**Smart Ecosystem**

**Team Name: CODEHAWKS**

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1. **Use Case Overview**

**cloud farming**

Digital Twin concept represents the unification of the physical and the virtual world. Many say, Agriculture is the back bone of every country. So, to make agriculture still more modern and easy we bring in our concept called cloud farming, designed especially for the farmhand.

* 1. **Why Cloud Farming:**
* It generates data in real time and predict the problems in advance or give early cautioning and prevent interlude, develop new opportunities and even plan better Agri-lands for the future by using simulations.
* Predicts water problem in farmstead.
* Predicts crop diseases and gives preventive measures.
* Forecasts the climatic conditions like humidity, rainfall and manage the irrigation.
* Checks soil fertility.
* monitoring of water quality for optimal plant growth.
* controlling water usage and irrigation management.

1. **Use Case Description**

**CLOUD FARMING** guides farm-man in 6 areas which play a predominant role in a healthy farming.

* **Fertilizer management**: **Overuse of fertilizers can even drive to crop’s death.** To overcome this we help farmers in better fertilizer management via digital twin. Essential elements can occur in either of the physical form: solid, liquid or gas. we tend to deal primarily with solid and liquid forms of the elements in soil but the non-mineral elements as well as NO2 and S can also occur in gaseous forms. under certain soil conditions the chemical form of an element strongly influence how a nutrient reactswith other elements or compound found in the soil. Soil nitrogen is the most difficult nutrient tocharacterize, it occurs in organic and inorganic forms in soil and as a gas. As cations and anions plantroots absorb only the inorganic forms. Common forms of nitrogen contained in fertilizers and freshmanures includes NH3 and CH4N2O &(NH4) (NO3).
* **Simulation based crop yield prediction and providing feedback to physical system**: Running simulations periodically and predicting the yield can help farmers to increase the yield. Simulations are ran in the cloud (**EC2**) and feedback are provided to the physical system’s edge software to make changes to physical system immediately. This helps to improves the crop yield. Simulation is ran using mathematical model in **Simulink** and **Agricultural Production Systems Simulator (APSIM)**.
* **Rain based irrigation management**: Efficient water usage is the most spoken topic worldwide. So even in agricultural lands,water management is an important.Based on the factors like humidity, temperature, climate, etc.,we can determine the rainfall in advance. Predicting the rain fall lets us to manage the irrigation. For instance, if it is to rain tomorrow we can predict it today and the water used for irrigation can be minimized for today or tomorrow. We achieve this by training a model for rain prediction based on previous years data. We use **Logistic regression, Neural Networks** and **classification algorithms** such as **k-nearest neighbors** to predict the rain fall. The atmospheric humidity and temperature are sensed using **DHT22** and the values are sent to the cloud where the predictions are done by the models with the help of these data. The feedback is sent to the physical system based on the predictions made.
* **Disease detection**: Machine Learning and Computer vision had a tremendous growth in past few years. Why can’t we apply these ideas to improve agricultural yield? The detection of diseases can aid farmpeople to produce good crop yield. What if a picture of a plant can say what disease it is affected by.Predicting the disease and providing solution to it, ease the work of famers and crops can be protected before any major setback. The farmer feeds the **image of the affected plant** to our twin and the twin predicts the disease it may be affected by. This is done by by **feeding the image** into the **CNN model** we have trained and provide necessary steps to be taken to protect the crops. This reduces the time and man work of the farmers.
* **Irrigation Automation**: As water is most essential for an agricultural productivity, water management is important. Automated Irrigation distributes water automatically when required based on the parameters such as soil moisture, humidity, temperature and weather conditions. This smart system is based on IOT using Raspberry pi which has a control in soil moisture, temperature and humidity acting as a sensor. This sensing leads to distribute water only for a required amount as the soil moisture must not exceed its limit affecting the plants or crops. With the help of an Automated Irrigation system, energy and time consumption of a famer could be reduced and can be irrigated in an efficient way. The farmer could sense the status of any lifespan of plants or crops at any time by implementing Automated Irrigation system. A user interface is provided to the farmer to sprinkle the plants at any time on his wish. Using sensors, it is easy to identify that if there is a block in the tube and the farmer could rectify the problem occurred manually. The Automated Irrigation is cost efficient and could be implemented in any farm field. The soil **moisture**, humidity and temperature (**DHT22**) sensors are used to measure the moisture content, atmospheric water vapor content and temperature respectively. The moisture sensor produces output as analog signal and hence it must be converted to digital signal that could be acceptable by Raspberry Pi which interfaces with driver circuit connecting the water motor. The analog signals are converted to digital signals using **Analog to Digital Converter** (**MPC3008**). In accordance with the digital signals obtained, the water is distributed to plants or crops at regular intervals of time or when plants/crops are in need of water.
* **water quality**: Parameters such as salinity, ph and microbes’ presence is checked. Polluted or poor-quality water can affect plant growth. Some of the water quality problems are Salinity, Infiltration rate and Specific Ion Toxicity. Salinity is based on the salts present in soil that can reduce water availability to plants or crops. water Infiltration Rate is based on theRelatively high sodium or low calcium content of soil or water reduces the adequate supply of water to the plants or crops.Specific Ion Toxicity is based on the ions like sodium, chloride and boron from soil or water that can affect sensitive or weak plants or crops. These problems could be found by using water quality sensors. Some sensors have the ability to test the water with the help of pH values which differentiates acids and bases. These sensors are connected to Raspberry pi board. As Raspberry pi is connected to a driver, the farmer can identify the water quality problem (if exists) with the help of a user interface and also the distribution of water is halted automatically. The sensors used in water quality testing are cost efficient and are usable by the farmers.
  1. **Abstract**

