# Smart hydroponic agriculture using genetic algorithm based k-nearest neighbors

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**ABSTRACT**

In this research, researcher has implemented supervised machine learning, namely k-nearest neighbor (k-NN) which is optimized using genetic algorithms, and the internet of things (IoT) on the nutrient film technique (NFT) hydroponic system. The aim of this research is to improve the accuracy of classification of nutrient and light conditions in NFT system, and evaluating the harvest of hydroponic farming. The dataset was obtained by observing and recording nutritional and light conditions using sensors for 35 days during the growing period of lettuce in the NFT system, thus obtaining 1,680 data. Then, a training dataset is created based on that dataset. The system architecture is divided into 3 parts, namely the sensor system, data processing, and actuator system. The conclusion of this research is the IoT can be used to monitor the nutritional and light conditions of NFT system in real time and automatic control actions can be carried out using actuators controlled by the Raspberry Pi, the impact of applying the k-NN algorithm and the genetic algorithms is the accuracy of classifying nutritional and light conditions is 92%, the lettuce in a NFT system controlled by the system grow better than the lettuce in a NFT system controlled manually.



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## 1. INTRODUCTION

The world's population is increasing day by day. This causes the area of agricultural land to decrease. Therefore, a soilless agricultural solution is needed that can be applied in rural and urban areas. Hydroponics is a solution for farming without soil. Plants are given nutrients for their growth, namely mineral water enriched with nutrients. Several hydroponic methods are circulating method (nutrient film technique (NFT), and deep flow technique (DFT)) and non-circulating method (root dipping technique, floating technique, and capillary action technique) [1]-[3]. Several things that affect on hydroponic farming good nutritional conditions are the level of acidity or basicity (pH), electrical conductivity (EC) [4], and nutrient temperature [5]. The light intensity is affected on hydroponic farming also [6].

Modern technology has made farming in many fields-especially agriculture-better. This includes the IoT [7]-[11]. Research on smart hydroponics that applies machine learning and IoT has been carried out. hydroponics using IoT and machine learning was created by [12]. The results of this study show the accuracy of action controls is 88.5%. Integrating intelligence in hydroponic farms using IoT, recurrent neural network (RNN), and long short-term memory (LSTM) was researched by [13]. The results of this study show action controls on hydroponic farming based on RNN-LSTM output, so productivity was increased. Smart hydroponics system integrating with IoT, k-nearest neighbor (k-NN), and lasso regression was researched by [14]. The results of this study show plants grew quickly when plants grew based on k-NN and lasso regression. using support vector regressor (SVR), extreme gradient boosting (XGB), random forest (RF), and deep neural network (DNN) to predict hydroponically grown lettuce yield was researched by [15]. The results of this study show the 3rd scenario of SVR and 2nd scenario of DNN have the best performance. However, the 2nd scenario of DNN was preferred because it requires fewer variables input. Verma and Gawade [16] conducted research on a machine learning approach for nutrient uptake analysis and prediction systems for improved crop development in hydroponic systems. The study’s findings provide a clever and simple methodology for hydroponic crop growth rate (CGR) model prediction based on the machine learning paradigm.

Researcher was interested in applying the k-NN algorithm to the NFT systems. Different from ordinary programming algorithms, the k-NN is a machine learning method that requires human involvement only once at the beginning and then takes place automatically [17]. The k-NN algorithm has the ability to find special patterns to solve the problem. However, the k-NN algorithm has weaknesses [18], including: the value of k bias, complex computing, memory limitations, and gullibility with irrelevant attributes. Based on this weakness, then an IoT-based hydroponic nutrition control system will be created by applying the k-NN algorithm that is optimized using a genetic algorithm (called as genetic k-NN (GKNN) [19]) to predict the classification of nutritional conditions. In addition, the nutritional condition classification accuracy of the proposed systems is expected to be 90%.

This research is expected to be useful for developing the application of the k-NN algorithm and genetic algorithm based on the IoT and also provides alternative solutions for nutrition control systems based on the IoT in the NFT system. The paper is organized as follows. Section 2 presents the method, and section 3 validates it by results and discussion. The last section draws the conclusions.

