fruit production. There was a higher percentage of drought-related vegetation loss. There was a higher percentage of drought-related vegetation loss. A 20% increase in apple evaporation rate and a scarcity of irrigation water were thought to be the two main causes of the predicted 80% production decline observed a drop in chill unit hours in Himachal Pradesh's apple-growing regions. Dependent on the cultivar, several apple types need between 1000 and 1600 hours of chilling.

Yunqiang et al. [105] found that a lack of moisture can lead to the formation of a dried-out topsoil layer, primarily due to an imbalanced soil water ratio. Often, research on these dried-out layers, known as DSLs, is limited to a certain sampling depth because obtaining deeper soil samples can be challenging. As a result, the true extent of DSLs remains somewhat ambiguous. To gain a clearer understanding, samples were collected up to a depth of 1,800 cm under apple trees of varying ages in Changwu, located on China's Loess Plateau. The aim was to study the characteristics of DSLs under apple trees of different ages and identify the optimal age of apple trees that would reduce the risk of DSL formation. It was observed that as the age of the apple trees increased, the soil water content (SWC) and the average SWC in the DSLs generally decreased. On the other hand, the thickness of the DSLs and the quantity of water deficit (QWD) in these layers showed an increasing trend. The DSL was notably thicker under 17-year-old apple orchards. The most rapid growth in DSL thickness and QWD occurred between the 9th and 17th years of apple orchard maturity. While the QWD and average SWC in DSLs seemed to be independent of the age and root depth of the orchards, DSL thickness had a significant correlation with both factors. From their findings, it was deduced that the best age for apple trees to mitigate the development of DSLs is approximately 9 years. The study provided insights that can potentially aid in managing underground water reserves by adjusting the growth age of plants.

In a study conducted by Song et al. [106] in the Loess Plateau, China, the distribution of roots and soil moisture in apple trees was investigated. These trees employed a method that collected and absorbed rainwater, known as the Rainwater Collecting and Absorption Method (RWCI). A noticeable decrease in “soil moisture content (SMC)” was found between depths of 40 and 80 cm. However, the RWCI method significantly improved the SMC at these depths. The RWCI system increased SMC at depths ranging from 20-140 cm and beyond 140 cm when the depths of the RWCI pits were set at 60 cm and 80 cm, respectively. When comparing different treatments – control (CK), RWCI60, and RWCI80 – the total dry root mass was recorded as 372.12. The distribution of root mass across depths of 0-100 cm, 100-200 cm, and 200-300 cm varied depending on the treatment. Interestingly, the distribution of the root mass was found to align with the soil depths that benefitted from the moisture enhancements of the RWCI treatments. The RWCI method seemed to mitigate the effects of dryness by improving water and nutrient uptake, thereby enriching the topsoil's moisture content.

Unterberger et al. [107] highlighted that spring frosts, especially the ones seen in Europe in April 2016 and 2017, pose a grave risk to the agricultural sector, leading to potential significant crop losses. One identified cause of these sudden cold episodes in spring is meteorological blockages. Although current knowledge doesn't allow for precise predictions about future shifts in the frequency or duration of such blockages due to climate change, the combination of their occurrence alongside the warming trend can translate to more financial losses. For a detailed analysis, the team combined a phenological modeling method with in-depth climate projections, focusing on apple farming in south-eastern Styria, Austria. The model indicates a shift in apple blossoming times, predicting an advancement of about -1.6 ± 0.9 days every ten years. This means that by the end of the 21st century, apple trees will likely start flowering by early April. The data suggests that, despite a warming climate, the overall frost risk for apple varieties might persist, and possibly increase. This is attributed to a stronger relationship between meteorological blockages and winter storms in the early spring – a connection that can be identified through empirical data. To manage the impending frost risks, strategies need to be devised either to sustain crop yields or ensure farmers have an alternative income source. The study goes on to discuss the best adaptation approaches and the associated costs due to the anticipated rise in frost threats. It's emphasized that, even if these measures are perfectly executed, the costs of these actions, along with expected consequential damages, signify substantial financial implications related to climate change.

Sugiura et al. [108] presented proof that the flavor and texture qualities of apples have altered as a function of current climate change based on 30-40 years of observations. Irrespective of the maturity index utilised for harvest deadline, significantly reduction in acid composition, fruit stiffness, and water core advancement were ascertained, while soluble-solids content enhanced in a few instances; all of these modifications could be attributed to relatively early flowering and higher temperatures throughout the growth and development phase. These findings show that the commercial quality of apples is changing over time.

The increasing warmth during winters due to climate change is a pressing concern for growers of temperate fruits, as it may hinder the orchards' chilling needs. It becomes essential to consistently monitor chill unit accumulation during winters to guide fruit growers on the necessary measures they should take to maintain production. Several chill unit estimation methods are available, but they aren't universally suitable. Each region needs its customized chill unit calculator. Kishore et al. [109] designed a chill unit reckoner specific to the apple-producing region of Shimla in Himachal Pradesh, India. This new approach rectifies some of the limitations found in previously established estimation methods.

Qu et al. [110] discussed about climate change and its pivotal role in determining the quality of apples. The study utilized statistical methodologies to study the variations and sudden changes in six crucial climatic variables influencing seven essential fruit quality indices across five prominent apple-producing areas in China. The objective was to understand how climate change might affect apple quality in China's leading apple-growing areas. The results showed considerable fluctuations in variables like yearly mean temperature, sunshine duration, summer temperatures, daytime temperature difference, and summer relative humidity. For example, in the apple regions of the "Loess Plateau and Bohai Bay", both yearly and summer temperatures increased, remaining within acceptable limits. In these areas, decreased sunshine hours improved the fruit structure index, sugar-acid ratio, and vitamin C contents. Conversely, in regions like Southeast Hebei and Northern Anhui, increased temperatures and reduced sunshine might negatively affect fruit firmness, sugar content, and skin anthocyanin levels. In the Southwest Mountains' apple-growing regions, higher summer temperatures and reduced diurnal temperature differences, which were still under ideal ranges, might have decreased fruit firmness while increasing sugar content. Yet, increasing temperatures and reduced sunlight could adversely impact the fruit's shape index and color. In Xinjiang, the climate became warmer and more humid, with shorter sunshine durations, possibly improving the apples' external appearance but reducing their firmness. To sum up, over the past 50 years, while climatic changes had a positive impact on apple quality in the Loess Plateau and Xinjiang, effects in other regions were mixed.

Spath et al. [111] examined apple replant illness, a condition that impedes young apple trees in replanted orchards, causing them to grow slowly and eventually die. While the root cause remains elusive, soil-borne microorganisms are often implicated. A study conducted in Laimburg, Italy, investigated the roles of various soil components in this disease. They compared apple trees grown in chloropicrin-treated soils, untreated soils, and a mixture of both. Natural, untouched soils were also analysed for reference. Significant microbial community shifts post-chloropicrin treatments were also detected. This suggests that soil biota plays a role in the illness.

Alternaria leaf blotch and apple fruit spot, caused by Alternaria spp., inflict substantial financial losses on the Australian apple industry. Control measures, usually involving fungicides, are inconsistent, possibly due to a lack of infection timing knowledge. Harteveld et al. [112] found that Alternaria leaf blotch infections began around 20 days after bloom (DAB), peaking between 70-110 DAB. Fruit spots appeared around 100 DAB. The study also observed variations in infection rates based on canopy height and leaf type. Environmental factors such as temperature, humidity, and rainfall influenced disease prevalence. This information can aid in refining disease management techniques.

Liu et al. [113] tackled the importance of timely diagnosis of apple leaf diseases like "Mosaic, Rust, Brown spot, and Alternaria leaf spot". They employed an advanced image processing technique combined with deep convolutional neural networks. The model achieved an accuracy rate of 97.62% and showed improved efficiency compared to standard Alex Net. The research confirms the potential of such deep learning tools in apple disease management.

Peruzzi et al.[114] delved into the link between soil properties, plant growth, and microbial diversity in apple trees affected by replanting illness under different fertilization regimens. The study focused on two apple orchards in South Tyrol, Italy, afflicted by replanting disease. The effect of six different soil treatments was assessed. The research identified various bacterial species that were correlated with the treatments and plant growth. The findings highlight the complexity of interactions between environmental and biological factors. High-throughput sequencing techniques suggested that soil bacterial communities were diverse and shifted based on environmental factors but were not necessarily tied to apple tree growth or specific treatments.

Orchi et al. [115] highlighted the significance of the agricultural sector to Morocco's economy, contributing around 15% to its GDP. Infectious outbreaks pose a constant threat, resulting in major financial impacts. Early detection is key to mitigating these threats. While manual disease detection is laborious and error-prone, automated methods offer efficiency. The study examined current research on crop disease detection using machine learning, image processing, the IoT, and hyperspectral imaging. The authors also contrasted various detection methods, addressed challenges, proposed solutions, and shared recommendations. They emphasized the value of this research in advancing agricultural disease detection.

Lian et al. [116] discussed about the serious apple disease known as Apple Marssonina Leaf Blotch mostly results in early leaf dethatching in various apple-growing regions across the world. Temperature and precipitation have a direct impact on how the AMLB pandemic develops. This research looked at how temperatures and humidity affected the growth of conidia, the infections of leaves, and the generation of acervulus in carefully regulated settings. The optimal temperature for conidium germination and infections was at 23°C. The temperature spectrum needed for these processes was 5 to 30°C. The ideal temperature for the development of acervulus was somewhat larger, at 24.6°C. Only a few conidia grew at 100% RH, indicating that conidia require moisture to develop and spread infection. On the other hand, in dry circumstances, lesions might generate acervuli. At 10, 15, 20, and 25°C, correspondingly, conidia needed 14, 8, 4, and 6 h of leaf dampness as the minimal amount of time to finish the full infecting procedure. The relationship between temperature and the length of leaf dampness was modelled. The ideal temperature for conidial illness, according to the framework, is 22.6°C, and the least amount of wetness needed is 4.8 hours. To aid in the control of the illness in commercial apple cultivation, this method can be utilized to predict D. mali conidial infections.

Xue et al. [117] identified that apple orchards all across the world are affected by the fungal infection Botryosphaeria dothidea, which causes canker, dieback, and fruit rotting. In China, ascospores are a significant resource of Botryosphaeria canker inoculum. To investigate the relationship between ecological factors and perithecium synthesis, tests were carried out in both regulated and uncontrolled environments. During the whole apple planting period, with the exception of

July and, in several years, August, B. dothidea perithecia were seen on cankered lesions. The initial perithecium on freshly developed canker lesions was found as soon as August, roughly one week after rainfall. With a peak in late September or early October, perithecia evolved in stages over the course of earlier August through June of the following year. The production of perithecium is significantly influenced by temperature and precipitation in the surroundings. Under carefully regulated circumstances, perithecia were only formed on cankered branches incubated at experimental temperatures of 20 and 25°C and moistened by more than three days of simulating precipitation each week. As precipitation duration lengthened, more perithecia were formed on canker lesions. Only in June, July, and August, but not in September, did perithecia develop on canker branches subjected to precipitation. In China's primary apple-producing regions, precipitation of more than three days per week could be utilized to forecast the early perithecia development and aid in illness administration.

Bui et al. [118] evaluated the quality of "Ingrid Marie" apples gathered from eight distinct orchards in south Sweden between the years of 2015 and 2017, as well as their sensitivity to grey mold contamination. During the months of April through September, researchers attacked apples and gathered information on the fruit's stiffness, starch index, weight, and lesion size in addition to gathering information on the climate. Heavy precipitation in early April, throughout tree blossoming, and in beginning of June, throughout the initial stages of fruit growth, was associated with better quality, specifically smaller lesions and lesser levels of stiffness. Additionally, earlier June humidity levels greater than 77% made apples more resistant to grey mold, whereas lower temperatures and increased moisture between the end of August and the end of September, at the conclusion of the phase of fruit cell expansion, were associated with bigger apples. Researchers come to the conclusion that temperature, moisture, and precipitation are significant weather elements that affect apples' health and vulnerability to grey mold. Apple producers might find this data useful in better understanding how atmospheric circumstances affect apples. Preharvest procedures can be used to enhance circumstances and apple quality and also lessen their resistance to virus attacks using this current data.