Digital Twin concept is the next big thing in the agricultural sectors, which helps in accurately predicting the current state and future of physical assets by analyzing their digital duplicate. By implementing Digital Twins, farmers can gain better insights on their crop performance, improve crop yield and make better strategic decisions based on these insights.

“Agriculture is the back bone of India”

It is not completely possible to manage the Yield, Irrigation, Rain Water, Fertilizer, Quality of plant, Water Quality, and other miscellaneous factors that are been a pain to a farmer these days. Here we introduce our Digital Twin “Farm-X” to manage all those farmer works in a single conversation and an application.

**sensors used:**

* **DHT22** (Temperature and humidity): helps in automatic irrigation system that causes the system to shut down in the event of rainfall. DHT22 output calibrated digital signal. It utilizes exclusive digital-signal-collecting-technique and humidity sensing technology, assuring its reliability and stability. Its sensing elements is connected with 8-bit single-chip computer.
* **Moisture sensor**: Soil moisture sensors measure the volumetric [water content](https://en.wikipedia.org/wiki/Water_content) in [soil](https://en.wikipedia.org/wiki/Soil). Since the direct [gravimetric measurement](https://en.wikipedia.org/wiki/Gravimetric_analysis) of free soil moisture requires removing, drying, and weighting of a sample, soil moisture sensors measure the volumetric water content indirectly by using some other property of the soil, such as electrical resistance, dielectric constant, or interaction with [neutrons](https://en.wikipedia.org/wiki/Neutron), as a proxy for the moisture content. The relation between the measured property and soil moisture must be calibrated and may vary depending on environmental factors such as soil type, [temperature](https://en.wikipedia.org/wiki/Temperature), or [electric conductivity](https://en.wikipedia.org/wiki/Electric_conductivity). Reflected [microwave](https://en.wikipedia.org/wiki/Microwave) radiation is affected by the soil moisture and is used for [remote sensing](https://en.wikipedia.org/wiki/Remote_sensing) in [hydrology](https://en.wikipedia.org/wiki/Hydrology) and agriculture. Portable probe instruments can be used by farmers or gardeners.
* **MCP3008:** In [electronics](https://en.wikipedia.org/wiki/Electronics), an **analog-to-digital converter** (ADC) is a system that converts an [analog signal](https://en.wikipedia.org/wiki/Analog_signal), such as a sound picked up by a [microphone](https://en.wikipedia.org/wiki/Microphone) or light entering a [digital camera](https://en.wikipedia.org/wiki/Digital_camera), into a [digital signal](https://en.wikipedia.org/wiki/Digital_signal_(signal_processing)). An ADC may also provide an isolated measurement such as an [electronic device](https://en.wikipedia.org/wiki/Electronic_device) that converts an input analog [voltage](https://en.wikipedia.org/wiki/Voltage) or [current](https://en.wikipedia.org/wiki/Electric_current) to a digital number representing the magnitude of the voltage or current. Typically, the digital output is a [two's complement](https://en.wikipedia.org/wiki/Two%27s_complement) binary number that is proportional to the input, but there are other possibilities. The **analog signal generated by the moisture sensor is converted to digital** by using MCP3008.
* **DS18B20:** DS18B20 is a direct-to-digital **temperature sensor**. DS18B20 Digital Thermometer provides 9 to 12-bit (configurable) temperature readings which indicate the temperature of the device. The DS18B20 communicates over a 1-Wire bus that by definition requires only one data line (and ground) for communication with a central microprocessor. This sensor is used to determine the **soil temperature** to determine the **fertility of soil**.

