Agri-Aid: An Automated and Continuous Farmer Health Monitoring System Using IoMT

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Abstract. Along with smart infrastructures, smart institutions and smart services, having smart and healthy people is also a key component of smart villages. There are number of applications and tools that are designed to monitor the growth of the crop but there are little to none to monitor the health of the farmers. Healthcare is not a luxury and it should be accessible to everyone. With that said, Agri-Aid is an automated system that continuously monitors the physiological, vital, environmental and location based features which have a direct or indirect relationship on farmer's health. This device will analyze the features and will let the user understand and allow them to make small changes in the process of farming. When in the case of severe threat to life, the Agri-Aid will connect to doctors automatically for immediate care. Agri-Aid is designed in the IoMT framework and an accuracy of approximately 98% is observed.

Keywords: Smart healthcare · Healthcare Cyber-Physical System (H-CPS) · Internet of Medical Things (IoMT) · Farmer health · Farmer fatigue · Heat strokes · Pesticide exposure · Visually impaired · Hearing impairment · IoT-Edge Computing

1 Introduction

In any given economy, agriculture plays a very critical role. It is the foundation of the successful system for an entire life of an economy. Along with the food production and raw supplies, agriculture enhances the economic growth by creating various job opportunities. In 2020 in the United States, among 19.7 million jobs related to agriculture and food sectors, 2.6 million jobs were accounted for farmers i.e., 1.4% of 10.3% of total employment [43]. The total number of farms in the world is approximately 570 million and there are roughly 500 million people whose livelihood is derived from farming [22].

While approximately 44% of the farmers are poisoned by pesticides every year, heat stroke is considered as the leading cause of death among farmers [6]. According to Center for Disease Control and Prevention, the death rate for farmers is 20% higher than the rest of the civilians in US alone [27].

While the technological industry is set on pace to exceed $5.3 trillion in 2022 [26] and the wearable technology market is projected to reach $380.5 billion by 2028

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Fig. 1. Device prototype of the proposed Agri-Aid system.

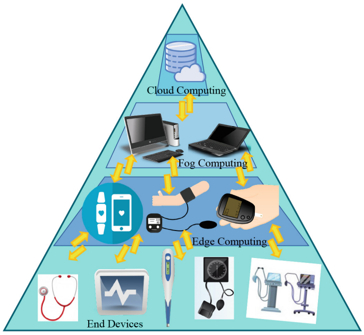

Fig. 2. Proposed Agri-Aid system in the edge computing paradigm.

[11], there have not been many advancements in agricultural sector especially targeting farmer health.

A comparison study reveals that farming can have an effect on the health status of the farmers [10]. Thus, Agri-Aid, a fully automated continuous monitoring IoMT based device is proposed to monitor the vital, weather and geographical parameters of the farmers to detect and predict fatigue, health hazards and exposures to pesticides among them. The device prototype of the proposed Agri-Aid is represented in the Fig. 1.

Agri-Aid is a state-of-the-art Edge computing device in IoMT framework. IoT can be defined as a network of things where each thing in the network is connected and is the capable of transferring information with a unique IP address upon need [35]. When the same fundamentals are applied to medical things and healthcare domains, IoT is termed as Internet of Medical Things (IoMT) [33]. IoMT framework can be observed in Smart Healthcare [32,36], Smart Transportation, Smart cities, etc., [34]

A distributed computing paradigm otherwise known as edge computing has been used here in Agri-Aid as shown in Fig. 2. Such computing paradigm allows the data processing and analyses to be done at the source or at the user end. Real time data processing, bandwidth utilization reduction, lower network traffic, increase in the efficiency, security and privacy of the devices with the reduction in the costs are few among the other advantages of adapting Edge computing [15].