## 2. METHOD

### 2.1. Hydroponic system design

Figure 1 shows the NFT system design. The system design consists of gutters (1) to flow the nutrient water, plant netpots (2) as a container for growing plants, cooling fan (3) as a nutrient water cooler. Furthermore, the system design also consists of a water pump (4) to circulate the nutrient water to the NFT system, several sensors (5) to monitor the nutrient water condition, water pump (6) to pump the nutrient water to the filter, filter (7) to filter the nutrient water. Several reservoirs are also used in this system design, including a water reservoir (8) as nutrient water containers, “A” nutrient reservoir (9) as a “A” nutrient solution container which is used to increase the EC value of the nutrient water, “B” nutrient reservoir (10) as a “B” nutrient solution container which is used to increase the EC value of the nutrient water, ph up reservoir (11) as a container for ph up solution which is used to increase the pH of the nutrient water, pH down reservoir (12) as a container for the ph down solution which is used to decrease the pH of the nutrient water. Raspberry Pi microcomputer (13) is also used in the design of this system.

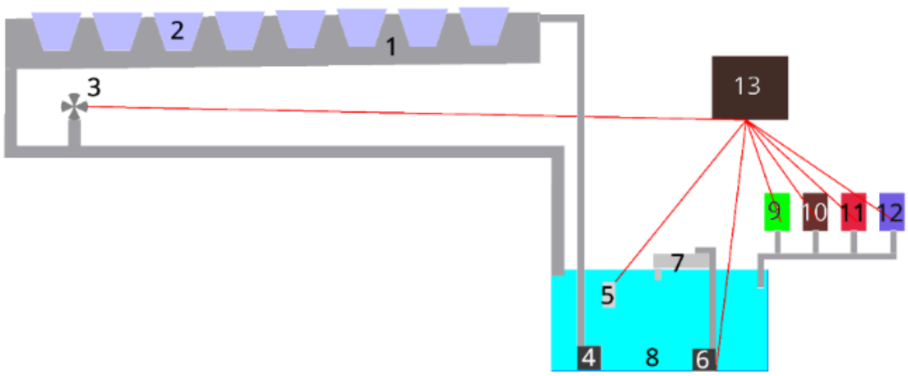



Figure 1. NFT system design

This research used lettuce. Good nutrient water for lettuce includes: 1700 µs/cm-2400 µs/cm of EC value [20], 5.5-6.5 of pH value [21], and 24 °C to 26 °C of nutrient water temperature [22]. In additional, lettuce needs 2152.78 Lux-4305.56 Lux of light. Lettuce will grow optimally if it gets 24 hours a day of light [6]. Table 1 shows the ideal conditions of nutrient water and light for lettuce summary.

Table 1. The ideal conditions of nutrient and light for lettuce

| | Minimum | Maximum |
|---|---|---|
| EC | 1700 µs/cm | 2400 µs/cm |
| pH | 5.5 | 6.5 |
| Temperature | 24 °C | 26 °C |
| Light | 2152.78 Lux | 4305.56 Lux |

## 2.2. Architecture system design

Figure 2 shows the architecture system design which consists of 3 parts, including a sensor system, data processor, and actuator system. The sensor system consists of a pH sensor (4), nutrient temperature sensor (5), EC sensor (6), and light sensor (7). These sensors will be connected to the Raspberry Pi. Data processing consists of Raspberry Pi module (1), GKNN server (2), and notebook (3). The data captured by the sensor will be sent to the Raspberry Pi. Then the data will be sent to the GKNN server. The GKNN server will store the data and classify it using the GKNN algorithm. The classification results will be sent to the Raspberry Pi. The data obtained by the sensor can be viewed using a notebook real time. The actuator system consists of solenoid valve placed in each solution reservoir (8), a hydroponic grow light (9), nutrient water-cooling fan (10), nutrient water filter (11), and a relay as an actuator (12). Based on the data obtained by the sensors, the actuator will receive instructions from the Raspberry Pi to turn on or turn off the solenoid valve, the hydroponic grow light, the nutrient solution cooling fan, and the nutrient water filter.