**Physical system**

* The **Raspberry pi** sensors which are connected together are used to get the real time data from farmlands.
* The data received from the sensors is stored in the **ThingSpeak** platform. It is used for the collection and analysis of data. ThingSpeak platform provide a new approach to physical assets.
* The data is stored in ThingSpeak are accessed by digital twin in **EC2**.

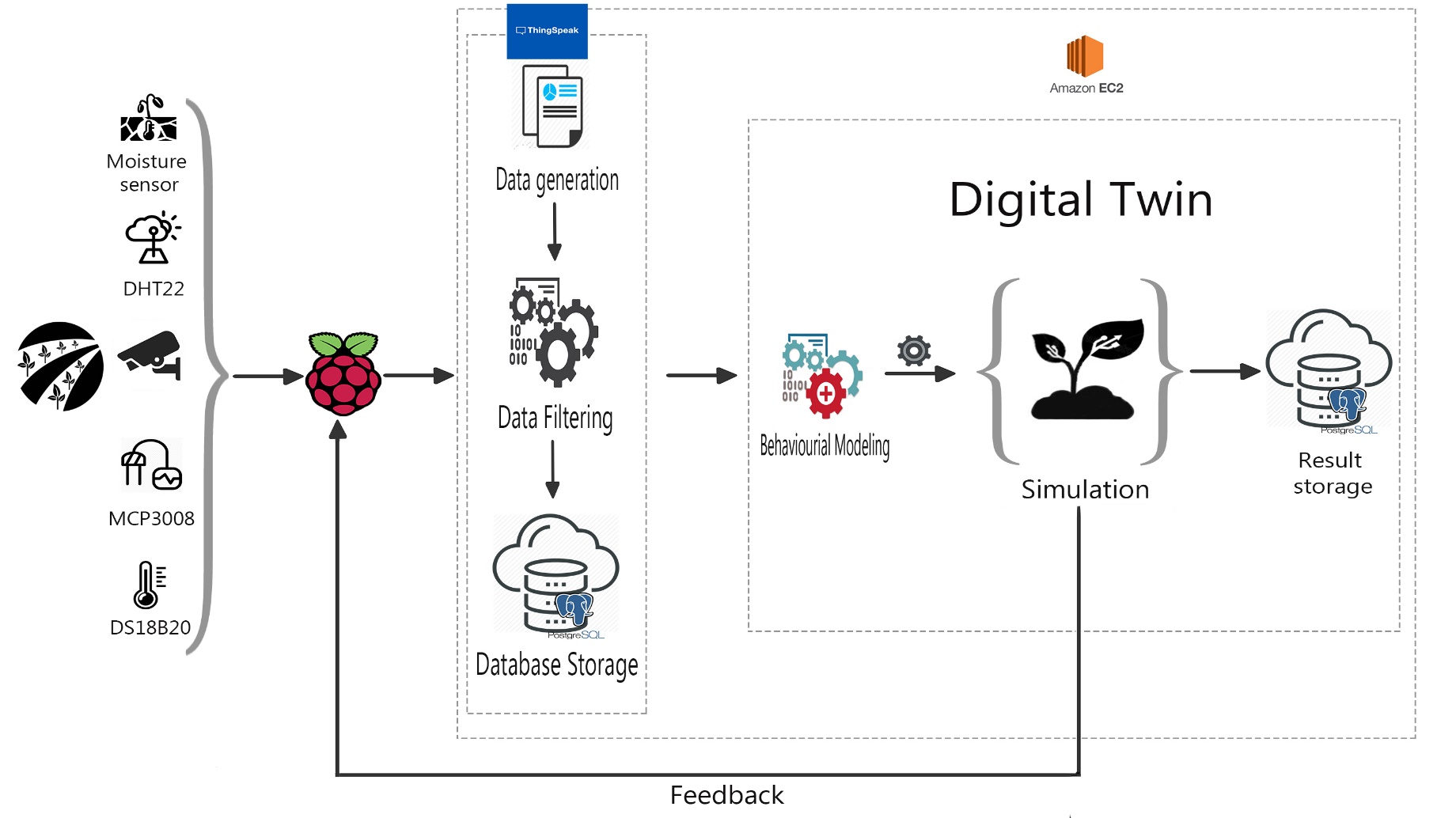
**Virtual system**

* Digital Twins, the virtual correspondence of the physical assets is created as digitalized duplicates of physical system using sensors.
* Digital twin suggests the crop conditions i.e., the real time conditions and even give useful measures for better farm-management.

