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Application of machine learning (ML) and internet of things (IoT) in healthcare to predict and tackle pandemic situation

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Abstract

The pandemic situation has pretentious the habitual life of the human, it also has surpassed the regional, social, business activities and forced human society to live in a limited boundary. In this paper, the application of the internet of things (IoT) and machine learning (ML) based system to combat pandemic situation in health care application has been discussed. The developed ML and IoT based monitoring system help in tracking the infected persons from the previous data and makes them get isolate from the non-infected person. The developed ML combined IoT system uses parallel computing in tracking the pandemic disease and also in the prevention of pandemic disease by predicting and analysing the data using artificial intelligence. The implementation of ML based IoT in the pandemic situation in healthcare application has proved its performance in tracking and prevents the spreading of pandemic disease. It also further has a positive impact on reducing medical costs and has recorded improved treatment for infected patients. The proposed methodology has an accuracy of 9[illegible]% in monitoring and tracking. The result obtained help in preventing the spread of the pandemic and provide support to the healthcare system.

Keywords COVID-19 · Machine learning · Artificial intelligence · Internet of things · Healthcare · Epidemic-monitoring and control

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1 Introduction

The pandemic disease is caused by a virus that originated from the wild animal's/birds. The virus affects the human through mutation. For e.g., the COVID-19 outbreak started in Wuhan City in Hubei Province in China in December 2019 through Seafood Wholesale Market [1]. Later, on January 30, 2020, by knowing the severity of COVID-19 the World Health Organization (WHO) declared the outbreak as an Emergency pandemic throughout the world [2]. As of 14th June 2020, there have been 7.41 Million confirmed cases, with 4,18,813 deaths reported globally. Since the COVID-19 gets transmitted from person to person through the infected people in many ways [3]. The government of several nations has declared it a hazardous pandemic situation and made a complete lockdown to prevent the spread of COVID-19. Several countries had flattened their growing infection through a strict lockdown and making their people maintain social distance [4]. Even though, through complete lockdown, the COVID-19 is not completely mitigated. Some nation has joined together in developing medicine to cure COVID-19 [5]. But to date, there is no specific medicine to cure COVID-19. However, few medicines have been suggested by potential investigational therapies. The suggested medicine is been studied under clinical trials under the guidance of WHO [6]. According to several studies, since COVID-19 is a transmittable disease the WHO has declared complete lockdown could be the only way to prevent COVID-19 [7].

Internet of Things (IoT) is getting familiar in recent days with their application in healthcare monitoring and surveillance. The IoT can also be used to tracking the infected patient during the epidemic situation. In [8], IoT-Based COVID-19 and other infectious disease contact tracing model has been developed. The developed model implies a digital contact tracking system to trace the COVID-19 infected patient. The developed model also integrates blockchain technology to trace the infected using mobile signal technology. In [9], the innovative technology IoT is been deployed as the monitoring system during the epidemic breakdown. The developed IoT technology is developed in such a way to get enabled during pandemic occurs and has tackling techniques of pandemic breakdown and also provide computerized and translucent treatment during the epidemic. In [10], early-stage pandemic monitoring and response framework based on IoT have been developed. The developed IoT framework identifies COVID-19 are early stage and also helps in real-time monitoring to track infected patients in case of medical treatment. In [11], the security threat in COVID-19 and methods to rectify has been presented. In the discussion, the author discloses the application of IoT in the medical field and methods to enhance the application of IoT. In [12], the author discusses the contribution of IoT and its associated sensor technology in tracking and mitigating the spread of COVID-19. The author has also discussed the real-time challenges in integrated usage of sensor and IoT for rapid assessment of epidemic. In [13], the integration of blockchain and IoMT amid the COVID–19 crisis has been discussed in this article. In the assessment, the author gives a novel solution for the COVID-19 pandemic using the blockchain-enabled IoMT. The discussion also traces the perspectives such as pandemic origin, quarantining and social distancing, smart hospital, medical data provenance, and remote healthcare and telemedicine. In [14], the author aims to explore the application of smart digital technologies that could be applied for recognition, pre-screening and deterrence of COVID-19 in the mining industry using IoT technology. The study also explores the application of digital technology in the medical revolution and also explores the method to prevent the spread of the COVID-19 pandemic.