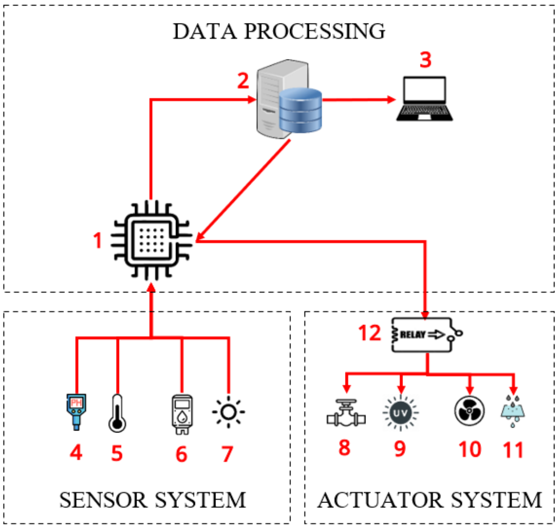



Figure 2. Architectural system design

## 2.3. Data acquisition method

This research uses observation methods to acquire the data. Overall, classifying ability depends on how well the data set represents the original distribution rather than its size [23]. Reduced datasets of even very small sizes achieve coverage identical or similar to the original datasets [24]. Data acquisition will be carried out by observing and recording the results of monitoring the sensors for 35 days during the lettuce planting period in the NFT system. Monitoring by sensors will be repeated every 30 minutes so 1,680 data will be acquired.

## 2.4. Determining k on k-NN algorithm

Classification is the process of finding models or functions that explain and differentiate data classes or concepts [25]. Unknown class labels of object are predicted using the models. k-NN is a classification method based on previously classified data. k-NN classification based on majority distance proximity from the category in the k-NN. Any new instance can be classified by the majority vote of its 'k' neighbours, where k is a positive integer, usually a small number [25]. A genetic algorithm is a method of searching and optimization that mimics the processes of evolution and modifications to the genetic makeup of real organisms [26], [27]. Genetic algorithm generates a sequence of populations by using a selection mechanism, where cross-overs and mutations are used as part of the search mechanism [28]. The three most common terminologies used in genetic algorithms are gene which acts as the entity that represents a particular characteristic of individual; chromosome comprises a string or collection of genes which represents an encoding of solution and; population is the collection of chromosomes [29]. Important factors in genetic algorithm include fitness values, genetic representation, and genetic operations [26]. In the selection process, the best individuals will be selected based on their fitness values. There are several selection process methods, one of which is the tournament selection method. Tournament selection perform better than other techniques in terms of convergence rate and time complexity [30], [31]. Genetic algorithm will be implemented to determine the value of k. Below is the pseudocode to determine the k value [19]:

1. From the training set, select k samples to create the initial population (p1).
2. Determine the fitness value by calculating the distance between training samples in each chromosome and testing samples.
3. Select the chromosome with the highest value of fitness. Save it as the global maximum (Gmax).
   a. Do for i=1 to L.
      i. Carry out the reproduction.
      ii. Utilize the crossover operator.
      iii. Carry out mutation to obtain the new population. (p2)
      iv. Determine the local maximum (Lmax).
      v. If Gmax<Lmax then
         a. Gmax=Lmax;
         b. p1=p2;
   b. Repeat
4. Output-The chromosome that receives Gmax has the best K neighbors, and the corresponding label is the classification result.

### 2.5. k-NN algorithm implementation

Figure 3 shows the implementation of the k-NN algorithm and genetic algorithm. The dataset will be created based on the observation data. A dataset is a group of data that is related to each other that can be manipulated by a computer as a single unit [17]. Then, based on the dataset, the training dataset will be created. Training dataset is the process of "training" to form a model based on a dataset. Each row of the training dataset will be labeled based on Tables 1 and 2. The training dataset will be split into 2, namely 30% as a test dataset and 70% as a training dataset. The next step is to determine the k value for k-NN based on the genetic algorithm. After that, the next step is to create a model and train it. Then, a scoring model is carried out based on the test dataset and training dataset. If the scoring model is good enough, then the k-NN model is tested to predict new data.