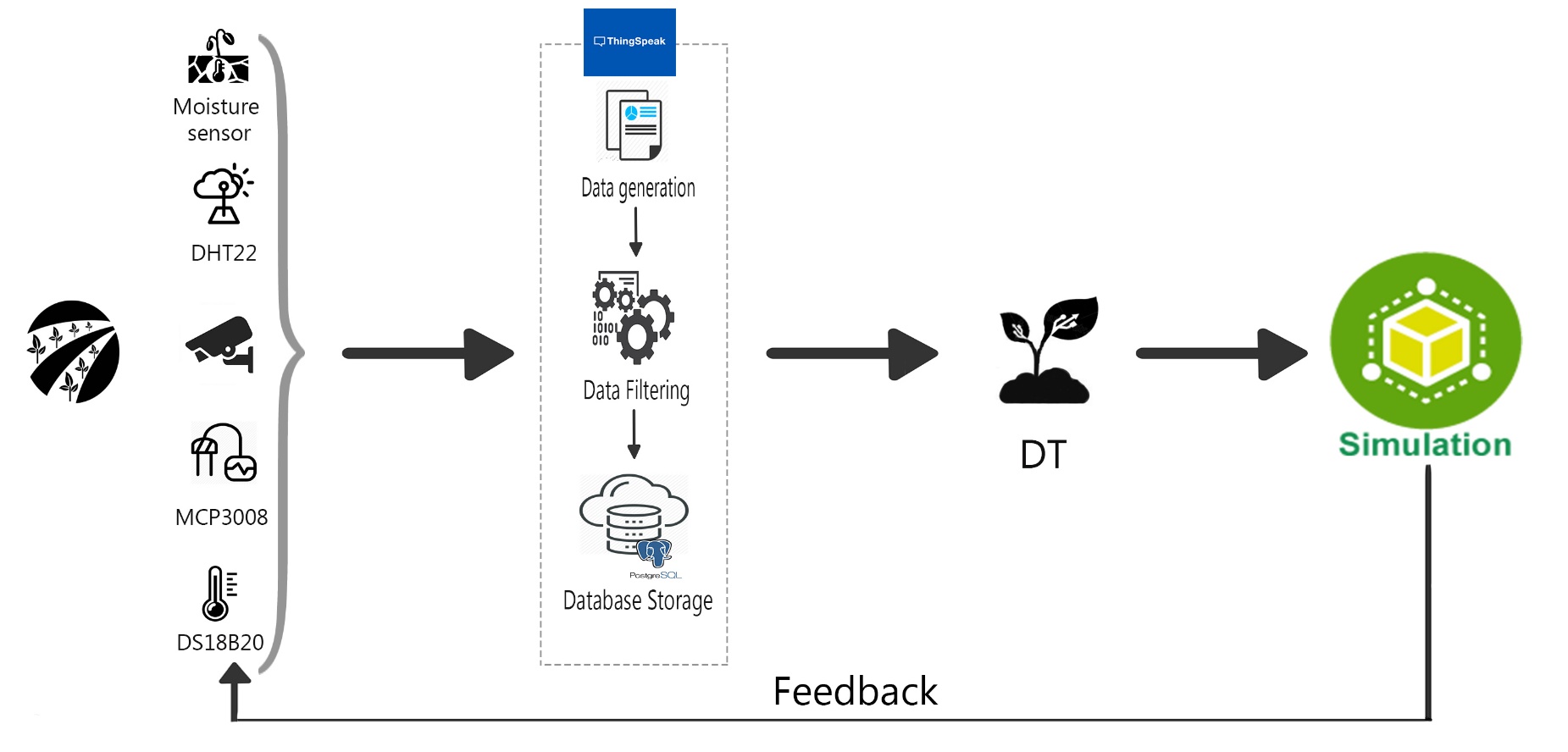
**Dataset**

* **Rain prediction**: **Climate Forecast System** (CFS)(<https://nomads.ncdc.noaa.gov/data/cfsr>).
* **Plant Disease Detection**: Referred from **PlantVillage Disease Classification** Challenge (**training data**: <https://crowdai-prd.s3.eu-central-1.amazonaws.com/dataset_files/1147c608-051e-437f-beed-4e9dccc88ee2/crowdai_train.tar?X-Amz-Algorithm=AWS4-HMAC-SHA256&X-Amz-Credential=AKIAILFF3ZEGG7Y4HXEQ%2F20180519%2Feu-central-1%2Fs3%2Faws4_request&X-Amz-Date=20180519T200700Z&X-Amz-Expires=604800&X-Amz-SignedHeaders=host&X-Amz-Signature=754a7896d472e96fffe1bb917d72f4d455eb8659a05c8c298a0ea9b1ca404cf5> ; **test data**: <https://crowdai-prd.s3.eu-central-1.amazonaws.com/dataset_files/2ab88525-0eff-4e3f-807f-345e2901eedb/crowdai_test.tar?X-Amz-Algorithm=AWS4-HMAC-SHA256&X-Amz-Credential=AKIAILFF3ZEGG7Y4HXEQ%2F20180519%2Feu-central-1%2Fs3%2Faws4_request&X-Amz-Date=20180519T200700Z&X-Amz-Expires=604800&X-Amz-SignedHeaders=host&X-Amz-Signature=086ef0b5e835325a2912550bb9168534a234457dd0058f6350986d333c8b31f6>).
  1. **Scope**
* Efficient time and labor management.
* Reduction in usage of fertilizers and hence money is saved.
* Good yield.
* Economical.
* Farmers are able to get good yield.
  1. **limitations**
* Certain sensors are too costly
* Farming is a low margin industry so the willingness to invest in innovation is low as well.