The organization of the paper is as follows: Sect. 2 discusses the motivation behind this research. Section 3 provides the state-of-the-art literature. Section 4 describes how Agri-Aid bridges the gap from the state-of-the-art research. Section 5 discusses the wide range of features both vital and environmental and their significant impact on the farmer health. Section 6 provides a flow of the concept followed by the feature extraction from the discussed parameters. Section 7 describes the working flow of the proposed Agri-Aid system. Section 8 comprises of the ML implementation of the modal and edge implementation of the same. A brief comparison followed by conclusions and future directions are provided in Sect. 9.

2 Motivation Behind the Proposed Agri-Aid System

Study indicates that only a small portion between 7% to 11% of the hired farmers have health insurance provided by the employer [44]. Healthcare services are expensive and not everyone can afford it. Reaching for help and accessing the desired help can be major issues depending upon the location of the farm. Most of the farmers face death because of the lack of knowledge on the side effects of exposure to pesticides or heat strokes. Thus the need for a system to not only monitor the vital signals of the farmers but also to educate about the possible health hazards has become important.

3 Related Prior Research

With the focus being on crop growth and the productivity of agriculture in general, farmer health monitoring and tracking is very much neglected. There are many state-of-the-art literature's and market ready devices for crop growth monitoring but there are no products and little to none literature that focused on unified farmer health monitoring.

With longer exposure of pesticides, regular health checkups especially vision and cardiopulmonary care are very important. There are studies which observe the impact on vitals focusing on pesticide poisoning and have conducted studies with the farmers exposed to certain chemicals to farmers who were not exposed to the same chemicals [8,25].

The official statistical data on pesticide poisoning in the country is considered under-estimated as only 2% of the cases are reported to the formal health centers [1]. Better quality pesticides may reduce the impact on farmers. Study indicates that the farmers are willing to pay 28% more than what they are currently paying towards pesticides for better health [13].

Health awareness campaigns for the farmers showed the improvements in the symptoms for chronic pesticide poisoning in farmers [41].

The mood and physical activity of the person can determine the mental health of a person. With the early diagnosis of the mental health, the rate of suicides in farmers can be reduced [24].

Older farmer health monitoring plays a very important role as a study shows that in a fatality data of 7064 deaths, over half of the deaths are accounted as older farmers between 1992 and 2004 [28].

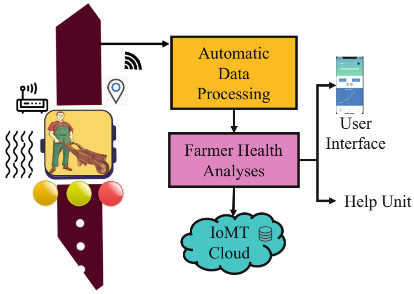

Fig. 3. Broad perspective of the proposed Agri-Aid system.

A study shows that even though most of the farmers are not well educated and have very little knowledge on the technology, with promoting protective eye-wear and training, farmers have experienced effectiveness and comfort with their regular chores [12].

Few questionnaire based approaches have been proposed to analyze the health of the farmers. An automatic risk detection system is proposed which takes the answers from the farmers to certain questions based on the farming practices and generates the risk percentage of the pesticide exposure [23].

There are few worker health monitoring mechanisms that are presented by monitoring the gait parameters, respiration parameters and heat stress of the farmer [3,7]. However, these mechanisms lack an easy access, lack of considering various parameters that effect the health of the farmer.

3.1 Major Issues with the Existing Solutions

Some of the major issues with the existing solutions are discussed below:

- For the farmer health or worker health monitoring, no unified detection is performed as various other physiological, weather and geographical parameters are not considered.
- Real time data processing is never provided.
- Farmers are required to self diagnose the situation and are required to ask for help instead of accessing the help.
- No wearable devices are proposed, thus not taking the complete advantage of the technological capabilities.
- Affordability, reachability and accessibility to the farmers has been neglected.

With this, having Agri-Aid, a wearable or a system to continuously monitor the health of the farmer can be helpful. The broad perspective of Agri-Aid is represented in Fig. 3.