Early discovery of any sickness, be it irresistible and non-irresistible, is fundamentally a significant undertaking for early therapy to spare more lives [15, 16]. Quick finding and screening measure forestall the spread of pandemic infections like COVID-19, practical, and accelerate the connected determination. The advancement of a specialist framework for medical care aids the new request of distinguishing proof screening and the executives of COVID-19 transporter by additional practical contrasted with the conventional technique. ML and AI are utilized to expand the finding and screening cycle of the recognized patient with radio imaging innovation similar to Computed Tomography (CT), X-Ray, and Clinical blood test information. The medical services representative can utilize radiology pictures like X-beam and CT filters as normal instruments to expand conventional determination and screening. Shockingly, the presentation of such gadgets is moderate during the high upheaval of the COVID-19 pandemic. In [17], show the capability of AI and ML instruments by proposing another model that accompanies fast and substantial strategy COVID-19 determination utilizing Deep Convolutional Network. The examination shows that conclusion using a specialist framework utilizing AI and ML on 1020 CT pictures of 108 Covid-19 contaminated patients alongside viral pneumonia of 86 patients with an 86.27 %, 83.3[illegible] % of exactness and particularity separately. In [18], Coronavirus location dependent on a profound learning algorithm. The created model uses crude chest X-beam pictures of 127 tainted patients with 500 no-discoveries and pneumonia instances of 500 records. With momentous execution exactness, double class of 98.08 %, and multi-class with 87.02 %. Multi-classes demonstrated the pertinence of the master framework to help radiology in approving screening measure quickly and precisely. In [19], a secured health care system using sensor tag to the IoT using Chebyshev Chaotic-Map based single-user sign-in has been developed. In [20], 5G based industrial internet of things (IIoT) has been used to interact with serval sensor in the application of health care systems. In [21], AI is used in the analysis of lung infection, this methodology can be used to predict the existence and growth of COVID-19 in the lungs.

In this paper, the IoT and ML have been applied to combat pandemic disease and studied, the IoT idea uses the interconnected organization for the successful stream and trade of information. It additionally empowers the social labourers, patients, regular folks, and so forth to be in association with the administration sponsors for talking about any issue also, collaboration. Accordingly, by utilizing the IoT strategy in a pandemic situation, the viable following of the patients, just as the dubious cases, can be totally guaranteed. The side effects identified with the pandemic disease are currently known to the majority of them. In this pandemic situation, IoT could be the solution to track and prevent the spread of pandemic diseases. The paper is organized as follows, the proposed framework for pandemic disease, monitoring and control is discussed in Sect. 3, the the architecture of the proposed framework is discussed in Sect. 4, the output of the proposed work is discussed in Sect. 5, and Sect. 6 discusses the conclusion of the work.

2 Role of IoT and AI in health care

A powerful consideration model requests IoT applications to be applied to different sicknesses in various medical services settings. By actualizing IoT in health care arrangements, health care suppliers get priceless information, which gives understanding into the indications and example of the infection, while empowering far off consideration. Nonetheless, the execution of IoT in Healthcare is as yet a test [4–6]. Numerous medical services suppliers are either not prepared for the interest in the IoT or don't have the necessary health care framework that upholds IoT execution. What's more, some of them are not completely sure about the usage cycle. We have attempted to address a couple of inquiries so they can take noteworthy measures with certainty [11].

IoT for Patients - Devices as wearables like wellness groups and other remotely associated gadgets like pulse and pulse checking sleeves, glucometer and so on give patients admittance to customized consideration. These gadgets can be tuned to remind carbohydrate content, practice check, arrangements, pulse varieties and significantly more [12]. IoT has transformed people, particularly old patients, by empowering the steady following of medical issue. This majorly affects individuals living alone and their families. On any unsettling influence or changes in the standard exercises of an individual, a ready system imparts signs to relatives and concerned wellbeing suppliers. IoT for Physicians—by utilizing wearables and other home checking gear inserted with IoT, doctors can monitor patients' wellbeing all the more adequately. They can follow patients' adherence to therapy plans or any requirement for guaranteed clinical consideration. IoT empowers medical care experts to be more attentive and interface with the patients proactively. Information gathered from IoT gadgets can assist doctors with distinguishing the best treatment measure for patients and arrive at the normal results. IoT for Hospitals - Apart from observing patients' wellbeing, there are numerous different zones where IoT gadgets are helpful in clinics. IoT gadgets labelled with sensors are utilized for following constant area of clinical gear like wheelchairs, defibrillators, nebulizers, oxygen siphons and other observing hardware. Arrangement of clinical staff at various areas can likewise be dissected continuous [16–20].

When the COVID-19 episode has influenced our day by day lives, IoT and AI have become significant weapons in following and following cases. Actualizing these advances have brought about adjusting the need to vanquish the infection with the clashing need to ensure singular protection [21]. It is basic to get that while there is a desperate need of investing amounts of energy to go up against the pandemic, it is immensely significant that such apparatuses should be restricted being used, both regarding reason and time and that individual rights to security, non-segregation, the insurance of editorial sources and different opportunities are thoroughly ensured [22–25]. The spread of diseases is a significant worry