1. **Architecture:**

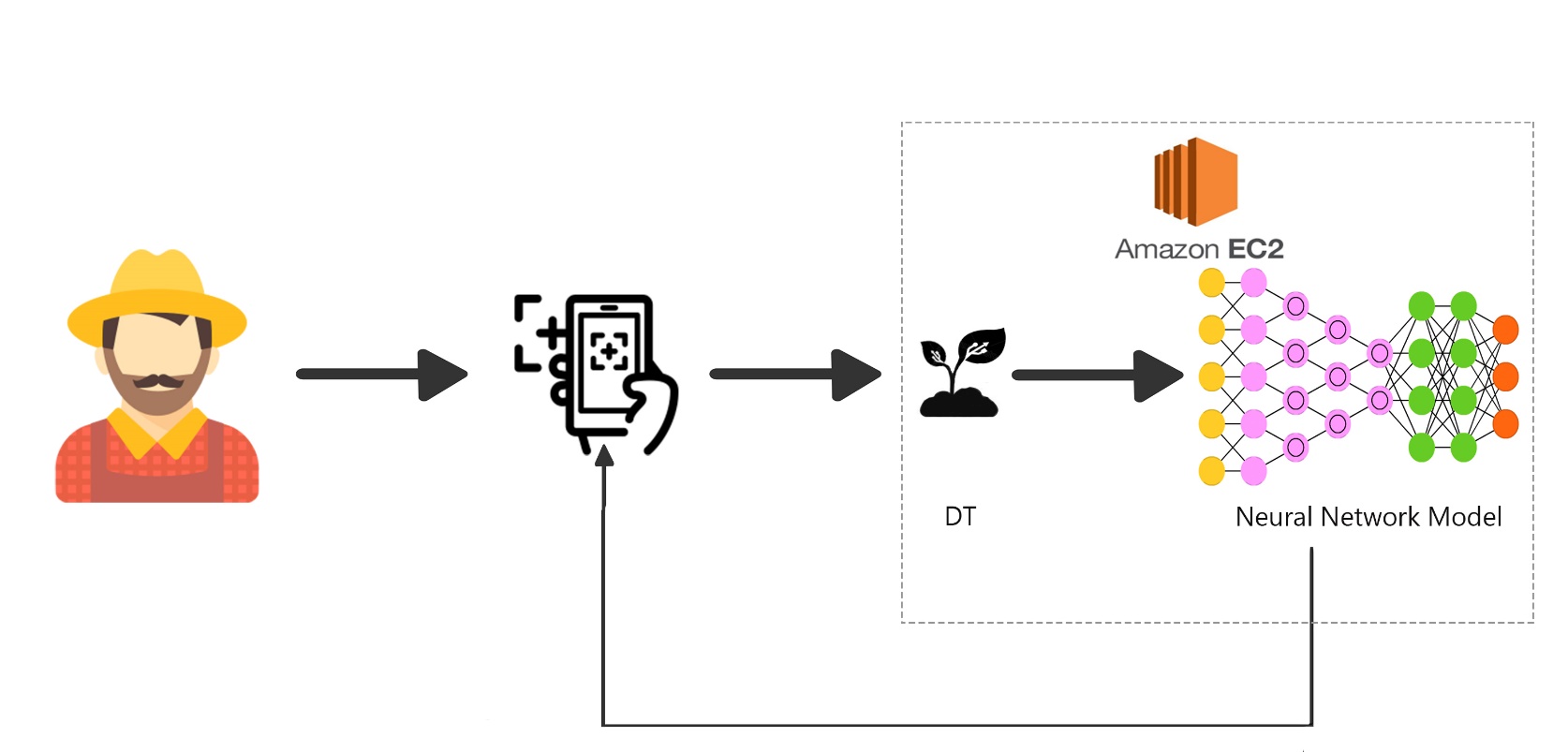