4 Novel Contributions and Issues Addressed Through Agri-Aid

The novel contributions and the issues that are addressed through Agri-Aid are listed below.

- For the farmer health or worker health monitoring, complete unified detection is performed.
- Precautionary methods and notifications are provided to farmers to eliminate excessive exposure to pesticide induced environments.
- Precautionary and timely notifications are provided depending upon the various features that are considered (detail discussion in Sect. 6).
- Real time data analyses is performed at the user end by incorporating Edge computing thus eliminating the delay in the process of providing help.
- The response system is designed in a way to provide care for visually impaired or hearing impaired farmers.
- Along with the regular vital analyses, special analyses is performed for older working adults and for farmers with disabilities.
- A wearable is proposed which allows the farmers to educate, understand and improve their lifestyles.

5 Various Parameters Considered for Farmer Health in Agri-Aid

There are wide range of parameters and life style habits that have an impact on farmer health [30]. Some of the considered features are classified into three categories in Agri-Aid. They are:

5.1 Vital and Physiological Parameters

Eyes and Vision Issues. With prolonged exposure to these pesticides, chronic eye irritations may be developed [38]. This in long term can diminish visual activity. For farmers who are exposed to these pesticides had a probability of 0.53 to get diagnosed with chronic eye issues [30].

Skin Issues. Depending on the method of farming practice, skin contamination varies. Hands and forearms are highly contaminated leading to skin thickening and accentuated markings in the long term [48]. The probability of farmers who are exposed to herbicides and other harmful pesticides to get skin issues was 0.50 [30].

Respiratory Effects. Long term exposure to harmful chemicals can cause respiratory tract issues like cough, cold, rales, tenderness and decreased chest expansion, etc.,. Smoking increases the probability of having respiratory tract infections by 50% [29, 38].

Cardiovascular Issues. Blood hardening is the common issue observed in farmers who practice spraying the pesticides which causes high blood pressure [38].

Gastrointestinal Issues. Pesticides are usually entered into the gastrointestinal tract through mouth. Prolonged intake can cause nausea, vomiting and diarrhea [38].

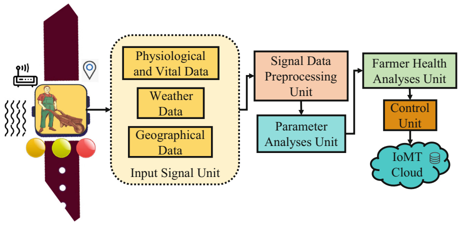

Fig. 4. Architectural flow of the proposed Agri-Aid system.

Neurological Issues. Prolonged exposure to pesticides and pesticide residue environments can lead to nerve numbness [38]. Excessive intake of pesticide residue by any means can also cause motor weakness.

5.2 Weather and Geographical Parameters

High temperatures, heavy UV radiation, wind speeds, wind directions, location, position and angel of the sun, sudden rains, air humidity, air quality, pollen percentage are few of the many factors that can affect the health of the farmer [4].

6 Architectural Flow and Feature Extraction for Farmer Health in Agri-Aid

The architectural flow of the proposed Agri-Aid is represented in Fig. 4.

In this system, features from the mentioned parameters (Sect. 5) are extracted.

6.1 Physiological and Vital Sensor Data Unit

The features which are extracted as sensor signal data from the vital and physiological parameters as mentioned in Sect. 5.1 are discussed in this section. As heat strokes are the major reasons for deaths in farmers as discussed in Sect. 1, the direct and indirect relationship with the physiological and vital signal data to heat strokes is also considered.

Body Temperature. Prolonged exposure to sun and pesticide induced environments can cause irritations and rise in human body temperature. The temperature quickly raises to 106° F or higher within 10 to 15 min. In general, the normal body temperature is considered in the ranges of 97° F to 99° F while temperature higher than 100° F is considered as fever [9].