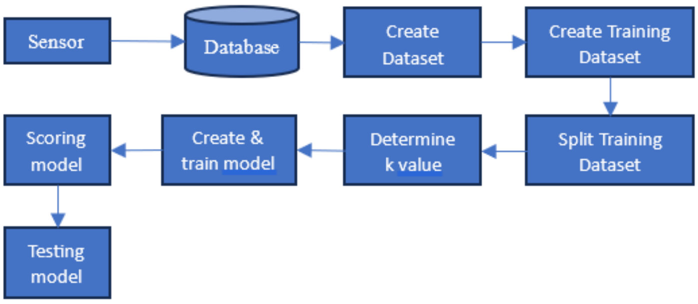



Figure 3. k-NN and genetic algorithm implementation

Table 2. Classification of nutrient condition and solution

| Label | Condition | Solution |
|---|---|---|
| 1 | pH normal, EC normal, temperature normal, light normal | - |
| 2 | pH normal, EC normal, temperature normal, light bright | - |
| 3 | pH normal, EC normal, temperature normal, light low | UV lamp On |
| 4 | pH normal, EC normal, temperature high, light normal | Cooler fan On |
| 5 | pH normal, EC normal, temperature high, light bright | Cooler fan On |
| 6 | pH normal, EC normal, temperature high, light low | Cooler fan On, UV lamp On |
| 81 | pH low, EC low, temperature low, light low | Solenoid valve ph up On, Solenoid valve nutrisi A B On, UV lamp On |

## 2.6. System implementation

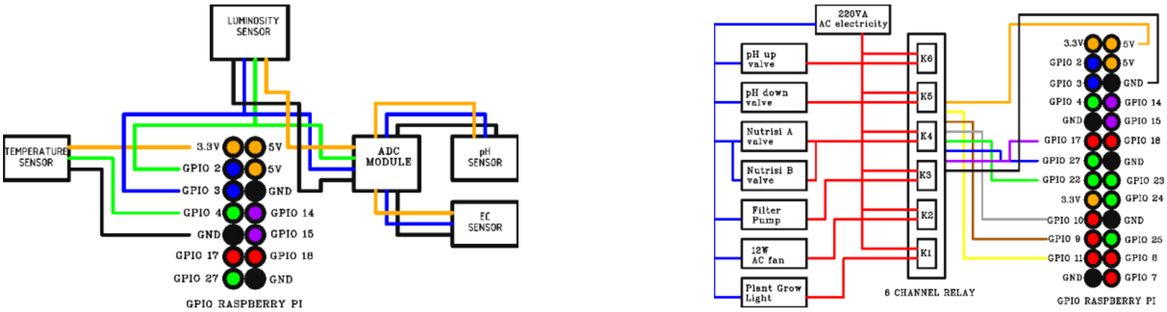
System implementation will be carried out to compare the yield of lettuce grown in an automatic NFT system compared to the yield of lettuce grown in a manual NFT system. In the manual NFT system, monitoring of nutrient water and light will be carried out once a day during the lettuce growing period in the NFT system. In addition, refilling the water reservoir will be done once a day at 0.5 liters. If the nutritional and light values do not match Table 1, action control will be taken manually.

# 3. RESULTS AND DISCUSSION

## 3.1. Sensor module and actuator module

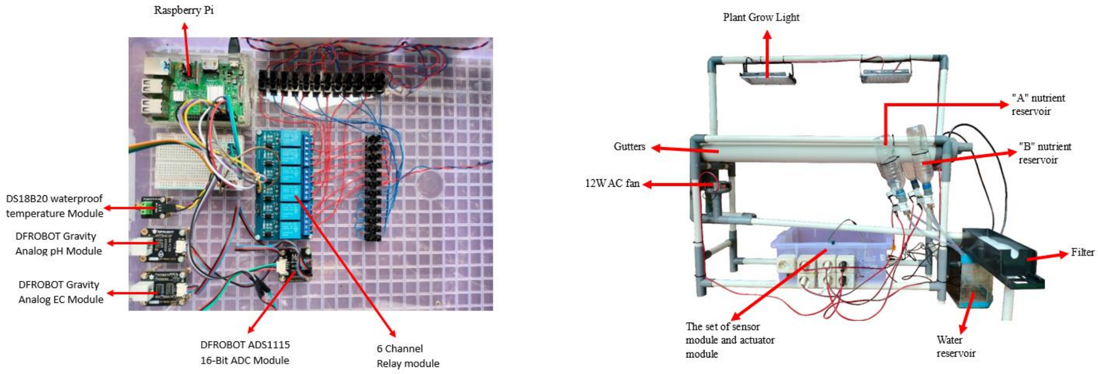
The sensor module consists of several component, including: analog pH sensor, analog EC sensor, ADC module, temperature sensor, luminosity sensor. These sensors and module were connected to the Raspberry Pi 3. Figure 4(a) shows the sensor module schematic.