Antos et al. [119] studied the possibility of an ozone-enriched environment to extend the storage lifespan of Gloster type apples in cold storing. The 84-day holding test was carried out. Throughout that time, ozone at a level of 1 ppm was dispensed for 1 minute per 12 hours. The contact with ozone at quite a high concentration proved ineffective in respect of inhibiting the growth of fungal diseases. Additionally, the captan levels in apples were lowered, making them more vulnerable to fungal diseases. On the contrary side, physical property studies revealed that using ozone decreased the ripening of apples, hence prolonging their storability unless they were not diseased.

Cantin et al. [120] investigated the impact of increasing height on the physico-chemical characteristics (soluble solid concentration (SSC), flesh stiffness, fruit weight (g), and titratable acidity (TA)), customer appropriateness, and interpretation of the primary sensory characteristics (sweetness, tartness, and appearance) of two standard apple varieties ('Golden D.' and 'Reineta' utilizing a group of 195 customers. An additional goal was to investigate if external data about variety and cultivation location influences user perceptions and consumption of fresh apples. The rising elevation had a major impact on the physicochemical and sensory qualities of the apple varieties 'Golden D.' and 'Reineta,' and these impacts were detected by customers. Furthermore, exogenous data regarding the cultivars and the cultivating place had a considerable impact on customers' sensory experiences.

Li et al. [121] used the gas chromatography with a flame ionization detectors to quantify dissolved sugars, malic acid, and ascorbic acid in 17 apple varieties and three wild varieties from three primary apple producing areas in China. The highest prevalent sugar was fructose, preceded by “sucrose, glucose, and sorbitol”. Wild apples have higher sorbitol levels, lower sugar levels, and are substantially more acidic than farmed apples. The overall sugar concentration ranged from 110 to 160 mg/g raw apples, and the overall acid concentration ranged from 2 to 6 mg/g, with hereditary history and growing area having a substantial impact. Generally, “Gala”, “Xiali”, “Liuyuehong”, “Lihong”, “Starking Delicious”, and “Starkrimson” had greater sugar/acid ratios, implying sweeter taste when contrasted to other varieties. The wild apples seemed to have the maximum ascorbic acid concentration (0.6-0.96 mg/g). “Zhongqiuwang”, “Qinguan” and “Nagafu No. 2” contained more ascorbic acid than other varieties. The ascorbic acid concentration of commercialized varieties was greatly depending on growing region. Malic acid and sucrose concentration were favourably connected to height, while glucose concentration was adversely linked. Malic acid was strongly connected with “ascorbic acid” and “sucrose”, while glucose concentration was significantly associated with “ascorbic acid”.

Wittich et al. [122] identified that the fruit temperature of apples might increase substantially beyond the air temperature in reaction to severe radiation warming. This can cause harm to the skin tissue as well as the epidermal and hypodermal cell membranes. To minimize financial shortfalls caused by ultraviolet signs on the skin, apple producers require temperature predictions of the fruits, which would also enable producers to plan sun-protection techniques ahead of time. Temperatures of separated apples subjected to incoming sunlight and wind were recorded in aim to determine the degree of apple warming under northern German weather parameters. Throughout chosen hot and sunny periods, the everyday highest skin temperature recorded on the exposed south surface of the fruit was approximately 7 °C higher than the everyday highest ambient temperature. Skin temperatures of high above 40 °C, on the other hand, were seldom measured, showing that sunburn remains an infrequent occurrence in northern Germany. Extreme apple-core temperatures were already on mean 4 °C greater than highest surrounding air temperatures. A simple framework that utilizes energy balancing concepts has been created to anticipate the daily cycles of sky- and ground-facing hemispherical apple temperature changes. In order to meet the objectives of fruit producers, everyday temperatures peaks from the simulated sky-facing hemispheres were contrasted to skin temperatures obtained on the sunlit south side, yielding an average absolute error (MAE) of 1.7 °C. Improved relationships were found when everyday extremes of overall sphere temperatures were compared to apple cores temperatures.

Nangul et al. [123] studied the survival and growth of L. monocytogenes on fresh apples during prolonged, low-temperature sea transportation from New Zealand to the United States and Europe. Lab experiments replicated any temperature variations from the target 0.5°C. Apples of different varieties and calyx types were treated with L. monocytogenes strains. Post-transport, a significant reduction of the bacteria was observed on the apple's surface but less so in the calyx. Apple variety did not impact bacterial survival. Most bacterial reduction happened in the first two weeks of storage. There was no significant difference in bacterial decline at either 0.5°C or 20°C, and its survival was not influenced by apple firmness or soluble solids content. The study indicates a potential higher risk from apples with infected cores due to lesser bacterial reduction in the calyx. Overall, L. monocytogenes does not grow during sea transport regardless of its duration or temperature. The findings can help in creating risk-reduction strategies for apples during extended cold sea transports.

Raman et al. [124] presented a real-time methodology for categorizing and segmenting the illness simultaneously, which greatly increases forecasting pace. To improve functionality, they had added a number of skipped links to UNet (using ResNet as the foundation). Outcomes from experiments using our presented approach show that it can categorize diseases with a precision of 94.29% and separate affected body parts with a dice value of 90.01%. In order to assist the usage of the suggested infrastructure and to show the aims, they also have designed Smartphone applications.

Racsko et al. [125] identified the impact of sunlight on several different stages, including structural and physiological alterations, alterations to the pigmentation content, effects on adaptation processes, impairment of photosynthesis, and a subsequent decline in fruit quality. Fruits' extensive defensive system include a variety of physiological and pharmacological responses. In the outdoors, photoprotective pigmentation, antioxidant enzymes and intermediates, heat-shock proteins, and the xanthophyll cycles frequently fall short of providing complete protection from sun exposure. Fruit marketing, customer acceptability, and conduct after harvesting are all highly impacted by losing quality. Exposure to sunlight has an impact on the intrinsic integrity of the apple, and these alterations persist throughout cold storage. Diseases caused by sunlight can develop in cold preservation. Producers have a number of options with a range of mediums of operation at their disposal to reduce sun burning in outdoor settings. The prospective effects of a changed climate on the frequency of sunburns are discussed towards the conclusion of this work, as both UV-B radiation and temperatures are expected to vary. Eventually, a number of issues that require more study are covered.

Watpade et al. [126] investigated white root rot in apple orchards, a severe disease caused by Dematophora necatrix. They evaluated fifteen fungicides – four contact fungicides, ten systemic fungicides, and one combination product – against the growth of D. necatrix using a contaminated food method. Further, selected fungicides were trialed for three years to treat the disease under both container and outdoor settings using seedling dip and drenching methods. The contaminated food method showed that fungicides effectively halted the growth of D. necatrix. However, when it came to seedling dip treatments, only carbendazim and propiconazole were found effective against D. necatrix, with all treated plants making a recovery. For the drenching approach, propineb, carbendazim, and propiconazole were identified as effective treatments against apple white root rot. Given the impending ban on carbendazim by the Indian government and taking into account the cost-effectiveness of fungicides, propiconazole, followed by propineb, emerges as a potentially efficient and economical solution for combating apple white root rot. Therefore, growers are recommended to dip in propiconazole for 30 minutes to treat D. necatrix in affected nursery plants. Additionally, drenching the soil with propiconazole and propineb is advised for treating plants already suffering from white root rot.

Huang et al. [127] identified that timely detection of plant illnesses and insects is crucial for sustaining food security and agricultural output. In anticipating plant illnesses and insects, information inputs like as recurrence, regularity, and infected areas are critical. Obtaining such information, though, currently depends on fixed-point assessments or fieldwork experimentations conducted by agricultural institutes. Thus, among the key issues impacting prediction system effectiveness are inadequate information and poor levels of local representation. In previous years, the advancement of mobile internet technology and easily attainable multi-source agronomic data has given rise to novel approaches for predicting plant illnesses and insects. This work presented a prediction models of Alternaria Leaf Spot (ALS) illness in apples based on portable internet illness assessment information and high precision spatial-temporal meteorological information. To begin, portable internet-based questionnaires were designed to effectively gather illness assessment information. To reduce the uncertainty in the information, a unique information cleaning process was devised. Following that, a vulnerability assessment was run on the humidity and temperature information to find disease-sensitive meteorological parameters as modeling inputs. Eventually, the illness prognosis framework for apple ALS was developed utilizing four machine learning algorithms: “logistic regression (LR)”, “Fisher linear discriminant analysis (FLDA)”, “support vector machine (SVM)”, and “K-Nearest Neighbours (KNN)”. The KNN algorithm is suggested in this research, which yielded an aggregate precision of 88% and a Kappa of 0.53. This study demonstrates that using a mobile internet illness survey and an appropriate information cleaning method, it is feasible to obtain the essential information for illness prediction in a limited period of timeframe. It is possible to anticipate diseases at a local level using high resolution spatial-temporal meteorological information and machine learning algorithms, which would promote effective illness preventative measures.

Singh et al. [128] highlighted that among all apple diseases, apple scab has historically caused the most extensive damage. The disease reduces the leaf's effective area, prompts premature leaf drop, and hinders the growth of spurs. It also affects fruit size, its storage life, and overall quality. In years with severe outbreaks, the loss in yield can surge to 70% or even more. In the Uttarakhand Himalayas, apple scab is predominantly controlled through a regular spraying routine of preventative fungicides. In a standard scab control program, fungicides are sprayed every 10 days following the emergence of new shoots. Even when infection conditions arise, spraying is conducted. In the Gangotri fruit-growing region, farmers can apply up to 12 fungicide sprays during the monsoon growth phase as a preventive measure against scab. An alternative to this preventative approach is the post-infection or "curative" spray method. Here, the fungicide is applied not in anticipation but after the disease has initiated and before any symptoms become visible.

Yu et al. [129] emphasized the crucial role of disease detection in safeguarding the health and productivity of apple orchards. The advent of various apple diseases poses a notable threat to the well-being of apple trees. Monitoring these diseases is paramount to the sustained success of the apple industry. Their study presents an advanced apple leaf disease detection system named MSO-ResNet, which is grounded in residual networks. By innovatively breaking down the convolution kernel, refining the identification mapping methods, minimizing the number of residual modules, and replacing batch normalization layers, the model achieves improved accuracy and speed. Moreover, this optimization results in a reduction in the model's parameters. Empirical tests showcased impressive results for the MSO-ResNet model. Its accuracy, memory, and F1-score metrics for detecting leaf diseases are reported as 0.957, 0.958, and 0.957, respectively. The model occupies a memory space of just 14.77 MB and can identify diseases in a leaf image in a swift 25.84 milliseconds. When compared to other existing methods, the MSO-ResNet demonstrated superior performance.

Below in table 2.1, recent research contributions are presented for apple disease detection based on environmental factors.