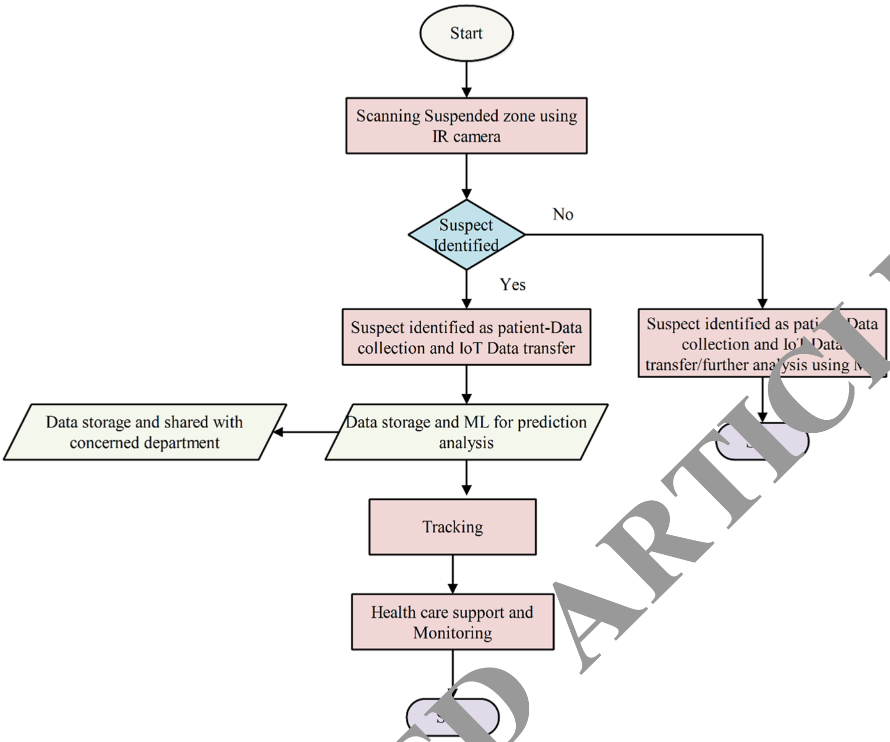

Fig. 1 Work flow of IoT application in monitoring pandemic disease

Table 1 Sensor for IoT applications in epidemic monitoring

Sl. No.	Sensor device	Applications
1	IR sensor	Measure the heat of an object as well as detects the motion.
2	IR thermometer	Measuring the temperature of a subject from a distance
3	Smart devices	Heart rate detection
4	IR camera	For surveillance, and note and change in thermal reading
5	Optical sensor	Used for surveillance, contact-less detection, counting or positioning of parts.
6	Optical camera	For virtual conference/meeting/news broadcasting

for patients in medical clinics. IoT-empowered cleanliness observing gadgets help in keeping patients from getting tainted. IoT gadgets likewise help in resource the executives like drug store stock control, and nature observing, for example, checking cooler temperature, and dampness and temperature control [26–28].

3 Proposed ML based IoT framework for pandemic disease monitoring and control

The application of ML based IoT for pandemic disease epidemic monitoring is shown in Fig. 1. The flow chart clearly addresses the work flow of IoT application in monitoring pandemic disease suspect and further steps in tracking and control measures taken in preventing the epidemic. Initially, the devices listed in the Table 1 have been used to scan the suspended zone.

In the next step, the sensor reads the temperature of the suspect entering the prevented zone from the restricted areas. If the temperature is above 98.6 °F, the suspect will be identified as a patient. If not, the data will be collected for future references and suspect is free to move. In case, when the suspect is identified as infected, he will be considered as a patient. His or Her data relating to location and patient mobile phone GPS data will be collected. The collected data will be stored in the cloud server and could be shared with the concern government body for treatment. The infected patients will be continuedly kept under observation and will be tracking their movement to prevent the spread of pandemic disease. In case of any violation in breaching the protected zone, the suspect can be tracked and can be prevented. This helps in further spread of pandemic disease.

4 ML based IoT architecture for epidemic monitoring and control

ML based IoT is an application-explicit, low force, viable, and simple to utilize an arrangement of any constant issues. Sensors are the information suppliers from the actual world, which moved over an organization, and actuators permit things to act