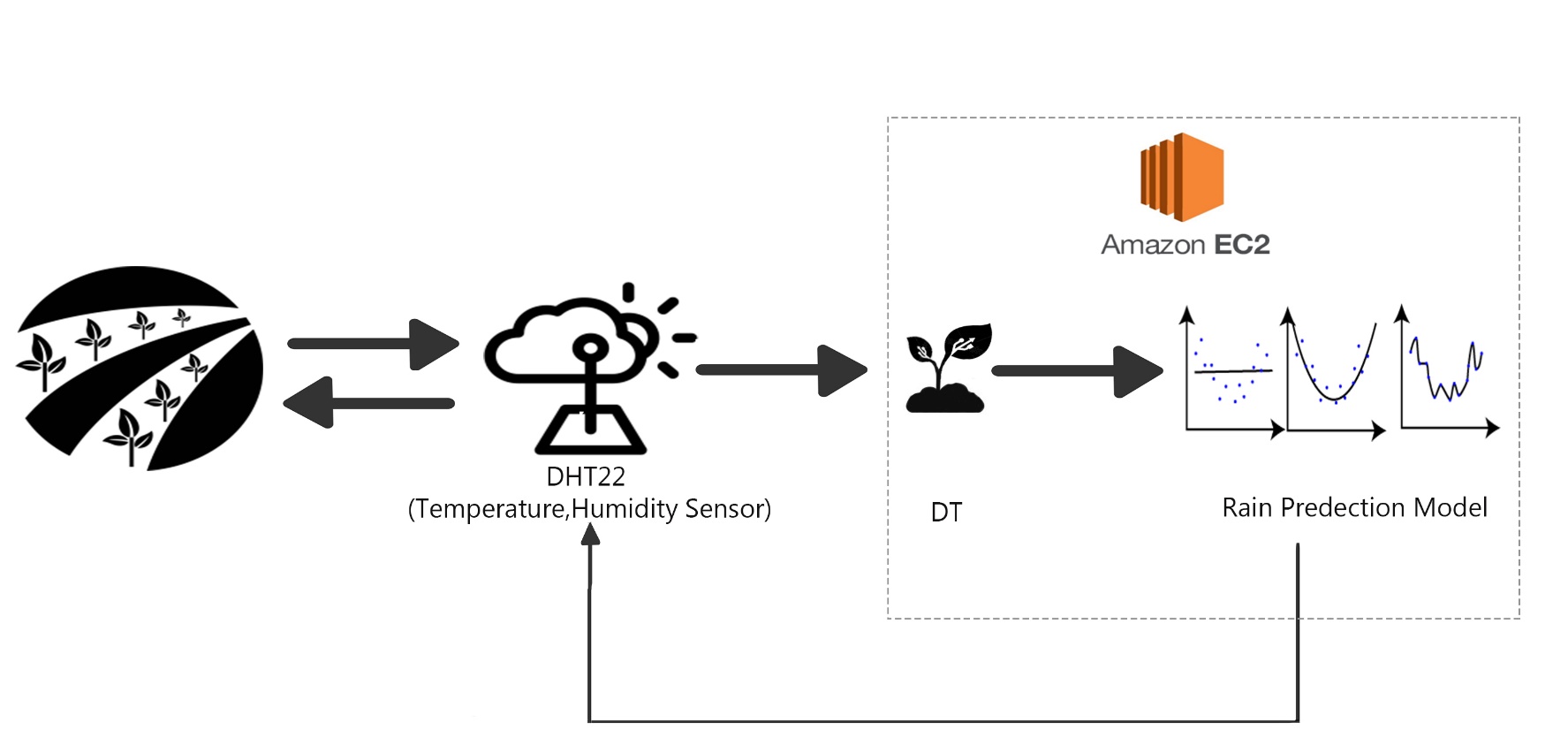