Table 2.1: Research Contribution for Apple Disease Detection

Authors	**Factors considered**	**Effect of factors on apple production**
Rana et al. [130]	Altitude	Apple farming is on the rise in the elevated regions of Lahaul, Spiti, and Kinnaur.
Sahu et al. [51]	Altitude	Apple production increases with altitude

Authors	Factors considered	Effect of factors on apple production
	temperature, relative humidity and duration of leaf wetness period	Conidia germinated across a broad temperature spectrum, ranging from 5°C to 30°C, with the ideal temperature for germination being 20°C. While conidia germinated effectively at all tested relative humidity levels (from 40% to 100%), optimal germination was observed at near-saturation humidity levels, exceeding 90%.
Sheel et al. [57]	different whether conditions.	Variations in climate and weather patterns significantly influence the cultivation and quality of apples.
Ahmadi et al. [59]	Temperature	A rise in air temperature could pose challenges to deciduous trees in Iran's colder regions.
Pramanicket al. [60]	global warming	Apple production decreases
Sharma et al. [61]	apple flowering phenology and weather parameters	Insignificant variations in weather conditions did not impact the phenologyor diversity of pollinators.
Eisavi et al. [62]	temperature changes/Lake Desiccation and AOP.	Temperature has played a significant role in altering AOP.
Argenta et al. [63]	growing site environmental conditions	“Fuji” apples grown in the chilliest location exhibited the greatest length-to-diameter ratio and watercore index upon harvesting, and they were more susceptible to CO2 damage and widespread flesh browning.

Authors	Factors considered	Effect of factors on apple production
Dong et al. [64]	effects of environmental conditions on sclerotium germination and hyphal growth of the pathogen	The ideal temperature range for the germination of sclerotium and hyphal growth of S. rolfsii is between 15 to 35°C, peaking at 31.5°C. Soil moisture must surpass 30% for optimal conditions, but beyond this level, it doesn't influence the germination or growth of the sclerotium and hyphae.
Juhnevica-Radenkova et al. [131]	effect of O3 treatment on the quality of different cultivars of apples	Ozone treatment shows promise for preserving the sensory quality and levels of biologically active compounds in apples during a six-month storage period. However, its efficacy varies based on the apple cultivar and the concentration of ozone used.

Conclusion: This chapter encapsulates the key findings from the literature review, emphasizing the importance of environmental factors in apple production and the emerging role of technology in disease management. It also identifies critical research gaps, setting the stage for future investigations aimed at enhancing the sustainability and productivity of apple farming.

The chapter presents a detailed exploration of how environmental factors such as temperature, humidity, light intensity, and rainfall significantly influence apple disease development. While these technical details are crucial, the narrative could be more cohesive in connecting these factors with the practical implementation of an IoT-based system. The proposed research leverages IoT to monitor these environmental conditions in real-time, providing a novel approach to disease prediction and management in apple orchards. By deploying sensors like DHT22 for temperature and humidity, BMP180 for altitude, and BH1750 for light intensity, the IoT system collects real-time data, which is then transmitted to a cloud server for analysis. This process allows the system to detect conditions favorable for disease development and provide timely alerts to farmers. The integration of IoT not only automates the monitoring process but also enhances the accuracy and responsiveness of disease prediction, addressing the gaps in traditional farming practices. Therefore, this chapter provides motivation for further emphasis on how IoT effectively covers these environmental factors.

CHAPTER 3

Factors Affecting Various Diseases in Apples andIts Possible Solution

The purpose of this chapter is to determine the various factors that contribute to the development of diseases in apples. An orchardist will have a difficult time determining the various factors that could lead to the development of diseases in an apple plant or apple fruit. When conditions are like these, the appearance of diseases that can impact the crop is probable. The proposed system would recognize the various parameters that have the potential to induce the appearance of disease, and it will then provide a warning to orchardists so that they can protect their crop.

There is a possibility that there are a great number of factors that can have an effect on the apple crop; however, there are a few major environmental and geographical factors, such as temperature, humidity, location, and height of the orchard, that are to blame for a variety of diseases caused by variations. Temperature, relative humidity, precipitation, snowfall, chilling hours, location, and height of the orchard are some globally established criteria that may be a major reason for the appearance of diseases in apple orchards. Other factors that may play a role in the appearance of diseases include: Apple growers may be able to protect their harvest by taking preventative measures, depending on the findings of an investigation that makes use of the Internet of Things (including Arduino Uno board, and sensors), which may reveal certain environmental conditions.

Background Study

The cultivation of any crop is dependent on the natural resources of any given region, particularly the soil, environment, and water resources of that region[132]. Apple orchards may thrive in Himachal Pradesh thanks to the region's fertile soil and temperate climate. The state is recognized across India as the "Apple Basket." The state's primary source of revenue comes from the sale of apples. It is a significant contributor to the overall economic health of the state. Apples account for 48 percent of India's overall production, and just this state is responsible for that [133].

Mr. Samual Evan Stokes was the one who first brought Apple products to Himachal Pradesh (also known as Satyanand Stokes). The country was in a poor economic state before the apple was brought there, but the apple altered the course of history for its people and changed the country's economic fortunes. As a result, it is now the most important cash crop in the state, and in the most recent years, apples have overtaken other fruit crops to become the most important crop overall [134].

The climate and terrain of Himachal Pradesh make it an ideal state for apple production. The state's name derives from the Himalayan Mountain range. However, because of climate change caused by global warming, this state and other NEIGHBORING states that produce apples are being negatively impacted by the situation. Changes in the climate, such as the retreat of glaciers and snowfall, an increase in temperature, a disruption in the pattern of rainfall, movement of the temperate fruit belt to higher altitude regions, AND an increase in the intensity of hailstorms [130].

When it comes to production, the quality of any crop is an important factor that needs to be taken into consideration. It is vital to recognize the diseases that may arise in the fruit or plant as well as the conditions that may encourage the appearance of diseases in order to create and deliver a product of excellent quality [55].

Apple trees in Himachal Pradesh are susceptible to a wide variety of infectious diseases, which lowers both the quality and the quantity of the fruit produced. Some of the fungal diseases that can affect apples are powdery mildew, Alternaria and Marssonina leaf blotch, root rot, apple SCABS, and others. Of these diseases, apple scab and leaf blotch are the most common and can be found in all apple-growing regions across the world. One of the economically significant diseases that can affect apples is called this. In order to prevent a significant drop in apple production across the state, eradicating these diseases has proven to be a difficult and problematic endeavor [135].

It's possible that eating apples could expose you to a number of different infectious diseases, many of which are caused by variations in temperature and humidity, as well as the geographic location of the apple orchard. Both ascospores and conidia have the potential to initiate infection [101]. There is a wide range of potential explanations for the manifestation of disease in the apple plant or apple fruit. However, certain aspects of geography and the environment, such as humidity, AND temperature play a significant part in the development of diseases.

Study Area

Himachal Pradesh is a state in India that is characterized by its hilly terrain and its wide range of climatic conditions. Apples are among the most important economic crops in the state because they thrive in the state's climate and geographic conditions [136]. However, at some point in the future, the effects of climate change will become a difficulty for apple growing. Apple trees are susceptible to a wide range of serious diseases as a result of frequent shifts in relative humidity, erratic rainfall patterns, hailstorms, and surface/environmental temperature. The apple-growing regions of Himachal Pradesh can be broken down into three distinct categories according to their elevation: (a) high altitudinal area [Lahaul & Spiti, Kinnaur, and Chamba 2500-3500 m and above]; (b) mid altitudinal area [Mandi, Kangra, Shimla, and Kullu, 1500-2500 m and above];

and (c) low altitudinal area [Solan] [137].

Materials and Methods

The state of Himachal Pradesh has been chosen in order to investigate the attitudes of apple farmers toward climate change and to determine the correlation between the following criteria and the occurrence of diseases in apples.

Effect of temperature on diseases development

Apples are susceptible to a wide variety of diseases, the growth, and appearance of which are greatly influenced by temperature. The majority of fungal diseases can manifest themselves at lower temperatures, but the majority of bacterial diseases, in comparison to fungal infections, become more severe when exposed to higher temperatures [138].

The pigmentation of the majority of plant species is determined by the relative concentration of three different pigments: carotenoids, chlorophyll, and anthocyanins. These pigments serve as an essential indicator of the overall health of the food. When temperatures are high, there is less of a concentration of the pigment anthocyanin in fruits. Apples are susceptible to a variety of diseases during the stages of fruit development if the temperature fluctuates between 10 and 30 degrees Celsius [52].

The following table 3.1 illustrates the diseases of apples which may be caused by temperature variation [139].

Table 3.1: Diseases of Apples by Effect of Temperature [140][141]

Disease Name	**Appearance Part**	**Reason for appearance**
Apple Scab	Fruit, flower, leaf	Average Temperature 20º C.
Marssonina leaf blotch	Leaf	High rainfall, temperature ranging 20-22º C.
Black Rot Canker	Fruit and Leaf	20-24º C temperature and moisture.
Powdery Mildew	Leaf, Fruit	Temperature lies 10-25º C.
Sooty blotch/ Fly Speck	Fruit	Temperature 18-27º C.
Alternaria leaf spot / Blight	Leaf	Temperature 25-30º C

Disease Name	Appearance Part	Reason for appearance
Seedling blight	Root	Low temperature below 24º C.

Effect of relative humidity on diseases development

By varying infection process, humidity triggers the diseases progressing. Rain and high humidity initiate diseases in different parts of the apple plant including fruit. The fiber density of the apple decreased more slowly at high relative humidity and the apple lost weight at low relative humidity [142]. Atmospheric humidity >70% is favorable for disease development and infection in apple plants. Powdery mildew, Core rot, brown rot, seedling blight, etc. are some common diseases of apples in Himachal Pradesh which are caused by high relative humidity [143].

The following Table 3.2 illustrates the diseases of apples which may be caused by relative humidity variation [143].

Disease Name	Appearance Part	Reason forappearance
Collar Rot	Root	Over-watering, moisture.
Powdery Mildew	Leaf, Fruit	Humidity is greater than 70%
Core Rot	Fruit	Warm weather and high Humidity
Brown Rot	Fruit	Humid wet conditions
Seedling blight	Root	High humidity.

Table 3.2: Diseases of Apple by Effect of Relative Humidity

Effect of location and height on diseases develop- ment

At the beginning of the 1980s, it was recognized that apple trees could be grown anywhere between 1200 and 1500 meters in elevation. Because to the rise in surface temperature over the past three decades [51], apple orchards have been forced to relocate to altitudes between 2500 and 1500 meters in the 2000s. As the average temperature of the earth's surface has increased, apple orchards have gradually moved higher. At this time in the state, apple trees are being grown at an elevation that is higher than 3,500 meters [144]. Increases in global warming have been linked to the introduction of diseases such as apple scab, Alternaria, Marssonina leaf blotch [5], fly speck, amongst others. When the climatic conditions support the optimal scenario, then these diseases sometimes may become endemic [53].

Possible Solution

It has been determined, on the basis of a number of earlier case studies, that climate change is the primary reason for the emergence of a number of diseases in apple [139]. The use of sensors could lead to the development of a prediction system that monitors various environmental elements. It may be able to anticipate the presence of disease using data from sensors and some fuzzy criteria [145]. In order for apple growers to be able to take the necessary steps to salvage their harvest [95].

IoT based Three Layer architecture

An IoT based three-layer architecture is proposed here to provide the possible solution for diseases prediction.

Input Layer or Hardware Layer

At this level, a number of different Internet of Things components are used to monitor different aspects of the environment, such as relative humidity and temperature [146]. The following elements serve as the basis for the measurement and monitoring of the disease-causing parameters:

- ESP8266 Wi-Fi Transreceiver
- Temperature and Humidity Sensor and DHT11/DHT22 [147]
- Light Intensity and Altitude Sensor BMP180 and BH1750

Transmission Layer

Data is sent through the wi-fi module of the input layer and is transmitted at this layer. The ESP8266 needs to be connected to the internet in order to send data over Wi-Fi Firebase, Google's Realtime Database, will be used to store the data that has been transmitted [148]. These data are collected in real time and serve as input for the software layer.

Application Layer or Software Layer

At this layer following applications are used to utilize the sensor data for prediction

Arduino IDE: An integrated development environment for the Arduino UNO microcontroller, which may be used to write software. This integrated development environment (IDE) is utilized in the proposed system to programme sensors and the ESP8266 Wi-Fi transceiver in order to sense/monitor and send the environment data of an apple orchard [149].

