Emerging Advances in the Internet of Things (IoT) Technology for Fast Response to Covid-19 Outbreak With ANOVA-K-NN Implementation

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***Abstract*—The internet of things (IoT) is a fast-growing technology that interconnects devices, homes, hospitals, facilities, and other locations together for faster transmission of data and communication. The present critical situation which is the coronavirus disease (COVID-19) outbreak. This pandemic has caused a lot of economic meltdowns coupled with instabilities and loss of lives worldwide. Several types of research and technologies have been implemented to tackle this pandemic. This study describes the vital steps to follow in IoT technology and the emerging advances it offers for rapid response to the COVID-19 outbreak in order to save lives and to put an end to the pandemic. Some key threats surrounding the IoT technology were highlighted in this study, however, if coped and implemented appropriately, rapid prevention of infection, monitoring of infected and suspected patients, treatment of infected patients, and forecasting of adequate solutions for a better environment is assured. Furthermore,Analysis of Variance (ANOVA) algorithm was used to fetch relevant information, and k-nearest neighbor (k-NN) was used as a classifier to predict the performance of the COVID-19 Iot data system obtained from San Francisco University. An accuracy of 79.17% was achieved. Therefore, this study will be proficient especially for clinicians in making decisions in the post COVID era.**

***Index Terms*—Internet of Things (IoT), Coronavirus Disease (COVID-19), Advances, Internet of Medical Things (IoMT), ANOVA, K-NN.**

I. Introduction

THE entire globe is under a serious pandemic that has placed the world in an unparalleled status today. Before now, people had feared more disastrous crisis related to nuclear weapons, hazardous changes in climates and world wars, little did we know that a virus will put the world on hold. The outbreak of a new coronavirus (COVID-19) originating in Wuhan, Hubei province in China, linked to the Huanan seafood market is apparently insuperable. As of 17th June 2020, the world has recorded 8,287,338 Covid-19 confirmed cases and 446,669 death cases and 4,341,853 recovered cases [1]. The virus is of the *genus beta-coronavirus* and is linked to the viruses which cause middle eastern respiratory syndrome (MERS) and severe acute respiratory syndrome (SARS) [2]. There was a delay in alerting the world health organization (WHO), and this delay pitched into the uncontrolled spread of the virus all over the world, thus the pandemic became a global concern [3]. As there is no effective treatment for coronaviruses and attempts to control the spread have so far failed, global surveillance of people with active COVID-19 infection is urgently needed. The emergence and development of some digital technologies like the internet of things (IoT), artificial intelligence (AI) with the incorporation of deep learning [4], [5] and blockchain technology [6], big data analytics [7], and 5G telecommunication networks become very important [8], [9], [10]. The IoT Proliferation promotes the establishment of hospitals, homes, offices, industries, and clinics digital ecosystem deeply interconnected, enabling data collection on a scale, in real-time in order to understand the prediction, prevention, monitoring, and the trends of every connected situation.

The internet of things (IoT) is a methodical design of interconnected digital machines, mechanical devices, and computing techniques that have their own personalized identifier codes or numbers and data transfer capabilities over the specified network without any degree of human involvement. IoT entails anything linked to the internet but it is primarily used to describe objects that speak to each other. The Internet of Things is literally made up of devices linked together from basic sensors to smartphones and wearable devices. IoT technology is gaining increasing global attention and becoming ever more available to predict, prevent, and monitor emerging infectious diseases. IoT has enhanced human life by offering access to everyone regardless of time and place. Some of the present applications of IoT are in smart homes, agriculture, transportation, utilities, energy, health care, etc.

During this COVID-19 outbreak era, every country, including Nigeria is seeking measures to monitor, control, and to proffer solutions to problems that have and will still arise in this pandemic. Several works and researchers from all fields of study most especially in engineering and sciences are working together to put an end to this pandemic by formulating theories, gathering data, testing results, and providing preventive measures. A machine learning approach is proposed for classifying COVID19 IoT data system. This study aims to provide more attention and awareness of the IoT technology and its benefits to respond fast to the COVID-19 pandemic.