**3.1 General Architecture**



**3.2 Simulation Based Feedback to the Physical System**

**3.3 Fertilizer Management**

**3.4 Rain based Irrigation Management**

**3.5 Disease Detection**

1. **Tools and Environment**

**Modeling**

* **MATLAB:** MATLAB (matrix laboratory) is a [multi-paradigm](https://en.wikipedia.org/wiki/Multi-paradigm_programming_language)[numerical computing](https://en.wikipedia.org/wiki/Numerical_analysis) environment. A [proprietary programming language](https://en.wikipedia.org/wiki/Proprietary_programming_language) developed by [MathWorks](https://en.wikipedia.org/wiki/MathWorks), MATLAB allows [matrix](https://en.wikipedia.org/wiki/Matrix_(mathematics)) manipulations, plotting of [functions](https://en.wikipedia.org/wiki/Function_(mathematics)) and data, implementation of [algorithms](https://en.wikipedia.org/wiki/Algorithm), creation of [user interfaces](https://en.wikipedia.org/wiki/User_interface), and interfacing with programs written in other languages, including [C](https://en.wikipedia.org/wiki/C_(programming_language)), [C++](https://en.wikipedia.org/wiki/C%2B%2B), [C#](https://en.wikipedia.org/wiki/C_Sharp_(programming_language)), [Java](https://en.wikipedia.org/wiki/Java_(programming_language)), [Fortran](https://en.wikipedia.org/wiki/Fortran) and [Python](https://en.wikipedia.org/wiki/Python_(programming_language)).Although MATLAB is intended primarily for numerical computing, an optional toolbox uses the [MuPAD](https://en.wikipedia.org/wiki/MuPAD)[symbolic engine](https://en.wikipedia.org/wiki/Computer_algebra_system), allowing access to [symbolic computing](https://en.wikipedia.org/wiki/Symbolic_computing) abilities. An additional package, [Simulink](https://en.wikipedia.org/wiki/Simulink), adds graphical multi-domain simulation and [model-based design](https://en.wikipedia.org/wiki/Model-based_design) for [dynamic](https://en.wikipedia.org/wiki/Dynamical_system) and [embedded systems](https://en.wikipedia.org/wiki/Embedded_system).
* **TensorFlow:** Neural Networks is one of the fast-growing concepts in the field of ML. It is a replica of small portion of human brain. The working of NN is similar to the human brain. We train a Convolutional Neural Network to predict diseases by usingthe image of affected plant.TensorFlow is an open source software library for numerical computation using data flow graphs. Nodes in the graph represent mathematical operations, while the graph edges represent the multidimensional data arrays (tensors) communicated between them. The flexible architecture allows you to deploy computation to one or more CPUs or GPUs in a desktop, server, or mobile device with a single API.
* **SkLearn:**SkLearn is an opensource python library. It helps to build ML algorithms like **Linear regression, k-Nearest neighbor, support vector machines, random forests, gradient boosting, *k*-means and DBSCAN**, etc., faster and in a most efficient way. We use these algorithms for rain fall prediction, yield prediction from the results of the simulation.
  1. **Simulation**
* **Simulink:** Simulink is a simulation and model-based design environment for dynamic and embedded systems, integrated with MATLAB. Simulink, also developed by MathWorks, is a data flow graphical programming language tool for modelling, simulating and analyzing multi-domain dynamic systems. It is basically a graphical block diagramming tool with customizable set of block libraries.It allows you to incorporate MATLAB algorithms into models as well as export the simulation results into MATLAB for further analysis.