Google Firebase: The Firebase framework is helpful for the construction of portable and web apps for companies that require real time databases [150].

Android Studio: A powerful environment for the development of mobile applications [151]. To anticipate the conditions under which diseases may manifest, a graphical environment that follows certain principles and is programmed in Java could be constructed here [152].

Fuzzy Logic: Fuzzy logic benefits from including all of the various intermediate digital values that are not quite YES or NOT NO [153]. It provides a way for determining the many possible fluctuation values of humidity and temperature in order to make predictions regarding the environmental conditions under which diseases may become visible. The utilization of fuzzy logic makes it possible to assess a great number of fuzzy rules in order to arrive at an accurate forecast [154].

Conclusion: In conclusion, the chapter has highlighted the critical factors contributing to the development of diseases in apple orchards, emphasizing the challenges faced by orchardists in identifying and mitigating these factors. The significance of environmental and geographical elements such as temperature, humidity, location, and orchard height in causing diseases in apples has been underscored, along with the need for preventative measures to protect apple crops.

The study area, focusing on Himachal Pradesh, showcased the economic importance of apple cultivation in the region and the susceptibility of apple trees to various diseases due to climate fluctuations. The investigation into the impact of temperature, humidity, and other factors on disease development in apples provided valuable insights for understanding disease patterns.

Proposing an IoT-based system utilizing sensors and data analysis, the chapter suggested a proactive approach to disease prediction in apple orchards. By leveraging technology and monitoring environmental parameters, orchardists can receive early warnings of potential diseases, enabling them to safeguard their crops effectively.

The three-layer architecture outlined for the IoT-based system presents a structured framework for predicting diseases in apples, integrating hardware components for data collection, transmission layers for real-time data transfer, and software applications like Arduino IDE and Google Firebase for analysis and prediction using fuzzy logic.

Overall, the proposed system offers a promising solution to address the challenges faced by apple growers in combatting diseases, ultimately aiming to enhance crop protection and ensure the production of high-quality apples. Implementation of such innovative approaches can revolutionize apple cultivation practices and contribute to the sustainability of orchards in the face of changing environmental conditions.

CHAPTER 4

Real-Time Application for Monitoring Apple Or- chard Disease Causing Environmental Factors us- ing Embedded System and Cloud Services

Agriculture has been the backbone of India's economy for generations. One-way farmers have boosted their income is by exporting fruits, enhancing the country's economic potential. In this paper, we present an Internet of Things (IoT) based framework specifically designed for Apple Orchards to detect Disease-Causing Environmental Factors (DCEF) such as temperature, humidity, light intensity, and rainfall. The goal is not only to identify these factors but also to offer a real-time system that is proficient in detecting and responding to conditions conducive to apple diseases. The real-time system design architecture is divided into three layers: first is physical layer, data transmission layer and application layer. The physical layer is deployed with sensors for identification of DCEF, then collected data is transmitted to the cloud server through transmission layer and finally at application layer automated monitoring is integrated with mobile application and for further analysis. For result analysis, proposed system is implemented and testing is performed in terms of processing delay. The experimental results show that our proposed work outperforms better as compared with state-of-art techniques.

Environmental Factors Affecting Apple Disease Diagnosis

Temperature plays a pivotal role in various plant processes, such as photosynthesis, transpiration, and respiration. As temperatures rise, these processes intensify. It's a critical element in plant growth. The anticipated temperature rise due to climate change is a key determinant in the alteration of plant diseases. Infection is most likely between temperatures of 18.3 to 30°C, especially when accompanied by rain or high humidity. Apple trees can be afflicted by numerous diseases caused by transferable agents like fungi, bacteria, viruses, and nematodes, as well as non-infectious factors like temperature, moisture, and soil conditions. Infections typically occur near petal fall, but can happen earlier if spring is warm. Favourable temperatures for specific diseases range from 60 to 80F, but can be as low as 50F if conditions are warm.

Lowest average temperatures for some processes have been found to be around 7°C or below. In some instances, consecutive chilling hours accompanied by sparse rainfall have shown maximum temperatures above 7°C.

Humidity is a second major factor. When relative humidity is excessive or airflow is restricted, a plant can't evaporate water or uptake nutrients, leading to potential rot. Diseases are especially prevalent in areas with consistent spring and early summer rainfall combined with cool, humid conditions.

To determine the favourability index for certain diseases, the impacts of weather on aspects like conidial production and germination are studied. This model relies on factors such as ambient temperature, humidity, and rainfall. A humidity level above 70% combined with high temperatures is essential for conidial germination. However, the fungus responsible for some diseases thrives in cooler conditions, becoming less active under unfavourable circumstances.

Climate changes have introduced new diseases to apple trees, such as scab diseases, premature defoliation, and alternation. These can become widespread if the climate provides an optimal environment for their spread.

Light intensity, another influential factor, determines plant food production, leaf color, stem length, and fruiting. Plants in low light usually have light-green leaves and are tall, while those in bright light are shorter with dark-green leaves. The three main light-related characteristics affecting growth are quality, quantity, and duration.

Higher light levels, especially at elevated altitudes, can enhance photosynthesis, leading to robust growth. At these altitudes, there's a reduction in carbon dioxide due to decreased air pressure. Carbon is vital for all plant life. The adaptability of the Apple strain to varying altitudes with changing chilling requirements highlights the growth of apple farming in cold deserts [58].

Technique Used for Disease and pest Detection and prediction

- It was previously stated that the majority of the diseases and insect attacks on the fruit or plant are related to excessive or less variation in temperature or humidity. As a result, the initial step is to create a hybrid device by making use of Internet of Things devices, as was covered in the previous section.
- Utilizing Internet of Things (IoT) boards equipped with sensors, the device will monitor the temperature and humidity level of the orchard and then transmit this data to the farmer's mobile device.
- An Android application that will be produced using Android Studio will be installed on the farmer's mobile device, and the installation of the application will take place.
- A database will be kept up to date with information concerning the details of illnesses and pests, as well as their ability to survive and the ideal conditions under which they may attack the plant or the fruit.
- When information is gathered from sensors, it will be analyzed with the

database. If the conditions are good (for illnesses or Pest), an alert will be created, and a prognosis for disease will be shown on the mobile app that farmers use.

- The application will provide the idea or advise on what actions a farmer could do after receiving notification about the possibility of illnesses or pests on fruit after the notification has been received.
- It's possible that spraying the orchard is the available mode, but it might also be managing the humidity and temperature level there instead.

1.

Methodology

In this work a methodology is presented for apple disease detection depending on environmental factors. The methodology focuses on identifying the factors that cause apple disease while integrating internet of things (IoT) applications in orchards. By utilising cutting-edge sensors and actuators, it is intended to transform orchards into intelligent orchards. This study used orchard monitoring data, including temperature, humidity, pressure, and light. The first section of the system design architecture consists of data transmission to a cloud server and automated monitoring for additional analysis. As part of the project plan, a hardware package for identifying the factors that cause apple disease will be made using microcontrollers and sensors. The microcontroller is connected to the sensing sensors to create a network of functionally ready devices. The software applications gateway will then be connected to the microcontroller, allowing it to receive and process data from the sensory devices.

The work presented the Internet of Things (IoT) and artificial intelligence together for predicting disease. Here IoT devices are used for sensing environmental factors such as temperature, light, altitude, and humidity from Apple Orchard. The data captured is processed on the Arduino UNO unit. The Wi-Fi module is used to send data to a cloud storage server and fuzzy logic is implemented to identify the type of disease.

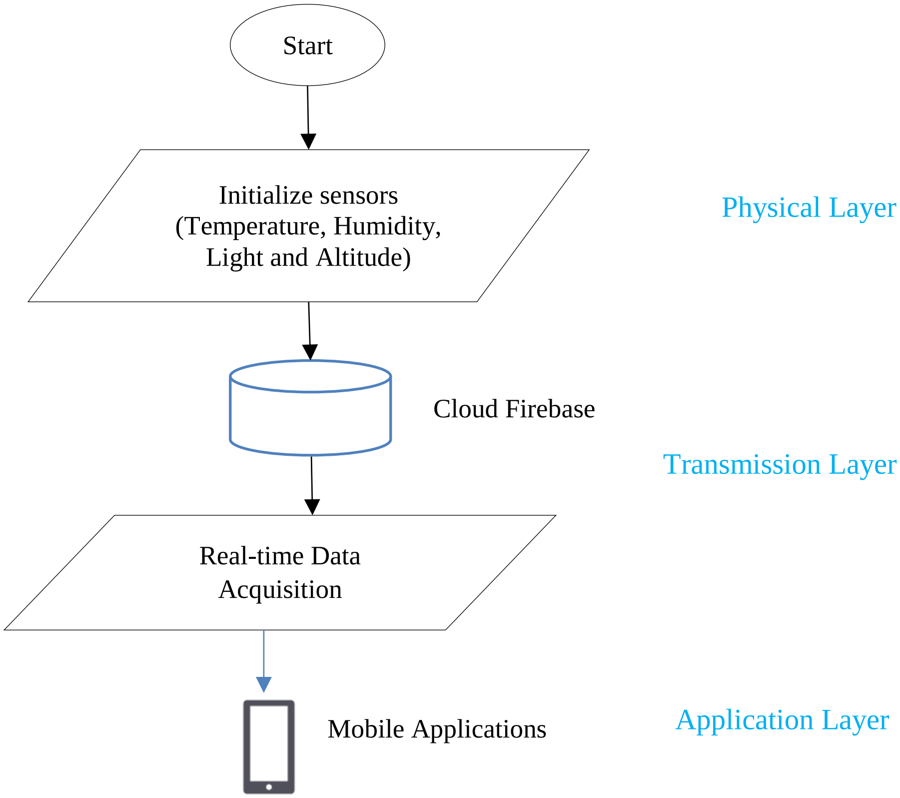

Figure 4.1: Working Flowchart

Fig 4.1 represents the flowchart of entire working that is being presented in this work. The entire work is divided into four basic steps: data capturing, data transmission, disease prediction, and recommendation, as presented in Figure 4.2. All these steps are discussed in below sub-sections.

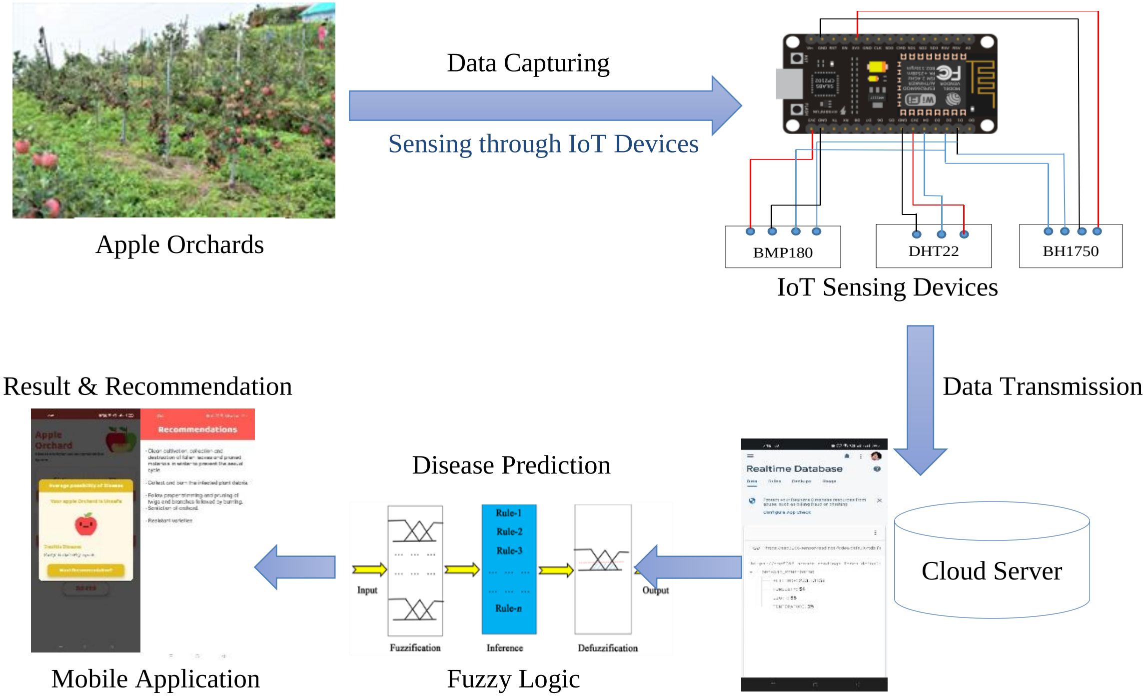

Figure 4.2: Working Steps for Apple Disease Detection

Data Capturing Layer

Using IoT sensors, environmental factors are gathered in this step. Four sensors have been set up to detect the environmental factors that can cause disease in orchards. For this, four different types of sensors, including the temperature and humidity sensor (DHT22), the altitude sensor (BMP180), and the light sensor, are utilized (BH1750). NodeMCU (ESP8266) is used to design and connect these sensors in a single circuit aside from these sensors. The experiment was performed in the apple orchard of Shimla, (H.P), India.