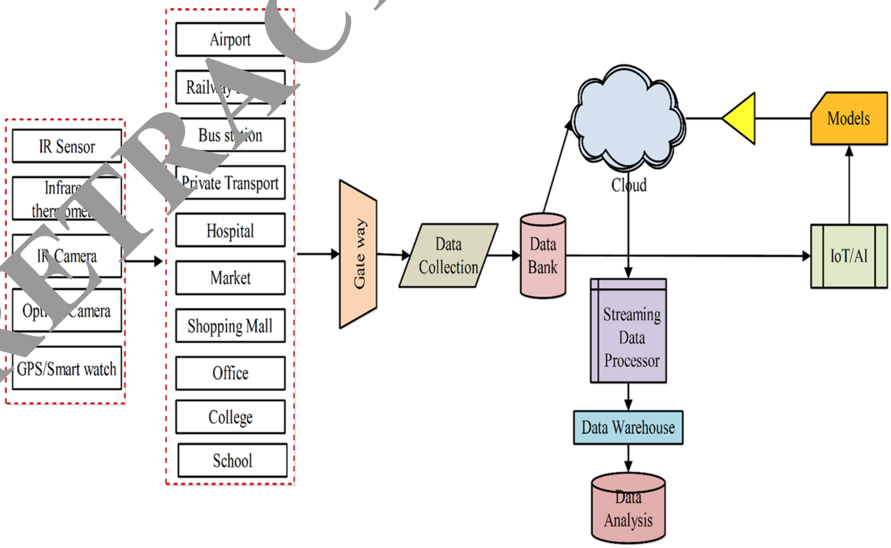

Fig. 2 Proposed IoT architecture for epidemic monitoring

or respond as per the information got from sensors. The proposed IoT design to avoid the spreading of pandemic disease is shown in Fig. 2.

The preliminary data collection and action is taken are discussed in Sect. 3. The information correspondence is through a passage gadget that will further be moved to the cloud passage. In the large information distribution centre, separating of information, i.e., which means full information, is extricated. A major information distribution centre as it was containing organized information. ML-based AI is utilized to make models of the framework dependent on necessities and got information. Information examination can be utilized for the representation of results, execution correlation. IR sensors can be utilized in open latrines for the programmed activity of entryways and water gracefully. Infrared thermometers can be utilized to check the internal heat level to recognize the tainted among group and face acknowledgement by utilizing optical camera at the passage purposes of doors of air terminals, railroad stations, transport stand, shopping centres, and so forth Essentially, sensors, as proposed in the engineering, can be introduced to screen the internal heat level, programmed entryway activity, water gracefully control at public spots and latrines, online meeting to maintain a strategic distance from direct contact with the actual world and people connect. Simulated intelligence profound learning can assist with understanding health care patterns, model danger affiliations, and foresee results. For little applications or for people, the setup of one temperature sensor, one Node-MCU, or Arduino board with sensors and the Internet can be utilized.

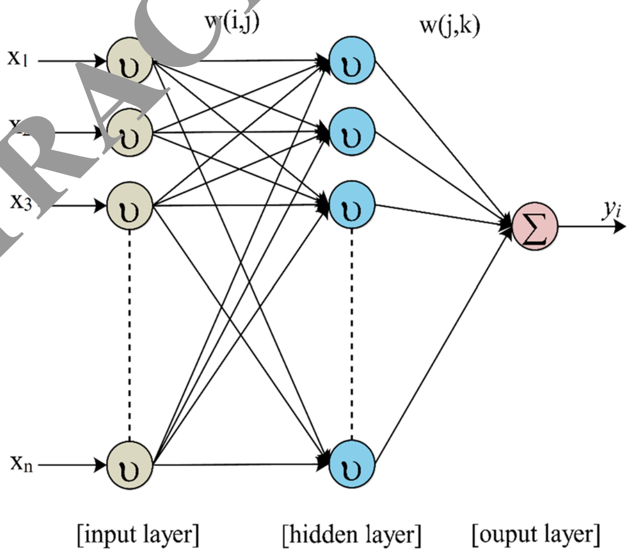

Fig. 3 Neural architecture of the multiple linear regression model

4.1 Machine learning modelling

In the study, multiple linear regression (MLR) model has been adapted for the investigation. MLR is well known for its statical technique which uses testing variables to forecast the output variable. Figure 3 shows the neural architect of the MLR model of the proposed system. The MLR restructures a linear relationship between testing variables and output variables. Where testing variables act as independent variables and output variables acts as dependent variable. In this investigation, COVID-19 spreading has to be prevented through IoT dataset collected in the gateway. The mathematical expression for MLR for the population regression of the n testing variables $x_1, x_2, x_3, \ldots, x_n$ is given as,

$$y_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots\ldots.. + \beta_n x_n + \varepsilon \quad (1)$$

Equation (1) defines how the mean response varies with respect to the testing variables. The practical value of y varies when there is change in i and further presumed to have standard deviation σ. The tailored values $b_0, b_1, \ldots, b_n$ approximates the parameter $\beta_0, \beta_1, \ldots, \beta_n$ of the population regression [22–28].

As the value y changes with i, the MLR includes variation and is expressed as,

$$Data = Fit + \mathrm{Re}\,sidual \quad (2)$$

Where, the Fit represents the $\beta_0, \beta_1 \times_1, \ldots, \beta_n x_n$. The Residual term signifies the change in variable i with respect to y_i that is generally circulated with the mean term 0 and σ. In the developed model, the best fitting line for the observed data has been calculated through the vertical deviation data points. The sum best fit the solution is obtained by minimizing the data points exactly fettling the vertical deviation to 0. The variation σ_i that is known to be mean squared error (MSE) can be assessed through the following expression,

$$MSE = \sqrt{\frac{\sum \varepsilon_n^2}{n - i - 1}} \quad (3)$$

The following assumptions have been made for the regression algorithm.