Humidity. In extreme heat exposure, there will be no sweat discharge. Body becomes hot and dry to touch [16]. The ideal and normal range for humidity in the human body is between 30 to 50% and anything greater than 60% is considered unhealthy [37].

Respiration Rate. Due to extreme heat, as the temperature of the body increases and causes dehydration, the nasal passage, bronchial tubes and lungs may dry out which leads to shortness of breathe. The normal and healthy respiration rate per minute is considered in the range 12 to 16 and anything lower than 12 is considered harmful [42].

Heart Rate. For every degree rise in the human body temperature, the heart beats about 10 beats faster per minute. So when the body is experiencing heat stroke or prolonged exposure of heat, the heart rate significantly rises. A normal resting heart rate is in the range from 60 to 100 beats per minute. When working in farm, farmers should expect an average healthy range from 80 to 157 beats per minutes for ages across 35 to 60 [45].

Loss of Consciousness (Coma). When farmers are exposed to prolonged sun exposure and chemicals from pesticides, the physiological signals inside the human body alter leading to falls, which causes loss of consciousness. So in order to monitor the state of consciousness, the following parameters are considered along with the above discussed data. A detailed explanation of the below discussed signal data is available in [36].

– **Gait** Gait is the pattern a person walks in [40]. With the motor weakness and heat, the coordination of the human body maybe disturbed causing a lag between the movement of legs which can result in falling [31].
– **Twisting** Falls may occur when a balance loss happens when a person's body orients in a different direction than the position of the feet [47]. Accelerometer and gyroscope are used to monitor gait and twisting.
– **Blood Sugar Levels** Sugar levels below 70mg/dL increases the chances of falls by increasing the weakness and older adults may feel anxious, shaky, tiredness and may suffer strokes [14].
– **Blood Oxygen Saturation Levels** If the oxygen saturation levels are lowered due to heat, then farmers may experience breathing issues, asthma, low heart rate and unconsciousness. SpO_2 levels ranging from 95% to 100% are healthy normal in adults [17].

6.2 Weather and Environmental Signal Data Unit

The relative humidity of the surroundings is monitored. The growth and residues of pesticides and chemicals including bacteria and viruses along with the exposure to respiratory tract infections is observed high when the relative humidity is less than 40% and greater than 60% [2]. The ideal outdoor temperature is $75 - 85°$ F, the side effects from the pesticides and exposure to heat starts gradually increasing from $90 - 105°$ F and when the temperature is in the range of 105–130° F, the individuals are advised to stay indoors for protection [46]. If the location of the farm is elevated when compared to the sea level, the sun's radiation, direct light and UV exposure increases [18]. The solar radiation and intensity is observed higher closer to equator [19]. The ideal wind speed ranges from 1.2 to 4mph while 4–6mph is considered a little risky and higher than 6mph is considered danger to spray pesticides [5].

6.3 Geographical Signal Data

The GPS location of the farm and farmer are considered. With this a detailed analyses on the location with respect to altitude, natural calamities, the type of crop that is usually grown, livestock type and population, nearby factories and industries is obtained. A prediction of the productivity of the farm is derived to monitor the mental health of the farmer.

6.4 Parameter Analysis Unit

The detailed representation of the mentioned parameters is shown in Table 1.

Table 1. Parameter range descriptions for farmer health in Agri-Aid.

Wind Speed	Out Temp	HRV	Sugar Levels	SpO_2 Levels	Acc	RH	Time	Dust Flow	Air	Body Temp	Body Humidity	Resp Rate	Result
1.2–4 mph	70 − 85°F	60–90 bpm	70–80 mg/dL	> 90	< ± 3g on Y axes	< 40 and > 60	8-10AM & 4-7PM	low	No	96 − 97°F	20–30%	12–16 bpm	No danger
4–6 mph	90 − 105°F	90–95 bpm	50–70 mg/dL	90–95	> ± 3g on Y axes	< 40 and > 60	10-12PM & 2-4PM	med	No	97 − 98°F	30–40%	12–16 bpm	No danger, plan to take a break
6–9 mph	105 − 130°F	95–105 bpm	30–70 mg/dL	80–90	> ± 3g on Y axes	< 40 and > 60	12–2 PM	high	Yes	98 − 102°F	40–55%	10–12 bpm	Possible weakness and illness
> 9mph	> 130°F	>105 bpm	< 30 mg/dL or > 160 mg/dL	<80	> ± 3g on Y axes	< 40 and > 60	12–2 PM	high	Yes	> 103°F	>60%	<10 bpm	Heat stroke and illness