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II. Essence of the Study

The rate at which the infected patients are increasing in the world is alarming. This calls for an immense need to maximize the benefits offered by the use of IoT technology. More so, IoT has been deployed in the industry which is called the industrial internet of things (IIoT), in the medical field which is the internet of medical things (IoMT), and in the health care system which is called the internet of health care things (IoHT) [11], [12]. However, fast responses to the COVID-19 outbreak could be achieved by developing the existing methods employed in IoMT and IoHT.

III. Background of the Internet of Things on COVID-19

The first appearance of internet of things in a scientific publication was in the year 2006 [13]. IoT is basically a robust network system consisting of various linked real-world objects based on the technologies of sensory, information processing , networking and communication [14]. The base technology for IoT is radio frequency identification (RFID). The use of RFID, development of wireless sensing technology, use of the internet in medicine and the use of artificial intelligence (AI) are the major developments in IoMT. IoT goes beyond the idea of an overall architectural context. In the end, allows for integration and effective exchange of data between vulnerable individuals and service providers. The majority of problems arise in the present imminent situation, because of the ineffective patient accessibility, which is the second most significant issue after vaccine development issues. Using the IoT technology makes it very convenient and accessible patients, which eventually gives them significant treatment for the virus.

IV. Steps in IoT for Rapid Response to COVID-19 Outbreak

The IoT technology offers significant and rapid response in fighting COVID-19 even during the social distancing and lockdown status, majorly because, the IoT technology offers real-time data capturing of both infected and suspected patients at any location. Figure 1 depicts the vital steps to be followed in IoT for fighting COVID-19. The first step collects and stores the infected and suspected patients data from any location, then followed by analysis of the data collected. The third step involves suitable treatment and monitoring and then followed by the virtual management (supervision, communications, and interactive sessions). Finally, all the data collated over time will be modeled by using a suitable statistical tool to predict and forecast the virus so as to enable a better environment in the nearest future incase a similar outbreak occurs.

V. Applications of IoT and its Emerging Advances on COVID-19

IoT technology is a relatively new technology when compared with old technologies. For the past less than two decades now, IoT has experienced growth and development in different fields of study including the medical and health care sector. These fields of study are in the energy sector [15], [16], [17], [18], [19], [20], [21], [22], electrical and electronics sector [23], [24], [25], [26], [27], production and manufacturing sector [28], [29], [30], [31], [32], [33], [34], [35] management and public service sector [36], [37], [38], agricultural sector [39], [40], [41], [42], [43], and the health sector [45], [46], [47], [48], [49], [50]. Several studies have been carried out on IoT relating to COVID-19 [51], [52], [53]. The emerging advances in IoT in order to respond quickly to COVID-19 pandemic are;

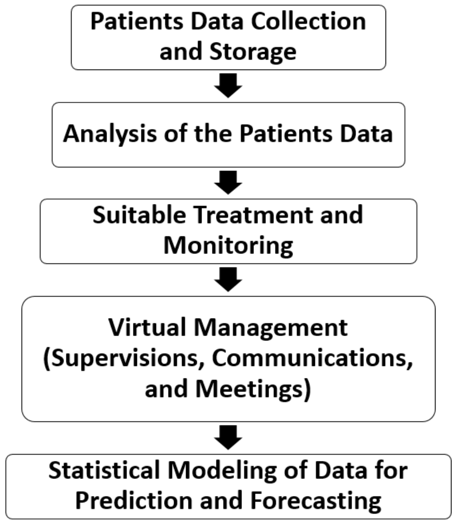

Fig. 1. Vital steps in IoT for rapid response to COVID-19

A. Enhanced Diagnosis or Pre-screening

While hospitals and health centers were quick to begin telemedicine services for diagnosing, screening and answering COVID-19 questions, the number of calls was overwhelming. This led to increased waiting time on their hotline and eventually, most callers tend to drop out at this time. To tackle this problem, hospitals and health centers should collaborate with software companies to set up chat-bots and programmes on their mobile application and websites which will enable these chat-bots diagnose and screen visitors to ascertain the levels of their conditions. This will ease of the burden on doctors and other health practitioners of attending to series questions and answers repeatedly, thereby enabling them focus on treating the patients. Firms like Bespoke, which is a Japanese company have launched a chat-bot that answers COVID-19 related question. Another hospital named Providence St. Joseph Health System in Seattle, launched a chat-bot in collaboration with Microsoft, to attend to patients. Hence, other hospitals especially in Nigeria should look forward to similar solutions.