Algorithms used for data capturing are presented in algorithm 1.

Algorithm 1: Data Capturing

```
Begin
While (NodeMCU(status) == “ON”)
Temperature ←DHT22
Humidity ← DHT22
Altitude ← BMP180
Light ← BH1750
Data←{Temperature, Humidity, Altitude, Light}
End
```

In this step, four sensors are deployed that will sense the disease-causing environmental factors for Orchards. For this, four types of sensors are used, i.e., Temperature and Humidity sensor (DHT22), Altitude sensor (BMP180), andLight sensor (BH1750). These sensors are shown in Figure 4.3. Apart from these sensors, NodeMCU is used for designing and connecting these sensors in one single circuit as shown in Figure 4.4. The collected data is then stored at cloud database server (Firebase). All these components are discussed as below:

Temperature and Humidity sensor (DHT22): The DHT22 sensor, illustrated in Figure 4.3 (a), integrates two primary elements: a capacitive humidity sensing element and a thermistor for temperature detection. The foundation of the humidity sensor is a capacitor, where a moisture-retaining substrate functions as a dielectric between its two electrodes. As humidity levels fluctuate, there is a corresponding change in the capacitor's value. An integrated circuit (IC) within the sensor takes care of measuring, processing, and digitally converting these variations in resistance. For accurate temperature readings, the DHT22 makes use of a Low-Temperature Coefficient Thermistor. The unique property of this thermistor is that its impedance decreases as temperature increases. To ensure high sensitivity and responsiveness, the thermistor is typically manufactured from materials like semiconductor ceramics or polymers. This ensures a noticeable change in resistance, even for minute temperature variations. In terms of technical specifications:

- Temperature Range: The DHT22 can measure temperatures ranging from 0 to 50 ℃ with an accuracy of ±2℃.
- Humidity Range: It can detect relative humidity levels between 20% to 80% with an accuracy margin of ±5%.
- Sampling Rate: With a sampling rate of 1Hz, the DHT22 captures one measurement every second.
- Power Specifications: The DHT22 operates within a voltage range of 3 to 5 volts. During its measurement phase, it draws a maximum current of 2.5mA.

- Compact and efficient, the DHT22 sensor is an ideal choice for various environmental monitoring applications.

The Temperature and Humidity Sensor, also known as the DHT11, is a Regulated Digital Signal Output Device that also has the Capability to Sense Temperature and Humidity. A resistive element and a sensor for wet NTC temperature measurement devices are both included in this sensor. The sensor consists of four pins and is compatible with any Internet of Things board. It is a user-friendly sensor that is also very cost-efficient.

Altitude sensor (BMP180): The BMP180 replaces the BMP085, a new series of high-precision digital pressure sensors for consumer applications, with a function-compatible replacement. The I2C protocol makes it simple to integrate a system with a microcontroller. For EMC resilience, high precision, and linearity, as well as long-term stability, the BMP180 is based on piezo-resistive technology. Figure 4.3(b) illustrates the diagram of BMP180. The absolute pressure is measured by the BMP180 pressure sensor, as it is by many other pressure sensors, and the actual pressure varies with elevation. As a result, detecting the pressure may be used to compute the relative height.

Light sensor (BH1750): BH1750 is a digital ambient light sensor, as shown in Figure 4.3(c). It's an intensity of light sensors breakouts boards with a built-in 16-bit Analog to digital converter that can generate a digital signal without any difficult computations. This is a much more precise and user-friendly variant of the basic LDR, which merely produces a voltage that must be computed to receive useful data. The data from these sensors is instantly converted into Lux (Lx).

Node MCU: Node Microcontroller Unit is a hardware development environment and open-source software based on the ESP8266, as shown in figure 4.3(d), which is a low-cost System-on-a-Chip (SoC). The Espressif Systems designed the ESP8266 that contains all features of the essential components of a computer, including a CPU, RAM, networking (Wi-Fi), and even a current operating system and SDK. IoT board with a generic purpose that is the Arduino Uno. It features an 8-bit microcontroller that is included. It possesses all of the following characteristics:

- USB plug
- External power supply
- Digital I/O pins
- Analog reference pin
- Digital ground
- Serial In/Out
- Reset Button
- Microcontroller

- Circuit serial programmer
- Digital ground

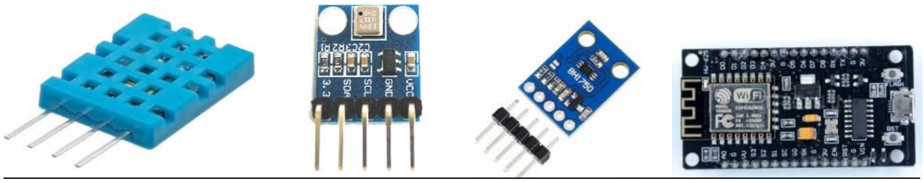
(a) DHT22 (b) BMP180 (c) *BH1750* (d) Node MCU

Figure 4.3: Sensors Used

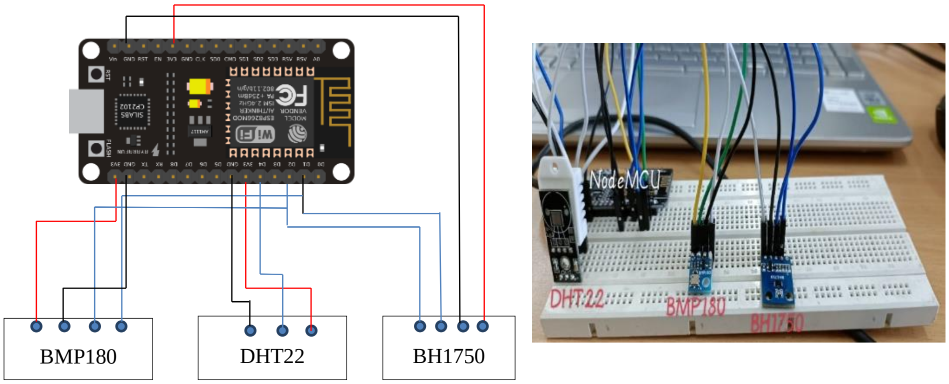

Figure 4.3: Circuit Diagram of Identification of DCEF for Orchards

Transmission Layer

At the transmission layer, a Wi-Fi transceiver is utilized. This component is a highly integrated semiconductor that facilitates wireless connections with android applications. In this case, an ESP8266 is utilized to send the data from the sensor to Google's firebase real-time database. In this layer, real-time collected data are transmitted over internet for further analysis. For real-time data storage, this work used "Firebase". The information collected from sensors are send to cloud server for further processing. James Tamplin and Andrew Lee formed Firebase in 2011, but the company would not officially begin operations until April of the following year. The firebase framework is helpful for the development of commercial applications, both portable and web-based, that require real-time databases. It is utilized in the event that one user modifies a single record in the database and that modification needs to be promptly sent to all users. It offers a straightforward and unified environment in which multiple apps can coexist at the same time. When it comes to the development of the application, Firebase is responsible for the majority of the server-side work. The creation and management of a real-time database is made possible with the assistance of Google Firebase services. This database can be further connected to android applications in order to make use of the data that has been stored.

Application Layer

In this layer, the mobile application is linked with this server which displays the real-time data over mobile application i.e., android devices. On the basis of the aforementioned four criteria, the use of fuzzy rules is carried out for disease prediction and recommendation.

Disease Prediction and Recommendation

The paper employs fuzzy logic, specifically the Mamdani fuzzy inference system (MFIS), for predicting apple diseases. The system's operation is characterized by fuzzy rules that consist of linguistic variables (LV). These variables assume values within a term set that corresponds to real-world interpretations. The construction of MFIS encompasses the creation of a rule base (RB), a database (DB), and a method for defuzzification. The input to the proposed MFIS is a set of data $D = \{d_1, d_2, \quad d_n\}$.

The $d_n$comprises input parameter temperature, humidity, altitude, and light intensity, i.e.,$d_n = \{d_{temp}, d_{hum}, d_{alt}, d_{light}\} \mid d_n \in [d^r_{\min}, d^r_{\max}] \in R$.$d^r_{\min}$termed as minimum and $d^r_{\max}$ is the maximum values for the given environemntal variables as presented in table 4.1. The rule base of an $F_i \mid F_i \in FU$ is composed of R fuzzy rules, where FU is the universe of all possible MFIS. Further, for a given set of inputs, the R for F_i is limited as $R^{F_i}_{\min} \leq R^{F_i}_p \leq R^{F_i}_{\max}$.The fuzzy rules $R^{F_i}_p$is represented as input fuzzy set I_{F_i} $(R^p_{F_i}, \mu^p_{F_i})$ of $x$elements and output fuzzy set O_{F_i} $(R^p_{F_i}, \mu^p_{F_i})$f of y elements.

In the given scenario, the inputs are $d_{temp}, d_{hum}, d_{alt}, d_{light}$, where the out-put is disease occurrence possibility as $d_{high}, d_{average}, d_{low}$.Therefore $|x| = 4$ *and* $|y| = 1$, respectively. The membership function,μ_{F_i} shows relation between I_{F_i} $R^p_{F_i}, \mu^p_{F_i}$and O_{F_i} $(R^p_{F_i}, \mu^p_{F_i})$. The database, DB of μ_{F_i} is evaluated according to Cauchy function, that is represented as:

$$F_{(I_{F_i},\ cent,\ h,\ s)} = \frac{1}{1 + \left|\frac{I_{F_i} - s}{cent}\right|^{2s}} \tag{4.1}$$

Where, *cent*= center of membership function

h= half-width of membership function

s = slope at crossover point of the membership function.