From the above gathered signal data, heat index temperature and wet bulb globe temperature score are calculated. These metrics are very important as they also help in analyzing the environmental conditions of the location.

Heat Index. The heat index is a temperature that is obtained by combining temperature and relative humidity in the shaded areas. This value may be much less when compared to the outdoor temperatures as it is predicting the temperatures in shaded areas. The formula to calculate the heat index is denoted in the Eq. 1 [39].

$$HeatIndex(HI) = c1 + c2T + c3R + c4TRH + \\ c5T^2 + c6RH^2 + c7T^2RH + c8TRH^2 + c9T^2RH^2 \quad (1)$$

where, T is the ambient temperature in °F, RH is the relative humidity and c1 through c9 are constants; c1 = −42.379, c2 = −2.04901523, c3 = −10.14333127, c4 = −0.22475541, c5 = −71.3783, c6 = −0.05481717, c7 = −0.00122874, c8 = 0.00085282, c9 = −0.00000199.

Wet Bulb Global Temperature. $WBGT$ is a measure of heat stress that is calculated in direct sunlight. This $WBGT$ can be given more credibility than HI as this is calculated under direct sunlight. The formula that is used to calculate $WBGT$ is represented in Eq. 2 [21].

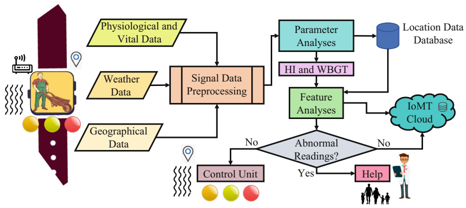

Fig. 5. Working flow of the proposed design in Agri-Aid system.

$$WBGT = 0.7T_w + 0.2T_g + 0.1T \tag{2}$$

here, T is the outdoor temperature in °C, Tg is the global thermometer temperature in °C and Tw is the wet bulb temperature in °C. The formula to calculate Tw is given in Eq. 3.

$$\begin{aligned} Tw = T * arctan[v1 * (RH + v2)^(1/2)] + arctan(T + RH) \\ - arctan(RH - v3) + v4 * (RH)^(3/2) * arctan(v5 * RH) - v6 \end{aligned} \tag{3}$$

where T is the temperature in °C, RH is relative humidity and v1 through v6 are constants; v1 = 0.151977, v2= 8.313659, v3=1.676331, v4=0.00391838 , v5=0.023101, v6=4.686035.

6.5 Farmer Health Analyses and Control Unit

Depending on the feature analyses from the above mentioned parameters, the health and wellness of the farmers is analyzed. The inhalation of pesticides, exposure to the pesticide residue environments and exposure to direct sunlight are the main scenarios that are monitored through Agri-Aid system. If the analyzed scenarios produce dangerous outcomes the call for help is automatically made. In healthy outcomes, there are continuous reminders sent to the person to consume water and seek shelter or to rest for a while. If the outcomes do not indicate heat stroke but indicate a possible fall which may be lead to the state of unconsciousness, control mechanisms are provided. The system is provided with a buzzer, LED and a vibration module so that the farmer will get the message even in loud disturbing environments. Continuous monitoring of the vitals will not only help analyze and keep track of the well-being of the farmers but any abnormality in the patterns can be used to detect and predict underlying diseases.