B. Quarantine Tracking

A crucial move in curbing COVID-19 spread is the successful quarantine of individuals infected or considered to be infected. But that is easier said than done in a global environment. Thus, countries around the world turned to IoT and global positioning system (GPS), allowing apps to track and, if necessary, restrict movements of such people. Hong Kong began the Airport quarantine effort. Passengers arriving were given a wrist-band along with a unique quick response(QR) to track their movements. Passengers downloaded their smartphones to an app called 'Stay Home safe,' and scanned the QR. Each individual had to walk around the apartment on arriving home to calibrate the device. The basic technology behind this is geofencing, where GPS, RFID, Wi-fi, Bluetooth signal and cellular network are used to establish a virtual perimeter. Some other countries looking at this solution for a faster response are South Korea, Poland, Singapore and Poland. Nigeria should Key into this advancing solution.

C. Disinfecting and Cleaning

Disinfecting, sanitizing and cleaning of medical facilities are important and this step is further underscored by the infectious existence of COVID-19. Companies like Xenex Disinfection Services, TMiRob and Danish company ultraviolet disinfection (UVD) self-driving robots have already started this task. The disinfection of the surfaces by the self-driving robots is achieved by emitting ultraviolet light of high intensity which destroys the virus by tearing their Deoxyribonucleic acid (DNA) apart. These self-driving robots are based on wi-fi, and can be controlled via apps. Presently, Italy, China and the United states of America are using this technology. More countries allover the world especially Nigeria should consider this technology.

D. Home Infection Reduction

With the use of IoT enabled devices and wearables like smart security systems, smart speakers, smart lighting etc. to switch on the lights and open the doors of our homes, the risk of being infected reduces. One can easily place orders, open the doors and knobs with smart phones thereby avoiding physical contact with the door by visitors or relatives. Also, with the mandatory stay at home orders in place, IoT gives us the leverage of video conferencing and also a simple voice command to meet our loved ones virtually.

E. Ingenious use of unmanned aerial vehicle (UAV)

Drones and quad-copters can be used innovatively in this COVID-19 era to solve some problems, since social-distancing has become the new normal. Countries like China, Spain and South Korea have deployed the use of drones in response to this pandemic. Some of the services these drones render are;

- To transport/fly Covid-19 samples and other medical samples together with quarantine materials from one place to the expected destination.
- To administer and monitor the people so as to ensure that the stay at home policy is strictly adhered to.
- To read the temperature of suspected patients and infected patients in quarantine through infrared thermometers equipped with the drones while the patients stands somewhere visible like a balcony.
- To sanitize and disinfect highly contaminated locations.

F. Connected Thermometers

Hospitals use connected thermometers to screen their staff and patients often. For instance, in Shanghai Public Health Clinical Center (SPHCC),they use continuous temperature sensors to monitor Covid-19 patients to reduce the risks of hospital staffs. This device was developed by VivaLNK's, a connected health startup based in California. This temperature sensors provide real-time and continuous monitoring of any changes in body temperature. It collects real-time patient data with the use of uses IoT Access Controller by Cassia from the sensors and wirelessly transfer the data to a nurse's/ health practitioner's station for continuous monitoring. Some other hospitals in China are using this system. [geospatial]

G. Smart Wearables

Series of researches and implementations have been done in this field. These smart wearables mostly in form of wrist bands have been designed to send alert at any increase in above the normal body temperature, hence finding the closest hospital. Researchers at the IIT-Istituto Italiano di Tecnologia have developed sensorized suits which can track parameters of the human body. The smart band warns users when their body temperature is above 37.5deg C. When reading human body movement, the smart band releases radio signals from which it is possible to obtain the distance from another bracelet; when two smart bands are close, they vibrate, transmitting an warning signal that allows people to recognize social distance. The radio signal frequency is 2.45 GHz, the same as Bluetooth, but IIT developed a proprietary protocol for simpler and faster human proximity detection. Hong Kong is using electronic tracker wristbands to alert authorities when individuals especially those newly arrived from foreign destinations do not comply with mandatory home quarantines. In China on the other hand, are using rings and bracelets synced with an AI app from CloudMinds to provide continuous monitoring of vital signs, including temperature, blood oxygen levels and heart rate.