The actuator module consists of several components, including: 6 channel relay module, solenoid valve, plant grow light LED lamp, 12 W AC fan, pump and water filter 6 channel relay modules were connected to the Raspberry Pi 3. Figure 4(b) shows the actuator module schematic. Figure 5(a) shows the sensor module and actuator module sets. The sets are placed in a box. Figure 5(b) shows the complete installation of the sensor module, actuator module, and NFT system.




(a) (b)

Figure 4. The schematic for: (a) Sensor module schematic and (b) actuator module schematic




(a) (b)

Figure 5. The final installation for: (a) the set of sensor module and actuator module and (b) installation of the sensor module, actuator module, and NFT system

## 3.2. k-NN server

k-NN server was built on google cloud by utilizing one of its cloud service models, namely infrastructure as a service (IaaS). This server is a web server and database server also. To create the model based on the training data, researcher implemented the k-NN algorithm on the k-NN server using the scikit learn library in python. In addition, based on pseudocode researched by [19], the researcher created the getK_n () function. This function is used to determine the value of k. Figure 6 shows the execution of the getK_n () function.

```
(base) budindares@instance-thesis1:~/thesis$ python3 getkn.py
k =  5
(base) budindares@instance-thesis1:~/thesis$
```

Figure 6. Execution of the getK_n ()

After the model is created, the researcher evaluates the model to predict the testing data output so that it is known whether the model is good or not. Figure 7 shows the evaluation results of the model. Figure 7 shows that the model has an accuracy of 92% so it is good enough to make predictions.

| | precision | recall | f1-score | support |
|---|---|---|---|---|
| accuracy | | | 0.92 | 6075 |
| macro avg | 0.92 | 0.92 | 0.92 | 6075 |
| weighted avg | 0.92 | 0.92 | 0.92 | 6075 |

Figure 7. Model evaluation

### 3.3. System implementation

The NFT system contains 16 netpots. System implementation began by filling the water reservoir with well water and then monitoring it with the proposed system. The goal of this step is to prepare the nutrient water the lettuce needs. This step took 121 minutes. Once the nutrient water was ready, the 7 days old lettuce was placed in the netpot. Lettuce was harvested after 35 days from being placed in the netpot. As a comparison, a manual NFT system was created also where nutrient monitoring was done manually once a day. The lettuce yields show that the average weight of lettuce in the NFT system controlled by the proposed system is 21.69 grams, while the average weight of lettuce in the manually controlled NFT system is 4.94 grams. Figure 8(a) shows the lettuce in the NFT system controlled by the proposed system. The lettuce grew well, and it was large. Figure 8(b) shows the lettuce in the NFT system controlled manually. The lettuce grew poorly, and it was small.

(a) (b)

Figure 8. System implementation results: (a) controlled by the proposed system and (b) controlled manually

## 4. CONCLUSION

In this research, it can be concluded, including utilizing IoT in NFT system can be used to monitor pH, nutrient temperature, EC, and light in real time without human intervention. Automatic control actions are carried out using actuators controlled by the Raspberry Pi microcomputer. Application of the k-NN algorithm to classify nutrient and light conditions. Application of the genetic algorithm to determine the k value in the k-NN algorithm so there is no need to run the k-NN algorithm repeatedly, so the k-NN server workload is lighter. The accuracy of the classification of nutritional and light conditions by the k-NN server was 92%. The lettuce in the NFT system controlled by the proposed system is better than the lettuce in the NFT system controlled manually. For the future, it is necessary to compare with other systems that use machine learning to find out whether the harvest from the proposed system is better or not. It is necessary to encrypt the data also, so the data exchange process is not easily hacked.

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