i-Sheet: A Low-Cost Bedsheet Sensor for Remote Diagnosis of Isolated Individuals

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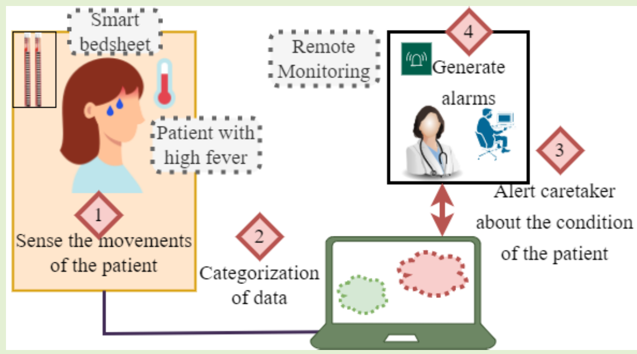
***Abstract*—In this article, we propose a smart bedsheet—i-Sheet—for remotely monitoring the health of COVID-19 patients. Typically, real-time health monitoring is very crucial for COVID-19 patients to prevent their health from deteriorating. Conventional healthcare monitoring systems are manual and require patient input to start monitoring health. However, it is difficult for the patients to give input in critical conditions as well as at night. For instance, if the oxygen saturation level decreases during sleep, then it is difficult to monitor. Furthermore, there is a need for a system that monitors post-COVID effects as various vitals get affected, and there are chances of their failure even after the recovery. i-Sheet exploits these features and provides the health monitoring of COVID-19 patients based on their pressure on the bedsheet. It works in three phases: 1) sensing the pressure exerted by the patient on the bedsheet; 2) categorizing the data into groups (comfortable and uncomfortable) based on the fluctuations in the data; and 3) alerting the caregiver about the condition of the patient. Experimental results demonstrate the effectiveness of i-Sheet in monitoring the health of the patient. i-Sheet effectively categorizes the condition of the patient with an accuracy of 99.3% and utilizes 17.5 W of the power. Furthermore, the delay involved in monitoring the health of patients using i-Sheet is 2 s which is very diminutive and is acceptable.**



***Index Terms*—Artificial intelligence, COVID-19, remote monitoring, sensors, smart bedsheet.**

I. Introduction

IN THE current pandemic scenario, when COVID-19 hits the world, sensors connected with artificial intelligence proved beneficial for remotely monitoring the health of isolated patients. Remote monitoring helps to track the health of the patients by measuring various readings related to vitals such as body temperature, blood oxygen saturation, and heart rate [1], [2]. There are different wearable devices and systems using a diverse range of sensors present in the market that help in the remote monitoring of patients. However, these systems are manual and practical during day time. It is difficult to check and monitor the health of the patients at night when they are sleeping and not able to measure the readings of their vitals. Furthermore, COVID-19 affects various vitals such as the lungs, heart, and others. There is a need for a system that monitors the health of the patients even after the recovery and prevents various further risks related to health. To solve these problems, there is a need for a one-stop solution that monitors the health of the patients during COVID as well as post-COVID and alerts the caregiver and medical officers.

In this article, we propose—i-Sheet—that senses the movement of the person to determine their condition during and after COVID-19. i-Sheet senses the pressure exerted by the patients, and based on that pressure, we determine whether they are in a comfortable state or not. As shown in Fig. 1, the smart bedsheet sends the data related to the patient for remotely monitoring the health. We utilize the machine learning (ML) model to categorize the data of stable and unstable patients. On the basis of this data, the caregiver or the healthcare gets alerts and remotely monitors the health of the patient.

Example Scenario: Consider a patient suffering from COVID-19, and the health of the patient becomes unstable at night. To monitor the health, as shown in Fig. 1, the smart bedsheet collects the data on the pressure exerted by the patient. On the basis of variation in the pressure, the system categorizes the condition of the patient and accordingly alerts the caregiver or the medical officer for remotely monitoring.

A. Biasness for i-Sheet

There are various smart bedsheets present in the market that utilize a large number of various types of sensors and complex ML techniques to determine the posture of individuals. This

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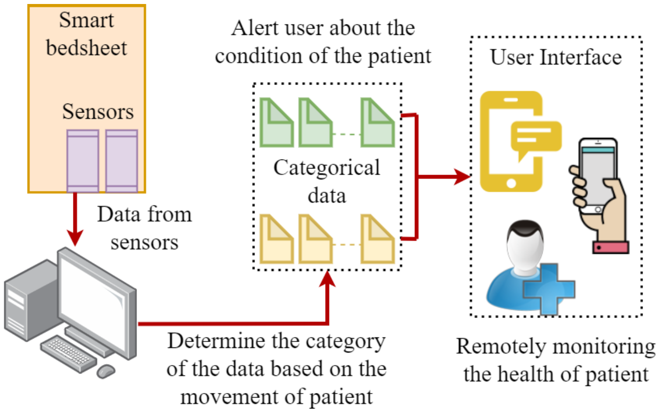


Fig. 1. Overview of i-Sheet for health monitoring.

results in an increase in cost as well as computational expense. However, i-Sheet utilizes only two flex force sensors to detect the movement of the patient. Furthermore, i-Sheet does not use a computational extensive ML technique to detect the posture of the individual. Rather, it only detects the movements by utilizing the fluctuations in the data and further utilizes K-means to categorize the condition. Indeed, the utilization of only two sensors and K-means for monitoring health reduces the cost as well as the computational overhead. Furthermore, we utilize flex force sensors in i-Sheet because these sensors do not create any discomfort to an individual when attached to any fabric and also measure small deflections on the surface. In addition to this, these sensors are very cheap. These properties of the flex force sensor make it suitable for i-Sheet.