H. Faster Consultation

With hospitals and patients real time data interconnected, it will be easier and faster to contact specialists in order to be able to connect with the difficult to diagnose patients so as to support the ongoing treatment and thereby increasing the success rate. It is known that some of the causes of death due to Covid-19 are hypoxic respiratory failure, multiple organ failure, acute respiratory distress syndrome (ARDS), sepsis, complications and pregnancy. Having all these causes addressed in a timely manner will result to very fast oxygenation, treatment and monitoring of the distressed COVID-19 patients, hence, reducing the rate of mortality. The IoT will assist in this job. Experts and physicians at the forefront with augmented reality(AR) technology can hold consultations and support them through AR, which can be easily and quickly completed without location , space, and time restrictions while minimizing the risk of infection and preventing isolation after consultation.[song2020]

I. Quality Control

In this era of COVID-19 pandemic where the infection rate is very high, ensuring the quality of medical care that really involves the participation of different doctors and hospitals becomes an inevitable challenge. To ensure quality control using IoT, patients data should be processed and

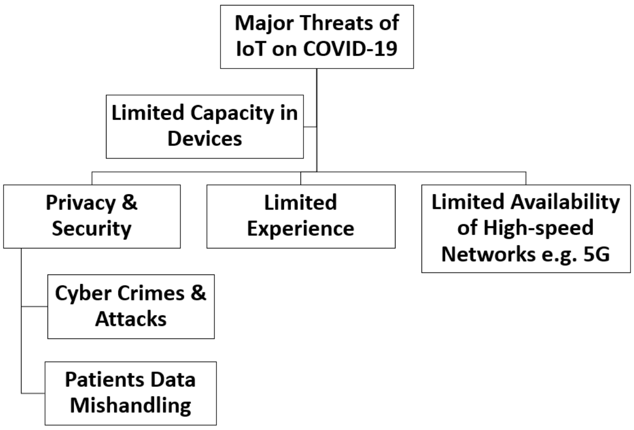

Fig. 2. Threats associated with IoT on COVID-19

classified accordingly with intelligent management system. Also, utilizing high-speed quality information control and a qualified statistical model of epidemiological evidence, we can obtain the findings of the most recent quality reviews efficiently, carefully monitor the potential risks and provide early warning, and reviews from hospitals and doctors at all levels in good time.

J. Precise Forecasting and Prediction of Virus

Relying on the diverse and numerous collated datasets and available reports, with the use of a carefully selected statistical tool [54] , it will ensure an accurate forecasting and prediction of the situation incase of any reoccurrence of the infection in the nearest future. This will also help to prepare and plan a better working environment for the engineers, health practitioners, academics, government and the world at large so as not to be paralyzed and severely affected by the infection.

K. Profer Innovative Solutions

IoT will provide more innovative approaches that will aid ultra-fast responses. This can majorly be achieved by a good quality of supervision and ensuring that the innovation will be accessible to everyone.

VI. Threats Associated with IoT on COVID-19

When dealing with this technology (IoT) on COVID-19, it is important to know some of the underlying threats and issues surrounding it. These threats are majorly concerned with the privacy, security and management of the patients data collected. The concise threats of IoT on COVID-19 is a depicted in Fig. 2.

These threats are valid, nevertheless, if coped properly, hospitals and other integrated organizations could be further assured and the path to IoT victory and productivity would be impartially smooth. It is very crucial to know that IoT is not a standalone device, It needs to be recognized as a broad, diverse and rich ecosystem that incorporates people, communications and interfaces. Subsequently, future work will look at the working advances in IoT together with the safety measures that has been utilized.

VII. Predictive Model

To construct a predictive model for our identification (or prediction) framework, this study used a preprocessed dataset. The aim of this model is to predict the probability that COVID-19 will infect a given individual. ANOVA algorithm was used with the K-NN classifier in this study. Fig. 3 shows the workflow of the procedures. MATLAB software

Fig. 3. Workflow of the procedure

was used in this study to run the algorithm on our data set [55]. Below is a brief description of the algorithm.