1. A MLR always exists among secondary factors and the independent factors.
2. There will be no big similarities amid inferior factors and the sovereign factors.
3. [illegible] has been selected randomly.
4. The residuals are mean value from 0 to ε.

4.2 MapReduce

MapReduce is a structure for composing applications which measures colossal measures of information in-equal on huge bunches of ware equipment in a dependable, flaw open-minded way. MapReduce has a wide assortment of uses in AI. It can help building frameworks that gain from information without the requirement for thorough and express programming. Aside from ML, it is utilized in a conveyed looking, disseminated arranging, record grouping [12]. Another application is measurable machine interpretation, where it deciphers an expression or a sentence in a greater number of ways than one thus the technique utilizes insights from past interpretations to track down the best fit one. It is likewise utilized in information grouping to settle computational intricacy because of enormous information utilized in preparing.

4.2.1 Processing

One square is prepared by each mapper in turn. In the mapper, an engineer can indicate his own business rationale according to the necessities. Thusly, Map runs on all the hubs of the bunch and cycle the information blocks in equal.

4.2.2 Writing to circle

Output of Mapper otherwise called moderate yield is kept in touch with the neighbourhood plate. A yield of the mapper isn't put away on HDFS as this is impermanent information and composing on HDFS will make numerous duplicates.

4.2.3 Copy

Output of mapper is replicated to reducer hub. This involves the actual development of information which is done over the organization.

4.2.4 Merging and arranging

Once all the mappers are done and their yield is rearranged on reducer hubs, at that point this middle yield is consolidated and arranged. Which is then given as a contribution to lessening stage.

4.2.5 Reducing

Reduce is the second period of handling where the client can determine his own custom business rationale according to the prerequisites. A contribution to a reducer is given from all the mappers. A yield of the reducer is the last yield, which is composed of hdfs file.

Algorithm: MLR for tracking and prediction

```
Input: Gateway data collected through IoT
Output:
MLR of (xi,yi) for i=0,1
Use RDD.map () to create (id, stages) sets with RDD
For i=0 to 1 do
{
        weight xi into hdfs
        end for
}
from the start β->0, x->0 in super centre
while x>0
{
        X->x+1
        For each centre in the gathering C, C=c1, c2… cm
        {
                S->s+1;
                S->s+n; \\ incorporate overall assistance vectors with subset of planning data
                train reinforce vector machine with new joined dataset.
                find all the assistance vectors with each data subset
                solidification all neighbourhood SVs and figure the overall SVs
                if hx =hx-1 stop, else go to organize 8
                if(x) as convincing class
                guide diminish ();
                produce (id, stages) with Map Reduce ()
        }
}
end
```


5 Results and discussion

The assessment of proposed IoT based ML architecture for epidemic monitoring and control has been discussed in this session. The assessment is carried out with stage-to-stage detection, data storage/sharing and monitoring with IoT and further prediction and control process has been carried out using MLR.

5.1 IoT based ML for data collection and monitoring

In the initial stage, IR camera/ the equipment listed in Table 1 has been installed in the gateway. It is to be noted that, the sensor/ IR devices are helpful only to identify the infected patients. The IR camera is connected to the control module with in-built IoT. The assessment function in the detection of pandemic disease infected patients using IoT application is shown in Fig. 4. The IR camera continuously records the suspects entering the gateway as shown in Fig. 5. The video signal is been processed by the control centre and it shares the data with cloud and monitoring scree. The suspect will be stopped in entering the gateway if his temperature is above the normal. The secondary stage of the process is data storage and sharing. In this process, the infected suspect is considered as patient and their data are been collected. Additionally, their GPS tracking and medial tracking app are been installed to monitor the infected patient through IoT and ML. In this process, the data have been shared with the government authorities to track and generate policies in the support of prevention.

The final stage is monitoring, in this stage, the infected patients are been monitored through the GPS in their smartphone. The health condition of the patients could also be monitored through a smartwatch and other transducer devices. The data segregation through the monitoring is listed in Table 2. Based on the monitor data, needful health support could be given to severely infected patients. Furthermore, the monitoring system also tracks the movement of the infected patients as shown in Fig. 6 to prevent the spread of pandemic disease.

5.2 ML function in COVID-19 prediction and controlling

The ML is used in the prediction and controlling assessment. In this study, MLR is considered for the prediction and control and the obtained results have been compared to the competitive algorithms such as, linear regression (LR), Stoc hasting gradient boosting, adaptive neuro fuzzy inference system (ANFIS). Based on the data collected through IoT module, the MLR has plotted the scattered diagram as shown in Fig. 7. Figure 8 shows the analysis carried-out in the scattered diagram. From the analysis, it is evident that the spread of pandemic disease is high in Airport, Private transport, Market and Office. Form the figure, it can also be noted that spread is minimum in shopping mall, and Colleges as they screen the persons entering in thoroughly.