7 Design Flow of the Proposed Agri-Aid for Farmer Health Analyses

The design flow of the proposed Agri-Aid system has been represented in the Fig. 5.

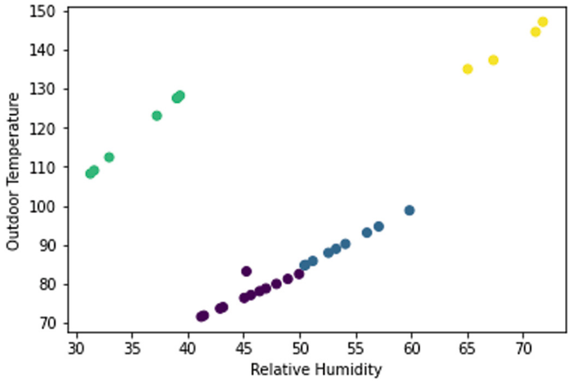

Fig. 6. Scattered plot of some of the features deployed in Agri-Aid system.

The data from the input unit is processed and analyzed. After the required features are extracted, the featured data is compared using the parameter ranges mentioned in Table 1. The design flow of the Agri-Aid System is also represented through an Algorithm 1.

8 Implementation and Validation for Farmer Health Analyses in Agri-Aid

8.1 Signal Data Acquisition

For the geolocational of the farm, a dataset which has the latitudes and longitude information of every country in the world along with the 50 states in the United States is obtained. This data was useful to analyze the solar radiation and the air quality which also includes the wind speed and direction. Alongside, a total of 3500 data samples with respect to the climatic changes were also obtained from open source websites. For the training and testing implemented in Agri-Aid, the parameter ranges from Table 1 is also considered.

8.2 Machine Learning Model for Training and Testing in Agri-Aid System

For the machine learning model, a total number of 9000 samples were used. Out of these, 8000 are used for training while 1000 are used for testing the model. The model had 4 labels- Caution, Extreme Caution, Danger and Extreme Danger and 13 features as mentioned in the Sect. 5. The scattered plot of few features considered in Agri-Aid are shown in Fig. 6.

A classification model has been deployed in Agri-Aid system with a linear stack of layers with 13 layers in the input layer, four dense layers with 25 neurons in each and 4 nodes in the output layer. Rectified linear and sigmoid functions are used as activation functions. 501 epochs with 35 batch size and 0.01 learning rate were considered.

Algorithm 1 Working Principle for Farmer Health Diagnosis in Agri-Aid.