* **Agricultural Production Systems Simulator (APSIM):** A Crop Simulation Model (CSM) is a simulation model that describes processes of crop growth and development as a function of weather conditions, soil conditions, and crop management.Typically, such models estimate times that specific growth stages are attained, biomass of crop components (e.g., leaves, stems, roots and harvestable products) as they change over time, and similarly, changes in soil moisture and nutrient status.The **Agricultural Production Systems simulator (APSIM)**is internationally recognized as a highly advanced simulator of agricultural systems. It contains a suite of modules which enable the simulation of systems that cover a range of plant, animal, soil, climate and management interactions. APSIM is undergoing continual development, with new capability added to regular releases of official versions. Its development and maintenance is underpinned by rigorous science and software engineering standards.  The APSIM Initiative has been established to promote the development and use of the science modules and infrastructure software of APSIM.
* **ThingSpeak**: The sensors’ data and result generated in simulation is stored in ThingSpkeak platform.
  1. **Cloud**
     1. Amazon Web Service:
* **Lambda:**Lambda is service provided by Amazon for server less computation. We do add skill to Alexa so that the user can communicate with digital twin over voice. Alexa communicates with our Digital Twin through Lambda service.
* **Elastic Cloud Computing (EC2):** Elastic cloud computing is a service provided by the Amazon for hosting servers. EC2 servers replicates its images based on the load. We use EC2 to host our Digital Twin. The data form the sensors are sent to ThingSpeak and to EC2 securely.
* **ThingSpeak:** ThingSpeak is an [open source](https://en.wikipedia.org/wiki/Open_source) [Internet of Things](https://en.wikipedia.org/wiki/Internet_of_Things) (IoT) application and [API](https://en.wikipedia.org/wiki/API) to store and retrieve data from things using the [HTTP](https://en.wikipedia.org/wiki/HTTP) protocol over the Internet or via a Local Area Network. ThingSpeak enables the creation of sensor logging applications, location tracking applications, and a social network of things with status updates.
* **Alexa Skill Kit:** To provide voice over interface to our twin we use Alexa. Skills for Alexa are added in the Alexa Skill Kit platform. The Skills request handling and response are coded in lambda.

* 1. **Physical**
* Raspberry pi
* DHT22
* Moisture Sensor
* MCP3008
* DS18B20
* MATLAB
  1. **Edge Software and Service**
* **Android/iOS** **App** (for visual interface with the twin).
* **React Native** (Hybrid app development framework).
* **Alexa** (for voice over interface with the twin).

1. **References:**

* Fertilizer Detection: Proximal soil nutrient sensing using electrochemical sensors-C. Lobsey, R.A. Viscarra Rossel & A.B. McBratney.
* Disease Detection Dataset: PlantVillage Disease Classification Challenge.
* Rain Prediction Dataset: Climate Forecast System(CFS).