A. Analysis of Variance (ANOVA)

By comparing the mean values of the data in each group, the Anova algorithm computes the difference between groups. The findings are obtained by checking the null hypothesis; the hypothesis that the means of the groups do not vary. More formally, under the null-hypothesis, the p-value is the likelihood of the real or a more extreme result. As a sum of components, the ANOVA algorithm simplifies the intensity value [56]. The ANOVA statistic is known as the F-statistic, which can be calculated as;

$$\mathrm{F} = \frac{SBG}{SWG} \tag{1}$$

where *SBG* is the ratio of the sum of squares between the groups to the degree of freedom between the groups, while *SWG* is the ratio of the sum of squares within the groups to the degree of freedom within the groups. A matrix of the form N X M is the input to the algorithm, where N in the dataset, is the total the number of feature sets and M is the number of samples.

B. K-Nearest Neighbors (K-NN) Algorithm

The k-nearest neighbor algorithm (k-NN) is a proposed non-parametric approach used for classification and regression in statistics. The input in both instances consists of the k nearest training examples in the space of the function. Whether k-NN is used for classification or regression depends on the output: k-NN is used for classification in this analysis. Particular features are defined as a contribution to this segment. Carefully selected are the Kth principles that are contiguous to the query opinion, considering distance between query-instance and training models. The distance is fixed and the nearest neighbors created on the Kth least distance are resolute, group Y of the nearest neighbors are grouped and use the prediction value of the query instance as an unassuming common group of nearest neighbors by arbitrarily fragmenting any drawings [57].

VIII. Performance Evaluation

To evaluate the performance of the ANOVA, six performance metrics were used: Accuracy, sensitivity, specificity, precision, F1-score, Matthews Correlation Coefficient (MCC). These metrics were computed using a confusion matrix and a cross validation methods.

A. Confusion Matrix

The confusion matrix is the common representation of classification model output and contains the values correctly and incorrectly classified relative to the actual results in the test data [58]. The four variables are:

- True positive (TP): which is the product where the positive class is correctly predicted by the model (condition is correctly classified when present);
- True negative (TN): which is the product where negative groups are correctly predicted by the model (condition is not detected when absent);
- False positive (FP): which is the consequence where the model predicts positive class incorrectly (condition is detected despite being absent);
- False negative (FN): which is the product of the negative class predicted incorrectly by the model (condition is not detected despite being present).

B. Accuracy

This is an indicator of statistical bias. It is given by;

$$\text{ACC} = \frac{(TP + TN)}{(TP + TN + FP + FN)} \tag{2}$$

C. Sensitivity

Sensitivity measures the level of real positive ones that are properly classified as positive. It is also known as true positive rate (TPR).

$$\text{TPR} = \frac{TP}{(TP + FN)} \tag{3}$$

D. Specificity

Specificity measures the level of real negative ones that are properly classified as negative. It is also known as true negative rate (TNR)

$$\text{TNR} = \frac{TN}{(FP + TN)} \tag{4}$$

E. Precision

Precision measures the level of positive results that are true positive. It is also called the Positive Predictive Value (PPV)

$$\text{PPV} = \frac{TP}{(TP + FP)} \tag{5}$$

F. F1 Score

The F1 Score is a measure of the accuracy of a test, defined as the harmonic mean of PPV and recall.

$$\text{F1 Score} = \frac{2TP}{(2TP + FP + FN)} \tag{6}$$

G. Matthews Correlation Coefficient (MCC)

This explains how changing one variable's value affects another variable's value and returns a value between -1 and 1. +1 describes a successful prediction; then, 0 implies unable to return any valid knowledge (no better than random prediction); while -1 describes total prediction of inconsistency [59], [60].

$$\text{MCC} = \frac{(TP \times TN – FP \times FN)}{(JK)^{0.5}} \tag{7}$$

Where J = (TP + FP) $\times$ (TP + FN) and K = (TN + FP) $\times$ (TN + FN)