1: Declare and initialize the input variables w for wind speed, ot for outdoor temperature, rh for relative humidity, h for HRV, sl for sugar levels, s for SpO_2, t for time, bt for body temperature, bh for body humidity and rr for respiration rate to zero.
2: Declare and initialize the output variables b for buzzer, v for vibrator and l for location to zero.
3: Declare string variables result of diagnosis r, d for dust flow, aq for air quality (VOC), m for measures of control and a for accelerometer to zero.
4: **while** $h \neq 0$ **do**
5: Start monitoring and gathering physiological, weather and geographical signal data which are w, ot, rh, t, bt, bh, rr, a, aq, d, h, sl, s and l.
6: Declare and initialize hi for heat index and tw for wet bulb temperature and $wbgt$ for wet bulb globe temperature and set them to zero.
7: Based on the Equations 2, 3 and 1, calculate tw, $wbgt$ and hi respectively.
8: **if** $1.2{>}w{<}4 \wedge 70{>}ot{<}85 \wedge 60{>}h{<}90 \wedge 70{>}sl{<}80 \wedge s > 90 \wedge a <$ 'Threshold' $\wedge$ $40{<}rh$ and $rh{>}60 \wedge 8{>}t{<}10 \wedge 16{>}h{<}19 \wedge 96{>}bt{<}97 \wedge 20{>}bh{<}30 \wedge 12{>}rr{<}16 \wedge$ d = 'low' $\wedge$ aq = 'no' $\vee$ $80{>}hi{<}90 \vee 80{>}wbgt{<}85$ **then**
9: r = 'Working in direct sunlight can stress your body after 45 minutes. Take minimum 15 minute breaks each hour if continued working.'.
10: $b = 1 \wedge v = 1 \wedge l = 1$.
11: **else if** $4{>}w{<}6 \wedge 90{>}ot{<}105 \wedge 90{>}h{<}95 \wedge 50{>}sl{<}70 \wedge 90{<}s{>}95 \wedge a >$ 'Threshold' $\wedge$ $40{<}rh$ and $rh{>}60 \wedge 10{>}t{<}12 \wedge 14{>}h{<}16 \wedge 97{>}bt{<}98 \wedge 30{>}bh{<}40 \wedge 12{>}rr{<}16$ $\wedge$ d = 'med' $\wedge$ aq = 'no' $\vee$ $90{>}hi{<}103 \vee 85{>}wbgt{<}88$ **then**
12: r = 'Take extreme cautions. Person may experience stress after 30 minutes. Take minimum 30 minutes of break each hour if continued working'.
13: m = 'Time for a water break!'.
14: $b = 2 \wedge v = 2 \wedge l = 1$.
15: **else if** $6{>}w{<}9 \wedge 105{>}ot{<}130 \wedge 95{>}h{<}105 \wedge 30{>}sl{<}70 \wedge 80{<}s{>}90 \wedge a >$ 'Threshold' $\wedge$ $40{<}rh$ and $rh{>}60 \wedge 12{>}t{<}14 \wedge 98{>}bt{<}102 \wedge 40{>}bh{<}55 \wedge 10{>}rr{<}12 \wedge$ d = 'high' $\wedge$ aq = 'yes' $\vee$ $103{>}hi{<}124 \vee 88{>}wbgt{<}90$ **then**
16: r = 'Possible heat stroke. Person may experience body weakness within 20 minutes. Take minimum 40 minutes of break each hour if continued working'.
17: m = 'Help is alerted. Possible heat stroke!'.
18: $b = 3 \wedge v = 3 \wedge l = 1$.
19: **else if** $w{>}9 \wedge ot{>}130 \wedge h{>}105 \wedge sl{<}30 \vee sl{>}160 \wedge s{<}80 \wedge a >$ 'Threshold' $\wedge$ $40{<}rh$ and $rh{>}60 \wedge 12{>}t{<}14 \wedge bt{>}103 \wedge bh{>}60 \wedge rr{<}10 \wedge$ d = 'high' $\wedge$ aq = 'yes' $\vee$ $hi{>}125 \vee wbgt{>}90$ **then**
20: r = 'Definite heat stroke. Person may loose consciousness within 15 minutes. Seek shelter immediately'.
21: m = 'Help is on the way. Go indoors and sit'.
22: $b = 3 \wedge v = 3 \wedge l = 1$.
23: **else**
24: r = 'Happy farming!'.
25: m = 'Happy farming!'.
26: **end if**
27: **end while**
28: Repeat the steps from 4 through 27.

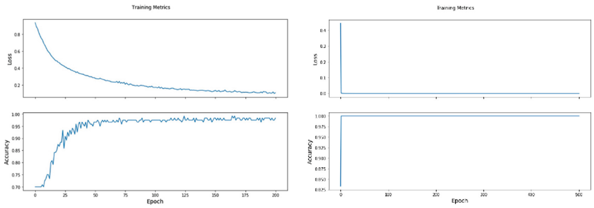

Fig. 7. Loss and accuracy plots of the model for farmer heath as proposed in Agri-Aid system.