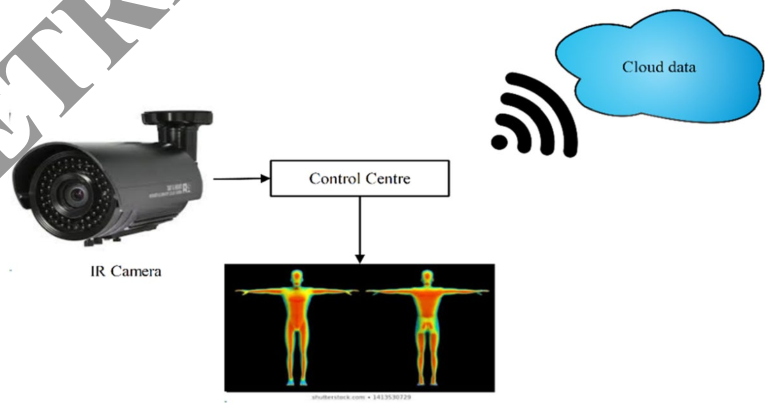

Fig. 4 Recognition of COVID-19 infected patients

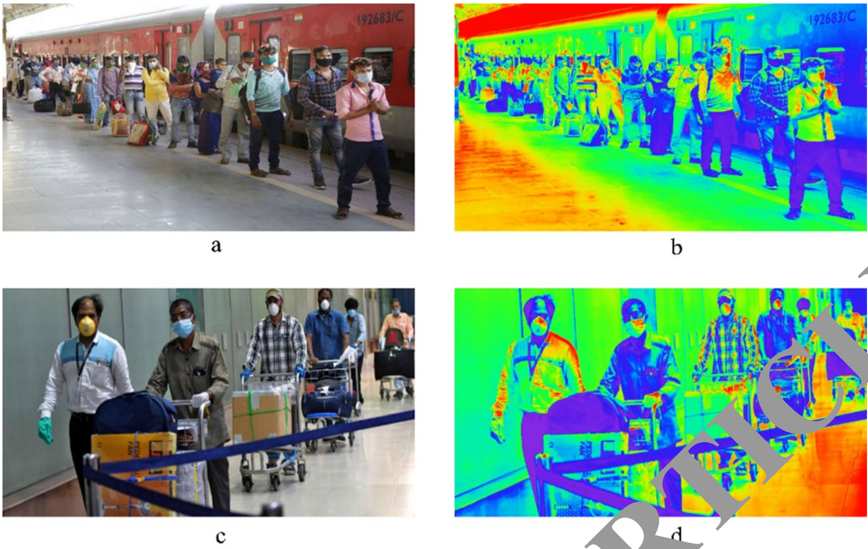

Fig. 5 Thermal images obtained using the developed IoT based ML module

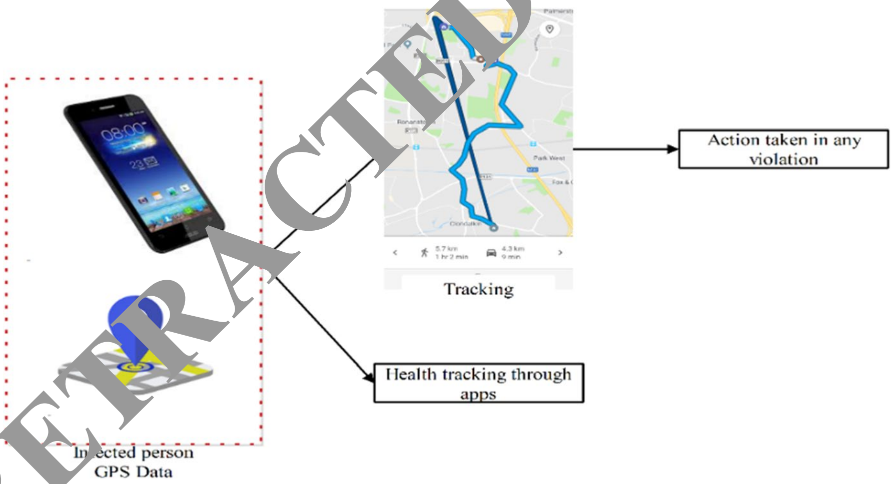

Fig. 6 Monitoring pandemic disease infected patients

In the assessment, the pandemic disease prediction and controlling are further analysed based on the accuracy, sensitivity, and precision. Where, accuracy is the percentage of the example set that is effectively characterized in the exactness of a classifier, as given in underneath condition,