H. Receiver Operating Characteristic (ROC)

Another means of evaluating the performance of a classifier is the Receiver Operating Characteristic (ROC). The True Positive Rate is plotted against the False Positive Rate to achieve this [58]. Then the region under the resulting ROC curve is used to calculate the classifier's accuracy. The nearer the region is to 1, the better the classifier is. The true positive rates and false positive rates are given by;

$$\text{True Positive Rate} = \frac{TP}{(TP + FN)} \tag{8}$$

$$\text{False Positive Rate} = \frac{FP}{(FP + TN)} \tag{9}$$

I. Cross Validation Methods

Cross Validation is a mathematical approach used to assess learning efficiency and methods of classification. This is achieved by dividing the available instances of labeled data into k folds. For research, one fold is for response, and the others are predictors [58]. 10-fold cross validation was used in this work. Instances of the dataset are split into ten folds. One-fold has been used for 10 iterations for testing and 9 folds for training, such that a different fold is used for testing in each iteration.

IX. Results and Discussion

This study incorporated a machine learning approach using ANOVA algorithm with k-NN on a COVID-19 data obtained from San Francisco University. The COVID-19 data consisting of 15979 feature and 235 samples was used [55]. ANOVA fetched out relevant subset features from the data and k-NN using simple tree was used to classify the experiment. Figure 4 shows the confusion matrix used in getting the performance metrics resulting from the application of the 10- fold cross validation on the k-NN classifier.

The performance metrics is shown in Table I. The result of the experiment is compared with the state of the art as shown in Table II. The result presented in Table I shows that the accuracy is 79.17% which out performed other classifiers shown in Table II. This also shows that the ANOVA-k-NN is effective in predicting potential and confirmed cases of COVID-19.

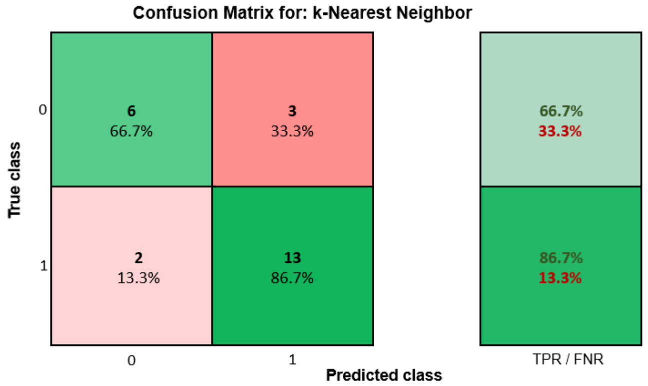

Fig. 4. Confusion matrix using ANOVA-k-NN TP = 13, TN = 6, FP = 3, FN = 2

TABLE I
PERFORMANCE METRICS

Measure %	Results %
Accuracy	79.17
Sensitivity	86.67
Specificity	66.67
Precision	81.25
F1 Score	83.87
MCC	54.77

X. CONCLUSIONS

IoT offers an comprehensive interconnected network for healthcare to rapidly respond and deal with COVID-19 pandemic. The underlying technologies and the IoT components that can be utilized to allow a healthcare system to deal with disease outbreaks already exist; however, they are fragmented and not yet linked. Therefore, the system needs to be able to build up its infrastructure rapidly to link the components of data collection, processing, and storage, so that the system can scale and expand for disease monitoring, Preventive measures, and the in-patient treatment of the infected. Furthermore, the interconnectedness of the healthcare facilities to the internet will enable fast and smart communication incase of any emergency, screen and diagnose patients effectively, monitor and ensure that policies are obeyed, ensure that all processes are under quality control and enable proper prediction and forecasting of the future situations of COVID-19 which will led to a well prepare and planned environment for everybody. Furthermore, an experiment was conducted to test ANOVA on real COVID-19 dataset using the k-NN as a classifier. The accuracy obtained is 79.17 % which is effective in identifying potential cases of COVID-19. Finally, with the accuracy of the result obtained in this study, faster responses in combating COVID-19 now and in the nearest future is assured. Further research will look into more algorithms that will yield even more accurate results and faster responses.

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TABLE II
COMPARISON WITH STATE OF THE ARTS

Authors	Approaches	Results %
Otoom [61]	ZeroR	57.86
Otoom [61]	OneR	68.36
Otoom [61]	Decision Stump	70.73
Raju [62]	Naïve Bayes	25

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