The rule base is represented as:

$R^{p}_{F_i}: IF\ I^{temp}_{F_i} is\ LV^{x_{tem}}_{n_j}\ and\ I^{hum}_{F_i} is\ LV^{x_{tem}}_{n_j}\ and\ I^{alt}_{F_i} is\ LV^{x_{tem}}_{n_j}\ and\ I^{light}_{F_i} is\ LV^{x_{tem}}_{n_j}\ THEN\ LV^{y}_{n_j^{tem}}$. The article provides a selection of rules showcased in Table 4.2. The centre of area or centre of gravity (CoA/CoG) defuzzification technique, which is among the most commonly utilized, was chosen to obtain a clear output. To determine the fuzzified result, the centroid of all subsections within the resultant continuous membership function is pinpointed and then combined. The mathematical representation of the CoA defuzzification is as follows:

$$O^{prob}_{F_i} = \frac{\int_{n^{pprob}_{\min}}^{n^{pprob}_{\max}} f(x).xdx}{\int_{n^{pprob}_{\min}}^{n^{pprob}_{\max}} f(x)xdx} \tag{4.2}$$

Table 4.1 Fuzzy Rule Conditions [111][139]

Environmental Factor	**Conditions**	**Possibility**
Temperature	<18^{0}C	Low possibility of disease
	>18^{0}C	High possibility of disease
Altitude	<2500m (Low Hills)	High possibility of disease
	>2500<=3000 (Mid Hills)	average possibility of disease
	>3000 (High Hills)	Low possibility of disease
Humidity	<50%	Low possibility of disease
	>50%<=60%	Average possibility of diseases
	>60%	High possibility of disease
Light Intensity	<11000 lux (shady)	High possibility of disease
	>11000 lux (sunny)	Low possibility of disease

Table 4.2: Designed Fuzzy Rules

Temperature	**Altitude**	**Humidity**	**Light Intensity**	**Fuzzy output**
Low	Low	Low	Low	low
Low	Low	Low	High	low
Low	Low	Average	Low	Low
Low	Low	Average	High	Average
Low	Low	High	Low	Average

Temperature	Altitude	Humidity	Light Intensity	Fuzzy output
Low	Low	High	High	Average
Low	Average	Low	Low	Average
Low	Average	Low	High	Average
Low	Average	Average	Low	Average
Low	Average	Average	High	High
Low	Average	High	Low	Average
Low	Average	High	High	High
Low	High	Low	Low	Average
Low	High	Low	High	Average
Low	High	Average	Low	Average
Low	High	Average	High	High
Low	High	High	Low	Average
Low	High	High	High	High
High	Low	Low	Low	Low
High	Low	Low	High	Average
High	Low	Average	Low	High
High	Low	Average	High	High
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High	Low	High	High	High
High	Average	Low	Low	Average
High	Average	Low	High	High
High	Average	Average	Low	High
High	Average	Average	High	High
High	Average	High	Low	High
High	Average	High	High	High
High	High	Low	Low	High
High	High	Low	High	High
High	High	Average	Low	High
High	High	Average	High	High
High	High	High	Low	High
High	High	High	High	High

Conclusion

The integration of an IoT-based framework for apple orchards marks a significant advancement in agricultural technology, poised to transform how farmers manage their crops. By focusing on detecting Disease-Causing Environmental Factors (DCEF) such as temperature, humidity, light intensity, and rainfall, the framework provides a comprehensive solution for real-time monitoring and disease prevention. The multi-layered architecture—encompassing physical sensors, data transmission, and a user-friendly application—facilitates efficient data analysis, enabling farmers to respond proactively to potential threats to Apple health. The experimental results demonstrate the system's superior performance compared to existing methodologies, underscoring its potential to enhance crop yield and quality, ultimately contributing to India's agricultural strength and economic prosperity. As climate change continues to challenge traditional farming practices, implementing such innovative technologies will be crucial in ensuring sustainability and resilience in apple production, thereby supporting the livelihoods of farmers and the broader economy.

By integrating sensors, cloud services, and a mobile application, the system enables proactive responses to potential threats, demonstrating improved performance over existing methods. However, challenges such as integration with traditional orchard management and system robustness in extreme weather conditions were identified, suggesting the need for training programs and hardware optimizations. These challenges will be considered as limitation of the work.

CHAPTER 5

Results and Discussions

In this section, we have presented the results and discussion of the designed real-time application for apple disease detection and recommendations.

Implementation details

The development process involves two primary phases: the creation of an experimental prototype and the analysis of environmental factors impacting apple diseases and recommendation system. The prototype centres around an embedded system based on the Node MCU, connected to a remote server. For this, four types of sensors are used, i.e., Temperature and Humidity sensor (DHT22), Altitude sensor (BMP180) and Light sensor (BH1750). Apart from these sensors NodeMCU is used for designing and connecting these sensors in one single circuit. The collected data is then stored at cloud database server (Firebase). Fuzzy logic was integrated into the recommendation system using Android Studio as the primary development platform. The recommendation system was developed using Android Studio, a prominent application development platform. Within this environment, fuzzy logic techniques were employed to enhance decision-making processes, allowing for more nuanced and accurate recommendations based on varying input parameters. This integration enabled the system to process intricate data sets and provide more refined outcomes tailored to specific conditions.

Data Description

There are four stages in this development process: the experimental prototype, analysis of environmental variables, disease forecasting, and recommendations. The experimental prototype phase is focused on the initial setup and proper functioning of hardware components. Meanwhile, the analysis of environmental variables deals with collecting and examining environmental data before uploading it to a server. Central to this is the embedded system, built around the Node MCU, which communicates with a remote server. Sensors, which are mounted on a breadboard linked to the main microcontroller, facilitate data transmission. These primary sensors gather real-time environmental analytics and relay them to the system. The whole evaluation can be categorized into two parts: the deployment of an IoT-based system that incorporates sensors for humidity, altitude, light, and temperature; and data analysis at a remote server using software tools available on a mobile app. The data gathered aids in refining prediction outcomes.

Parameters Used

For result evaluation following parameters are used:

Response Delay: Time difference between start and end of execution is termed as response delay time, Res_{time}. Mathematically, it is represented as:

$$Res_{time} = |T_{stop} - T_{start}| \tag{5.1}$$

Where, T_{stop}= Stop Execution time and T_{start}= Start Execution time.

Accuracy: Accuracy is ratio between true prediction by total tested samples. Mathematically, it is represented as:

$$Accuracy = \frac{TP + TN}{Total\ Samples} \tag{5.2}$$

Where, TP = True Positive, TN = True Negative

Results Analysis

The producers of apples in Himachal Pradesh (shown in Figure 5.1(a)), as well as the relationship between disease development in apples, are both investigated in this article. The Himachal Pradesh apples producers' perspectives on climate change are presented. Apples are susceptible to a wide range of illnesses, the development of which is thought to be significantly influenced by temperature. In general, fungal diseases manifest themselves at temperatures that are lower, whereas the majority of infectious infections, in comparison to fungal infections, become more dangerous when exposed to temperatures that are exceedingly high [51].

During the growth phases of apple fruits, it is possible for a multitude of diseases to manifest if the temperature ranges from 10℃ to 30℃ [144]. The progression of diseases is also impacted by humidity since it modifies the way infections take place. Rainfall and high relative humidity both contribute to the development of illnesses in multiple parts of an apple plant, including the fruit itself. Humidity levels in apple plants that are greater than 70% are ideal for the growth and infection of disease. core rot, brown rot, seedlings blight and Powdery mildew are among the most common diseases that can be caused by high relative humidity in apples [144]. Himachal Pradesh is home to some of the most beautiful landscapes in the world. Apple trees are currently being cultivated at altitudes in Himachal Pradesh that are higher than 3,500 metres. The proposed system is put through testing with the Arduino IDE before the results of the analysis are analysed. Below are some screenshots of the system in its tested state, which can be found in this section. In figure 5.1, the data captured from each sensor are presented. The figure represents the reading obtained from each sensor collected from different locations. Figure 5.1(b) and figure 5.1(c) represents Realtime data collection and storage at cloud server and its display on mobile application. This helps in Realtime monitoring of apple orchards.

a. Real-time Experimental Site

Realtime Database

Protect your Realtime Database resources from abuse, such as billing fraud or phishing

https://esp8266-sensor-readings-fcdea-default-rtdb.fi

https://esp8266-sensor-readings-fcdea-default-

ORCHARD_MONITORING

ALTITUDE: 233.13158

HUMIDITY: 54

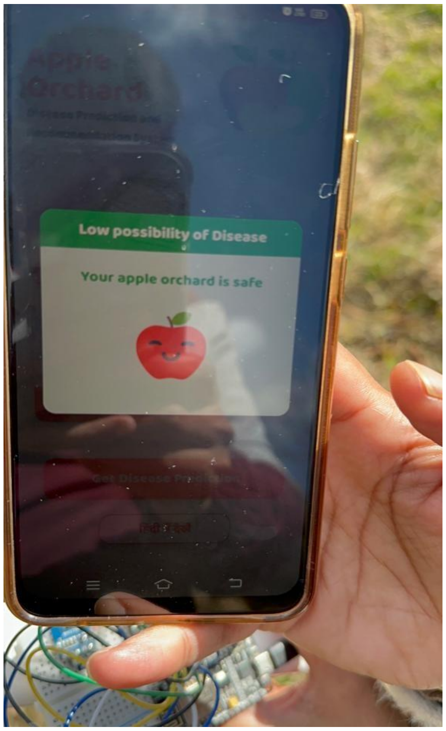
LIGHT: 56

TEMPERATURE: 25

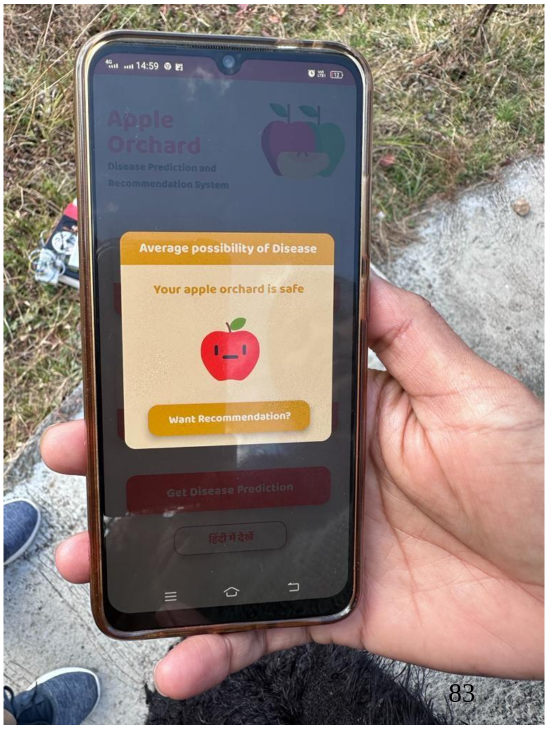
b. Real-time Cloud Database

c. Real-time Environmental Factor Monitoring on App

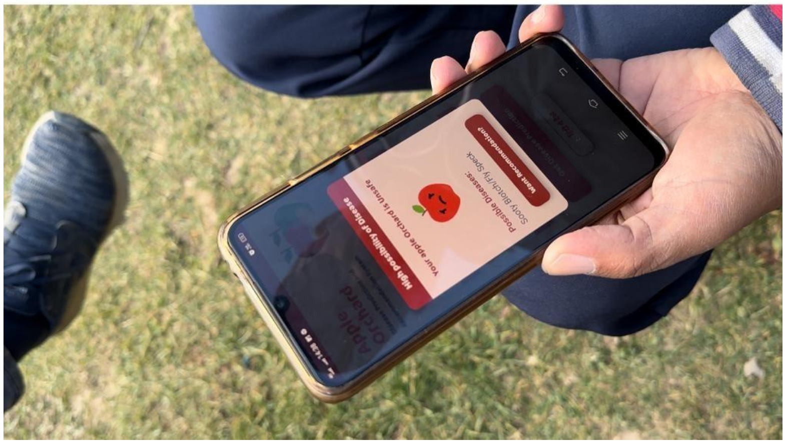
Figure 5.1: Real-time Experimental Setup



a. Prediction in High Light Intensity (Sunny)