Table 2 Data collection through IoT based ML module

Data segregation	Data collection in percentage									
	Airport	Railway station	Bus station	Private transport	Hospital	Market	Shopping mall	Office	College	School
Age										
1–15	12	18	15	–	6	16	–	–	–	–
16–30	45	33	35	45	27	32	63	66	14	–
31–65	29	31	42	[illegible]	34	45	37	29	78	–
> 65	14	18	8	2	33	7	–	5	8	–
Gender										
Male	67	55	63	80	57	60	54	64	73	–
Female	33	45	37	20	[illegible]	40	46	36	27	–
Location										
GPS data	100	88	90	100	100	81	100	100	91	–
Previous sickness										
Aarogya Setu	35	43	37	29	63	[illegible]	23	–	10	–
Health history										
Aarogya Setu	Monitored	Monitored	Monitored	Monitored	Monitored	–	[illegible]	Monitored	Monitored	Monitored

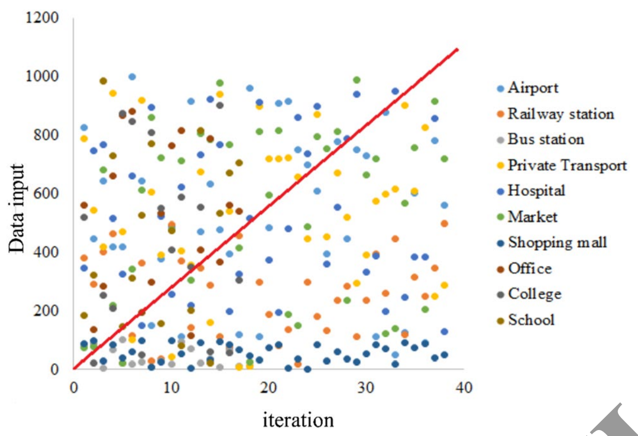

Fig. 7 MLR prediction assessment

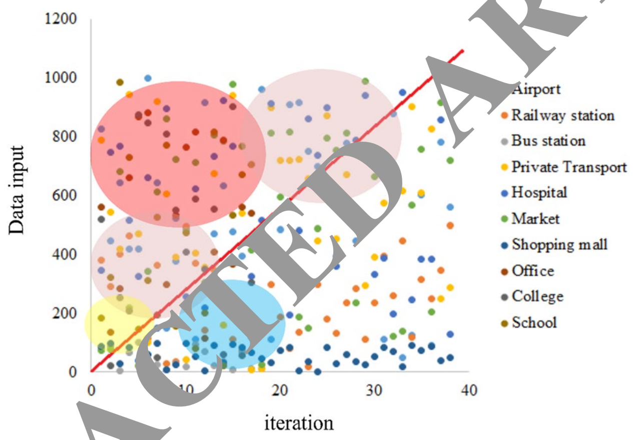

Fig. 8 Assessment data

$$Accuracy = \frac{Number\ of\ accurate\ positive + Number\ of\ accurate\ negative}{Number\ of\ accurate\ positive + faulty\ positive + faulty\ negative + accurate\ negative} \tag{4}$$

Sensitivity is the extent of positive tuples that are effectively recognized, which is otherwise called Genuine Positive Rate given by condition,

$$Sensitivity = \frac{Number\ of\ accurate\ positive}{Number\ of\ accurate\ positive + Number\ of\ faulty\ negative} \tag{5}$$

Precision is the extent of genuine positives against all the positive outcomes and the scientific portrayal of which is given

Table 3 Accuracy, sensitivity and precision of the various methods

Methods	Accuracy (%)	Sensitivity (%)	Precision (%)
MLR	93.4	96.28	94
LR	91.28	86.65	89.32
Stoc hasting gradient boosting	86.2	89	88.4
ANFIS	90	83.39	87.32

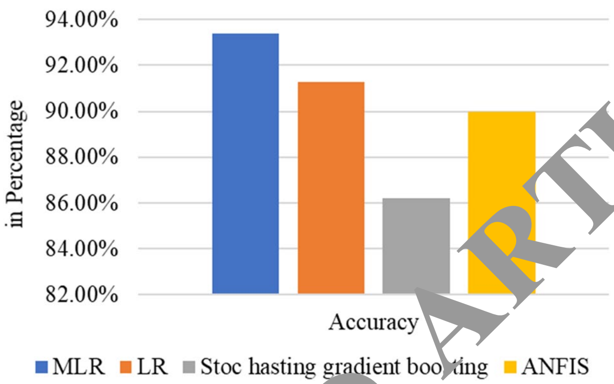

Fig. 9 Accuracy of prediction and control obtained in the assessment

$$Precision = \frac{Number\ of\ accurate\ positive}{Number\ of\ accurate\ positive + Number\ of\ faulty\ positive} \quad (6)$$