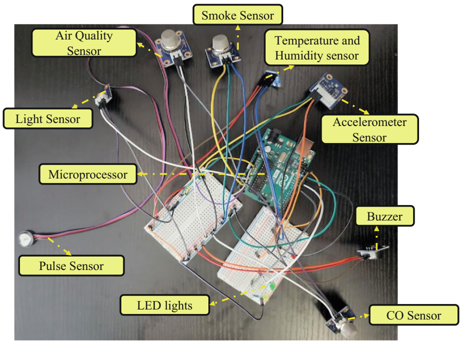

Fig. 8. Real time edge implementation of the proposed Agri-Aid system.

The training epochs deployed in Agri-Aid system is as shown:

Epoch 000: Loss: 0.444, Accuracy: 83.310%
Epoch 050: Loss: 0.000, Accuracy: 87.000%
Epoch 100: Loss: 0.000, Accuracy: 91.000%
Epoch 150: Loss: 0.000, Accuracy: 93.000%
Epoch 200: Loss: 0.000, Accuracy: 97.000%
Epoch 250: Loss: 0.000, Accuracy: 97.000%
Epoch 300: Loss: 0.000, Accuracy: 98.000%
Epoch 350: Loss: 0.000, Accuracy: 100.000%
Epoch 400: Loss: 0.000, Accuracy: 100.000%

A sample of 6 predictions and their confidences are shown:

Example 0 prediction: Danger (100.0%)
Example 1 prediction: Caution (100.0%)
Example 2 prediction: Extreme Danger (100.0%)
Example 3 prediction: Extreme Danger (100.0%)
Example 4 prediction: Extreme Caution (98.4%)
Example 5 prediction: Extreme Danger (99.1%)

The loss and accuracy of the training process during the initial stages towards the end is represented in the Fig. 7.

For the real time edge computing, multiple sensors along with the microprocessor is considered. The edge computing setup in Agri-Aid is represented in Fig. 8.

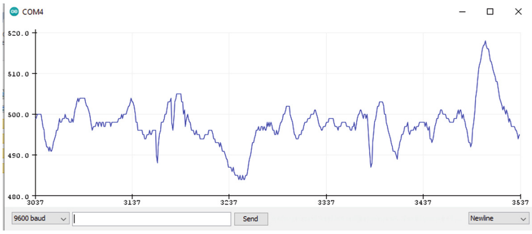

Fig. 9. Serial plot of the exposure to heat in farmers as proposed in Agri-Aid System.

Table 2. Comparison with the state-of-the-art research.

Name	Prototype	Method	Parameters	Stroke Prediction?	Pesticide exposure monitoring?	Accuracy
Jaime, et al. [20]	None	Questionnaire	location, type of crop	None	Partially, Yes	NA.
Baghdadi, et al. [3]	Yes	Microprocessor, placed at ankle	Gait - lifting nd delivering	No	Yes	NA.
Burali, et al. [7]	No	Spirometry	respiration rate, cough, nasal allergies	No	Yes	NA.
Agri-Aid (current paper)	Yes, a wrist watch	Vital, physiological, weather, location based data monitoring	13 features	Yes	Yes	98.67%

The exposure to direct sunlight during the working hours is represented using the serial plotter in Fig. 9.

A brief comparison with existing research is discussed in Table 2.

9 Conclusions and Future Research

9.1 Conclusions

Farmer health is one of the most neglected domains in smart agriculture sector. The crops that are raised by the farmers are given higher priority than the health of the farmers. For any village to be smart, all the components should be smart. People, most importantly farmers comprise most of the population in rural areas. Having prolonged exposures to pesticides, pesticide residue environments and working in the direct sunlight for majority of the day can be very harmful to their health. With the limited scope of help they get, I believe having an automated system to monitor their health can be very helpful. The proposed Agri-Aid watch is not too complicated as anyone with moderate education will be able to handle the device. The response mechanisms are designed keeping in mind the disabilities farmers may have.

9.2 Future Research

Including more robust and personalized response mechanisms is one among the many other future directions of this system. Considering various multi-modal data with security and privacy aspects can also help as education, knowledge and self-care are provided to very hardworking and deserving farmers.

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