b. Prediction in High Light Intensity (Sunny) and Lower Altitude



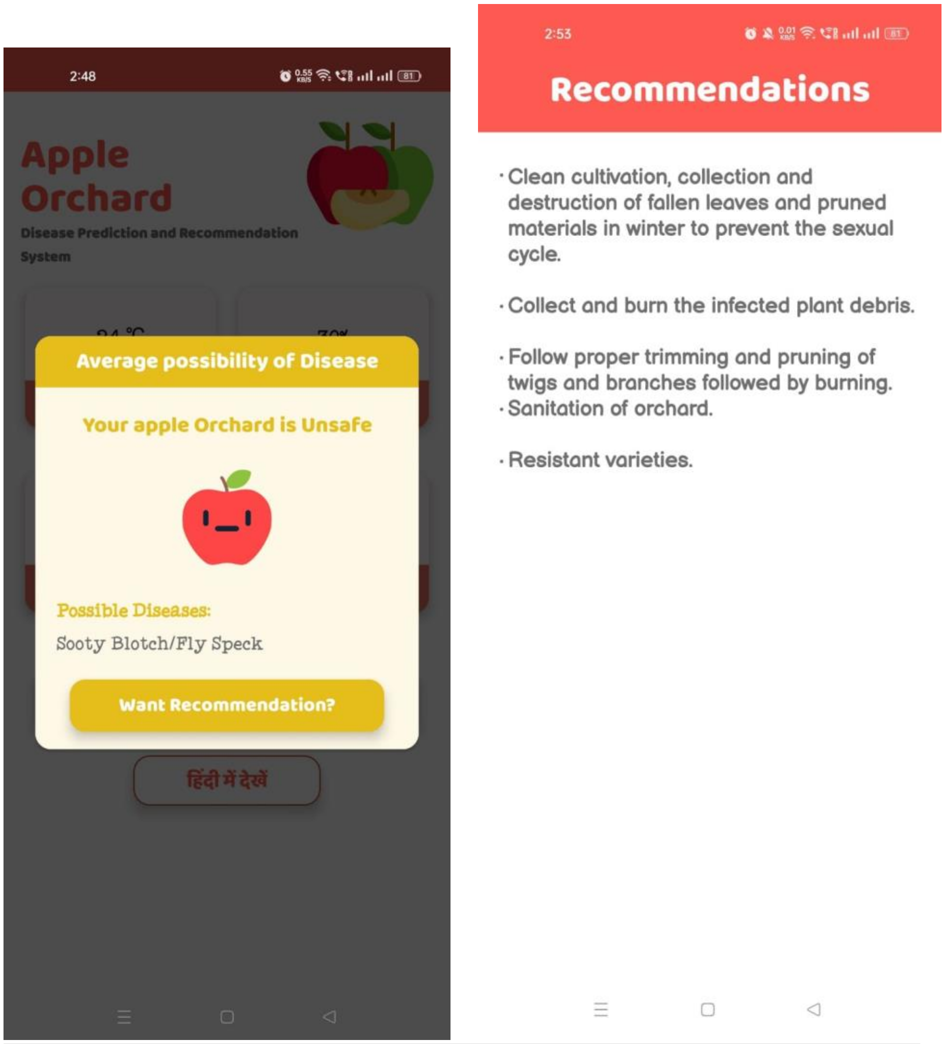
c. Prediction in Low Light Intensity (Shady) and Lower Altitude

Figure 5.2: Some Examples of real-time Prediction

a. Verification of Apple Conditions with Apple Orchard's Professionals

b. Verification According to Apps

Figure 5.3: Expert Verification for Disease Prediction



Average possibility of Disease

Your apple Orchard is Unsafe

Possible Diseases:

Sooty Blotch/Fly Speck

Recommendations

- Clean cultivation, collection and destruction of fallen leaves and pruned materials in winter to prevent the sexual cycle.
- Collect and burn the infected plant debris.
- Follow proper trimming and pruning of twigs and branches followed by burning.
- Sanitation of orchard.
- Resistant varieties.

a. Prediction Results b. Recommendations

Figure 5.4: Recommendation Result for Disease Prediction

Table 5.1 represents some samples of reading observed. Figure 5.5represents the Res_{time}evaluation of the proposed system to estimate the time delay occurred during data capturing. Similarly, Figure 5.6 represents the Res_{time}evaluation of the proposed system to estimate the time delay occurred during data transmission and figure 5.7 represents the $Res_{time}$for prediction and recommendation. Data samples are collected at different location and their delay (in sec) were observed. The average delay for data capturing was observed to be approx. 7 sec. Whereas the average time delay for data transmission was approx. 4 sec. Whereas, final prediction and recommendation shows an average of 2 sec time delay.

Table 5.1: Sample of Real-time Collected Data

Sample No.	Temperature	Humidity	Altitude	Light Intensity
1	25°C	59%	2146	6186 lux
2	26°C	60%	4234	5156 lux
3	25°C	64%	2354	4216 lux
4	27°C	69%	2325	6165 lux
5	25°C	73%	1353	6086 lux
6	26°C	54%	1235	3220 lux
7	28°C	78%	1478	3221 lux
8	24°C	46%	3438	6254 lux
9	25°C	64%	3566	6268 lux
10	26°C	79%	2357	3586 lux

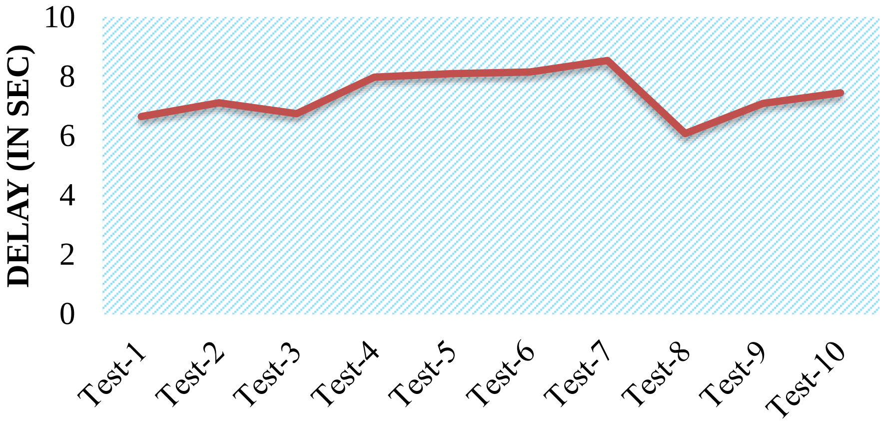


Figure 5.5: Time Delay Occurred During Data Capturing

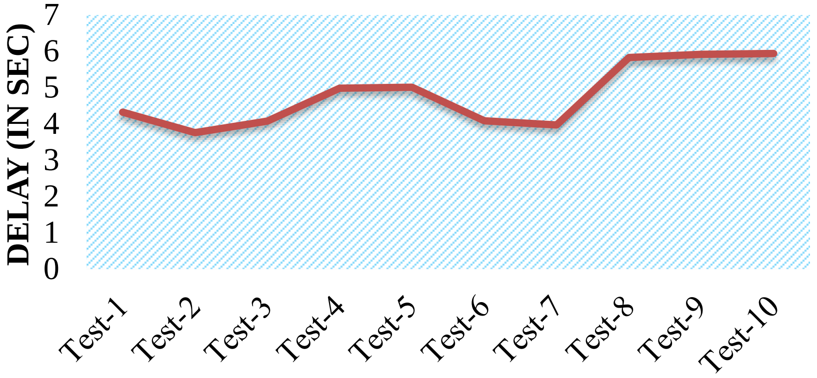


Figure 5.6:Time Delay Occurred During Data Transmission

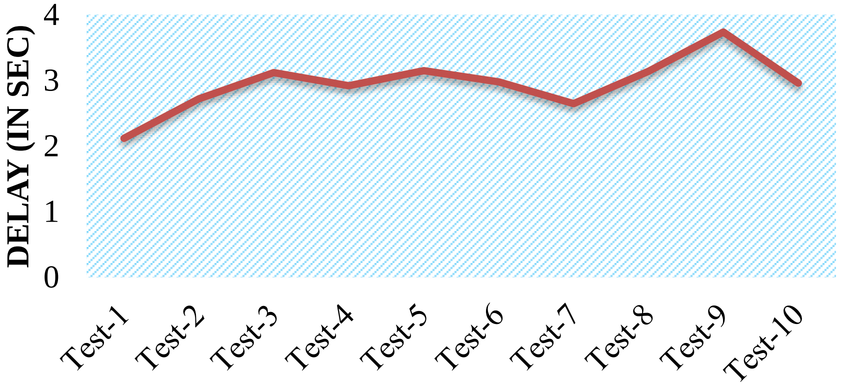


Figure 5.7:Time Delay Occurred During Disease Prediction and Recommendations

Below table 5.2 presents the accuracy of the proposed model. This accuracy was evaluated on the basis of samples collected quarter-wise. The accuracy of disease identification varies considerably across the samples, ranging between 77-86%. The average accuracy is approx. 82%. The number of samples collected varies widely. This might influence the accuracy in some cases.

Table 5.2: Accuracy of the Proposed Methodology

Quarter	**Samples Collected**	**Disease Identification**	**Correct Identification**	**Incorrect Identification**	**Accuracy**
Q1	3230	108	91	17	84.26%
Q2	4742	175	140	35	80.00%
Q3	4207	182	157	25	86.26%
Q4	3051	45	35	10	77.78%
Average					**82.08%**

Similarly, fig 5.8 presents the disease incidence through year from Jan-Dec in Shimla orchards. From observation, apple scab was most frequently in occurrence as compared to other diseases. In conclusion, while the disease identification method seems to be reliable on average.

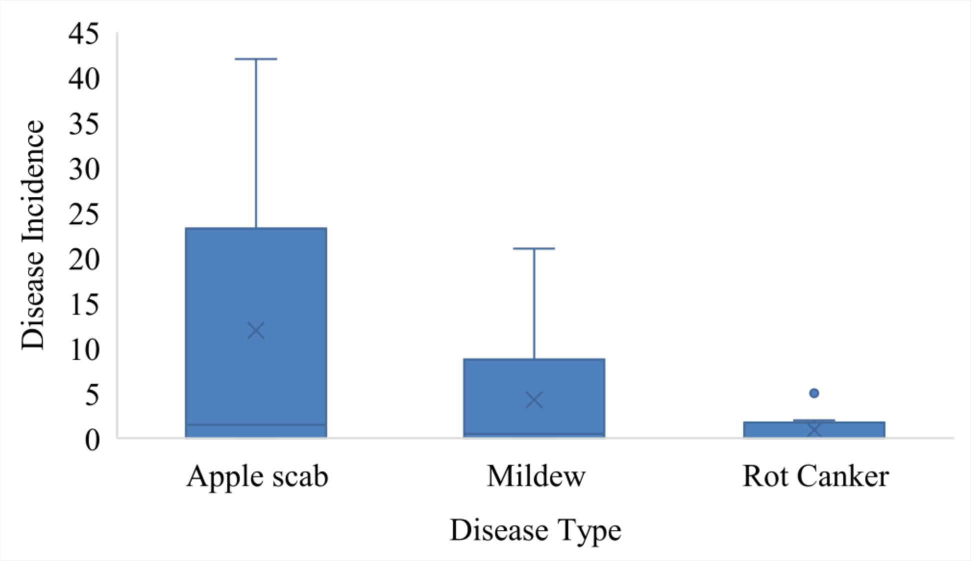


Figure 5.8: Disease Incidence

Validation

Fig 5.9 presents the accuracy comparison of the proposed model with existing model and it was observed that existing machine learning approach, SVM+NN[45] have achieved an average accuracy of 70% and our fuzzy based system have achieved an accuracy of 80%. Further investigation into these instances and refining the method might lead to even better accuracy rates.