The assessment for the prediction and controlling of the ML is listed in Table 3. Figure 9 shows the accuracy of the prediction obtained for the MLR, LR, Stoc hasting gradient boosting and ANFIS based AI techniques. From the assessment it has been identified that, MLR has the higher accuracy percentage of 93.4% when compared with LR of 91.28%, Stoc hasting gradient boosting of 86.2% and ANFIS 90%. The result proves that, the MLR technique-based ML gives higher accuracy. In the next assessment, sensitivity of the ML technique is tested and obtained result is depicted in Fig. 10. From the figure, it is evident that MLR has 96.28% and LR, Stoc hasting gradient boosting, and ANFIS has a sensitivity of 86.65%, 89%, and 83.39%, respectively. In the further assessment, precision of the ML technique is tested and obtained result is depicted in Fig. 11. From the figure, it is evident that MLR has 94% precision and LR, Stoc hasting gradient boosting, and ANFIS has a precision of 89.32%, 88.4%, and 87.32%, respectively. Finally, the performance analysis of the ML technique has been carried out and depicted in Fig. 12. For the performance analysis, the data set has been increased from 1000 to 25,000 and the analysis shows that MLR has higher performance than the other competitive techniques. The comparative analysis for the investigation is listed in Table 4. Form the comparative analysis, the proposed work has higher accuracy, sensitivity and precision in machine learning analysis.

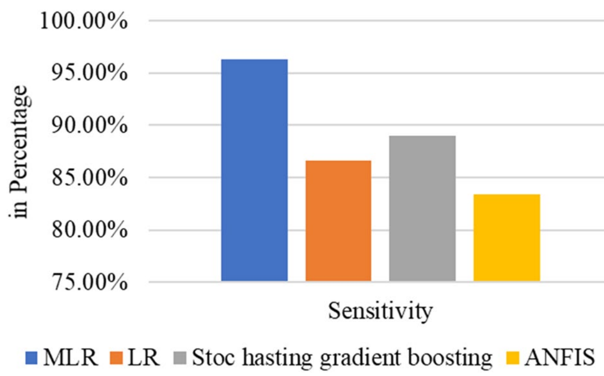

Fig. 10 Sensitivity of prediction and control obtained in the assessment

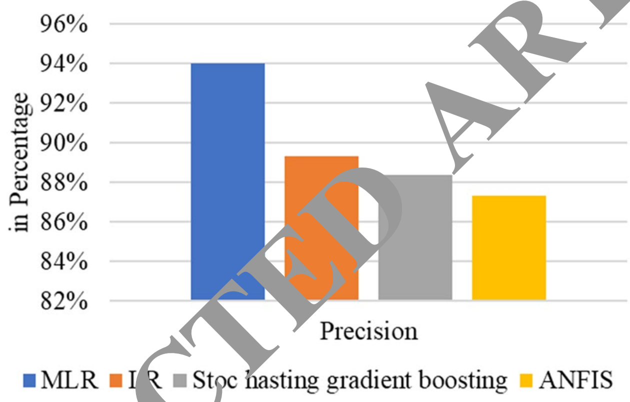

Fig. 11 Sensitivity of prediction and control obtained in the assessment

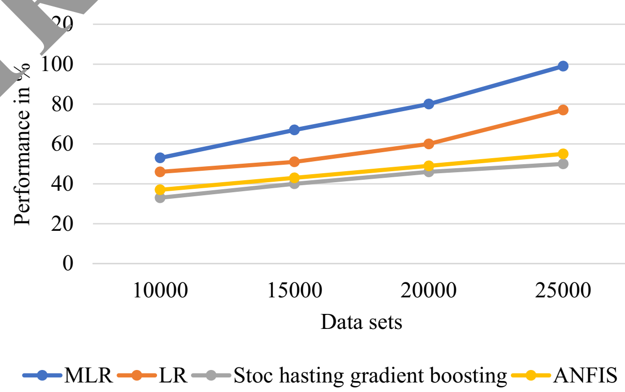

Fig. 12 Comparative analysis

Table 4 Comparative analysis

Methods	Accuracy (%)	Sensitivity (%)	Precision (%)
[21]	90.3	89.12	91
Proposed	93.4	96.28	94

6 Conclusion and scope for future work

Pandemic disease disaster is one of the major problems faced by the world today. High intelligent monitoring technology is the need of today to prevent and monitor the pandemic outbreak. In this paper, the application of ML integrated IoT based system for pandemic disease in health care application has been discussed in epidemic monitoring and control. The IoT is applied to track infected patients and thereby helps to extend the work boundaries for human society. The developed ML-based IoT system not only helps in tracking the pandemic disease it also helps in the prevention of pandemic disease. The developed model gives a broad coordinated organization to health care services to battle pandemic disease. All clinical gadgets are associated with the web, and during any basic circumstance, it consequently conveys a message to the clinical staff. The method gives an accuracy of 93.4 %, sensitivity of 96.28 % and precision of 94 %. The output obtained is higher than the competitive methods. Contaminated cases can be taken care of suitably in a distant area with very much associated tele-gadgets. It handles all cases shrewdly to give at last fortified support of the patient and health care. The developed ML-based IoT module could be the game-changer in epidemic monitoring, with appropriate execution of the proposed invention, expert, authorities from the government and academicians can establish a superior environment to combat this pandemic disease.

Declarations

Conflict of interest The authors declare that they didn't get any financial support or influential support to be reported in this paper.

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