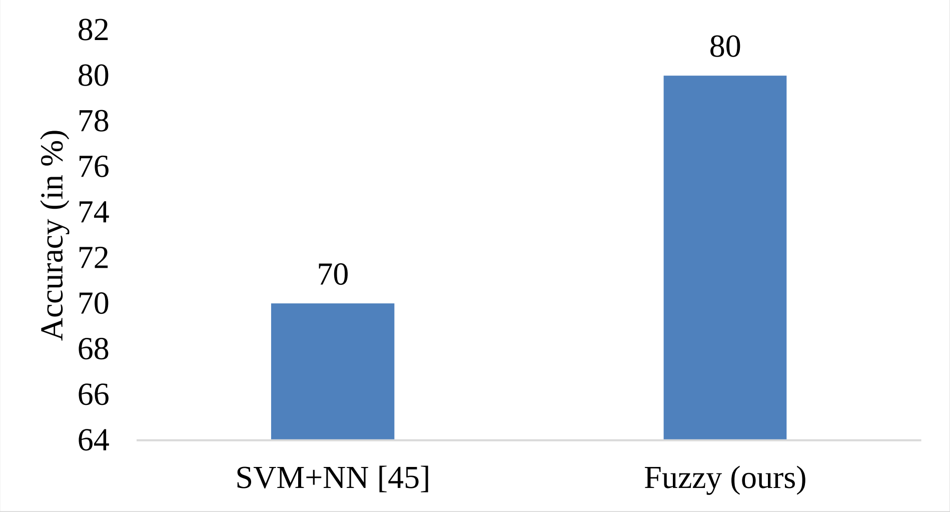


Figure 5.9: Accuracy Comparison

Table 5.3: Comparative State-of-art Features

Ref	IoT	MA	R_t	CS	Environmental Factors			
					Te	Hu	At	LI
[80]	×	×		×	×	×	×	×
[155]		×		×	×	×	×	×
[156]				×	×	×	×	×
[157]		×	×				×	×
[158]		×		×	×	×	×	×
[159]		×	×	×	×	×	×	×
[160]			×			×	×	×
Ours								

IoT= Internet of Things Application, MA = Mobile Application, R_t=Realtime, CS= Cloud Services, Te= Temperature, Hu= Humidity, At= Altitude, LI= Light Intensity, √ *= Feature Included, ×= Feature Not included*

The current state of the art is compared in table 5.3, which may be found here. In table 5.3, a comparison is made between the work that has been done by a variety of researchers and the work that has been done in the context of this study in the area of disease detection. The monitoring of diseases in real time in [147] is accomplished through the use of image processing techniques rather than the identification of environmental parameters. Internet of Things (IoT) is utilised in [148], alongside a real-time system, for the purpose of disease diagnosis by image processing; however, environmental elements are not taken into consideration. Researchers in the study [154] used image processing to detect disease, and one of the methods they used was the internet of things. The other two methods were mobile applications and real-time systems. Researchers predicted the occurrence of diseases using the internet of things by analysing environmental factors such as cloud service, temperature, and humidity. Their findings were published in [157]. The Internet of Things and real-time analysis are utilised in [157] as part of an image processing methodology for the purpose of disease detection. Only for the diagnosis of diseases using an image processing technique have researchers in [159] utilised the internet of things. The potential occurrence of diseases was predicted in [161] by employing a mix of the internet of things and mobile applications, as well as by determining environmental parameters like cloud service and temperature. In the current study, a combination of mobile application, IoT, and real-time is used to predict the potential diseases that will emerge in the near future by determining all of the environmental factors, such as temperature, humidity, pressure, light intensity and cloud service. This was accomplished by collecting data from mobile devices.

Conclusion: This chapter has presented the development and implementation of a real-time apple disease detection and recommendation system, integrating IoT technology with fuzzy logic. The system effectively utilizes multiple sensors, including temperature, humidity, altitude, and light sensors, to gather real-time environmental data, which is then processed and stored on a cloud server. By employing a mobile application developed on Android Studio, the system provides users with actionable insights into the health of apple orchards.

The experimental prototype was evaluated across various stages, demonstrating its capability to monitor environmental conditions and predict the occurrence of diseases with an average accuracy of approximately 82%. The response delay for data capturing, transmission, and prediction was observed to be minimal, indicating the system's efficiency in real-time monitoring and decision-making.

Comparative analysis with existing methodologies, such as the SVM+NN approach, highlighted the proposed system's enhanced performance. By incorporating fuzzy logic into the recommendation process, the system offers more nuanced and accurate disease predictions, contributing to better disease management in apple orchards.

CHAPTER 6

Conclusion

The exponential growth in technology has facilitated advancements in various sectors, and agriculture stands out as a domain that can benefit immensely from these enhancements. The research undertaken sought to address the pressing issue of apple disease detection in real-time, and the findings provide substantial insights into the progress made in this domain. The ultimate goal was to empower apple producers in Himachal Pradesh, an area known for its apple orchards, by enhancing their understanding of disease development influenced by environmental factors.

Relevant researches on the impacts of the environment on apple diseases should be carried out in accordance with new technologies that are already available, such as the internet of things. The monitoring of environmental conditions that could lead to disease in apples is becoming increasingly possible because to recent technological advances. The internet of things makes it possible for there to be a large number of different hardware supports available, any of which might readily record changes in the local climate and produce some kind of warning to protect apples from diseases. The current study summarizes its findings by describing the many parameters and the consequences of those parameters that have the potential to damage the apple crop in Himachal Pradesh. Apple producers may be supplied with a potential answer if the Internet of Things (IoT) is utilized in conjunction with some fuzzy rules and mobile applications. Following conclusions are devised:

In this work an Internet of Things (IoT) framework is used to detect the disease-causing environmental factors (DCEF) for Apple Orchards. Moreover, this work focuses on identifying the factors that cause apple plant disease such as like temperature, humidity, light, pressure, etc. The model discussed the framework in three layers, i.e., physical, transmission and application layer. All three layers are deployed for real-time environmental factor analysis for apple disease detection. For result analysis proposed system is implemented and testing is performed using NodeMCU.

The results highlighted the efficiency of the system, specifically in collecting real-time data on essential environmental parameters like humidity, altitude, light, and temperature. This granular data collection is vital, especially given the sensitivity of apples to a broad spectrum of diseases triggered by variations in these parameters.

A significant aspect of the research was the introduction and use of two evaluation parameters: Response Delay and Accuracy. The research elucidated that the average delay in data capturing was about 7 seconds, and the delay for transmission was approximately 4 seconds. These results, when coupled with the high average accuracy of around 80%, underscore the efficacy of the system.

It's essential to note that achieving such a high average accuracy in real-world applications is commendable and indicates that three out of every four disease identifications using this model are correct.

Moreover, the research showcased a comparative state-of-art model, shedding light on the current advancements in disease detection methodologies. By juxtaposing the presented methodology with other works, it becomes evident that while many focus on IoT or image processing for disease detection, very few incorporate an all-encompassing approach like the one presented in this study. This methodology, which integrates mobile applications, real-time data analysis, and environmental factors assessment, stands out for its comprehensive nature.

Limitations

The exponential growth in technology has facilitated advancements in various sectors, and agriculture stands out as a domain that can benefit immensely from these enhancements. This research aimed to tackle the pressing issue of apple disease detection in real-time, ultimately empowering apple producers in Himachal Pradesh. The study has shown how environmental factors significantly influence disease development, offering insights into more effective disease management.

While the system demonstrates promising results with an average accuracy of around 80%, several limitations were encountered during the study. One primary limitation was the variability in sensor accuracy under different environmental conditions. Sensor readings, especially for humidity and light intensity, were occasionally affected by factors such as dust accumulation and extreme weather conditions. To address this, future work could explore the integration of advanced sensor technologies with self-calibration features to enhance data accuracy. Additionally, incorporating machine learning algorithms to filter noise from sensor data could further improve the reliability of disease predictions. The response delay observed in data capturing and transmission indicates a potential area for improvement. Future enhancements could involve optimizing the communication protocol between sensors and the cloud database to reduce latency. Exploring the use of edge computing to process data locally before uploading it to the cloud could also be a valuable step, minimizing response times and enhancing real-time decision-making capabilities.

Future Scope

The strides made in this study hold promise for the expansion of technology-based disease detection and management tools in the agricultural domain. The following aspects highlight the potential future directions:

- Integration with Advanced Technologies: The introduction of Artificial Intelligence (AI) and Machine Learning (ML) can further optimize disease detection. As datasets grow with time, the system can learn and adapt, making predictions more precise and reducing false positives or negatives.

- Expand to Other Crops: While the current study focuses on apple diseases, the methodology can be replicated and tweaked to address diseases in other fruits or even staple crops. Such a move can enhance the yield and reduce losses across various sectors of agriculture.
- Cloud-based Analytics: By integrating cloud computing, data analysis can be done on a larger scale. This will not only provide a platform for centralized data storage but also facilitate real-time analytics and rapid feedback to farmers, regardless of their location.
- Improved Sensor Technology: As sensor technology continues to evolve, integrating more advanced sensors can lead to even more accurate data collection. Sensors capable of detecting minute changes in the environment, or even identifying pathogenic spores in the air, could be game-changers.
- Collaborative Efforts: Collaborating with agricultural research institutions, tech companies, and farmer groups can result in a more robust system that addresses specific needs while also gaining a broader acceptance.

Noteworthy Contributions Towards Society

- Enhanced Agricultural Productivity: By early detection and intervention of diseases, farmers can prevent large-scale losses, ensuring a consistent yield. This has a direct positive impact on the food supply chain, potentially stabilizing prices in the market.
- Educative Aspects: By integrating technology into farming practices, the methodology acts as an educative tool, bridging the knowledge gap. Farmers become more informed, leading to the adoption of better farming practices.
- Economic Upliftment: Especially for regions like Himachal Pradesh, where apple farming is a primary source of income for many, reducing disease-induced losses can lead to significant economic upliftment. Higher yields translate to higher incomes for the farmers.
- Environmental Benefits: Timely disease detection means that farmers can use pesticides and fungicides judiciously, only when necessary. This can lead to reduced chemical use, which is beneficial for the soil, water sources, and overall environment.
- Promotion of Tech in Agriculture: The research serves as a beacon, emphasizing the importance and benefits of incorporating technology in agriculture. This could motivate young tech-enthusiasts to innovate for

agriculture, a sector that, despite being crucial, often lags in technological advancements.

- Health Benefits: By ensuring the health of the crops, the end consumers also benefit. Healthier crops mean safer, more nutritious consumption, leading to a healthier society.

In essence, the methodology presented and its potential implications underscore the interconnectedness of technology, agriculture, and societal welfare. As we move towards an era of rapid technological advancements, such methodologies serve as a testament to the possibilities of harnessing tech for the greater good of society.

Potential Challenges and Limitations:

Data Accuracy and Sensor Reliability:

Sensor Calibration: The accuracy of disease prediction heavily relies on the precision of sensors used to measure environmental factors. Incorrect calibration or sensor malfunction could lead to inaccurate data, resulting in flawed predictions.

Environmental Interference: External factors such as dust, moisture, or extreme weather conditions could affect sensor performance, leading to data inaccuracies.

Data Transmission and Connectivity Issues:

Connectivity in Remote Areas: Apple orchards are often located in remote or hilly regions where reliable internet connectivity might be scarce. This could hinder the real-time transmission of data to the cloud server, delaying disease detection and response.

Latency in Data Processing: The proposed system depends on cloud storage for data analysis, which could introduce latency. Any delays in processing and responding to real-time data might result in missed opportunities to prevent disease outbreaks.

Climate Variability and Unpredictability:

Unpredictable Weather Patterns: Climate change can cause unpredictable shifts in weather patterns, making it challenging to rely solely on historical data or predefined environmental thresholds for disease prediction.

New Disease Strains: The system may not be equipped to detect emerging disease strains or those influenced by new climate conditions, limiting its effectiveness.

Scalability and Maintenance:

Scalability Issues: Scaling the system to cover larger orchards or multiple locations might require significant investment in additional sensors, infrastructure, and cloud resources, which could be cost-prohibitive for small-scale farmers.

Ongoing Maintenance: The system requires regular maintenance, including software updates, sensor recalibration, and hardware replacement, which may add to the operational costs and complexity.

Adoption and Usability Challenges:

Farmer Training: Successful implementation depends on farmers' ability to use the IoT-based system effectively. A lack of technical expertise or reluctance to adopt new technologies could limit the system's impact.

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