B. Biasness for K-Means

The incoming data from i-Sheet has a large range of spherical values, which varies at a different rate. There is a need to categorize this data to detect the condition of the patients as comfortable as well as uncomfortable. This categorization is done with the help of ML models. As proof of concept, we utilize K-means to categorize the data; however, i-Sheet is independent of the ML model. Indeed, K-means is less computational expensive over spherical data, guarantees convergence, and is easily adaptable, which makes us to use K-means. Furthermore, we also check the efficacy of i-Sheet for density-based spatial clustering (DBSCAN), affinity propagation, and fuzzy C means.

C. Motivation

In this COVID-19 scenario, it is important to monitor the health of the patients to continue to keep a check as well as prevent their health from deteriorating. However, it is very difficult to monitor the health of the patient at night, as the systems and wearable devices present in the market are manual and require the input of the patients to start health monitoring. Indeed, it is not possible to give continuous manual input at night, and it becomes difficult to monitor the health of the patients. Furthermore, COVID-19 also hits various vitals, and even after the recovery from it, there are chances of various diseases such as lung failure, heart failure, blood pressure, and others. To prevent these health risks and provide continuous monitoring of the patients during and post-COVID, we propose a smart bedsheet that prevents health deterioration.

D. Contribution

We propose a smart bedsheet for continuously monitoring the health of the patients remotely. Toward achieving this, the following are the specific set of contributions in this work.

1) *i-Sheet:* We propose a smart bedsheet—i-Sheet—that continuously senses the pressure exerted by the patient and further helps the caregiver or medical officer to monitor the health of the patient remotely. This helps in preventing the health of the patients from deteriorating.
2) *Automatic monitoring:* Irrespective of the input from the patient, i-Sheet continuously senses the pressure exerted by the patient and based on that data, it categorizes the condition as stable or unstable.
3) *24 × 7 monitoring:* i-Sheet provides continuous monitoring of the health of patients based on the pressure exerted irrespective of the daytime.
4) *Post-COVID health monitoring:* We propose a one-stop solution for monitoring health that not only proves beneficial during COVID, however, after recovery also. i-Sheet monitors the health of patients after the COVID, which is mandatory as there are chances of failures of various vitals such as lungs, heart, kidney, and others.
5) *Universal solution:* i-Sheet proves beneficial in monitoring the health of patients suffering from other diseases apart from COVID-19 as it detects the condition of the patients based on the pressure exerted on the bedsheet.
6) *Evaluation:* Through experiments and deployment of i-Sheet, we demonstrate the feasibility and efficiency of the same in monitoring the health of the patient remotely.

It may be noted that, in this work, we only focus on the health-related issues for data-centric categorization of the condition of the patient and do not take other factors influencing the data of sensors such as bad dreams and intentional movements.

The organization of the rest of the article is as follows. Section II contains the various research works done by the researchers in the field of COVID-19 monitoring and smart bedsheets. Section III describes the system model and the proposed solution. Section IV discusses the experimental setup, results, and the comparison of the proposed approach against other approaches, followed by the conclusion in Section V.

II. Related Work

A. Health Monitoring Systems

Ahmed *et al.* [3] proposed a health monitoring system that utilizes an optical camera for capturing the image and extracting the data. Furthermore, they also utilized the fusion of oximeter sensors and cameras for monitoring the health of COVID-19 patients. Apart from this, Jyothilakshmi *et al.* [4] utilized a Kinect camera to recognize the gesture of the patients. They utilized trained ML classifiers to enable smart wards and health monitoring systems. Furthermore,

TABLE I
DIFFERENCE OF I-SHEET WITH SOME EXISTING HEALTH MONITORING SYSTEMS

Paper	Real-time monitoring	Comfortable	Automatic	Complexity	Price
Schollas [7]	✓	×	×	High	High
Filho *et al.* [8]	✓	✓	×	High	High
Ahmed *et al.* [3]	✓	✓	✓	High	High
Jyothilakshmi *et al.* [4]	✓	✓	✓	High	High
Thiyagarajan *et al.* [12]	✓	✓	×	High	High
Rehman *et al.* [13]	✓	✓	×	High	High
Yang *et al.* [10]	✓	✓	×	High	High
i-Sheet (proposed)	✓	✓	✓	Low	Low

Zin *et al.* [5] proposed a stereotype depth camera for monitoring the sleep of patients. They utilized this sleep data to examine their health. Apart from this, they also monitored the location of the patients along with their activities to get an in-depth analysis of patient health. Yang *et al.* [6] proposed contactless monitoring of COVID-19 patients by utilizing video-based technologies and mm-wave radar for the detection of vital signs. Scholles [7] proposed a smart multimodal system for the detection of COVID-19. He utilized seven different types of sensors to fetch the data on the vitals of the patients. Furthermore, Filho *et al.* [8] proposed an IoT-based healthcare system to remotely monitor the health of the patient by these IoT solutions in intensive care unit (ICU) beds. Similarly, the authors in [9], [10], and [11] utilized various sensors such as oxygen sensors, body temperature, blood pressure, heart rate, ECG, breathing rate, blood glucose, and others to monitor the body of the patients. Apart from this, Thiyagarajan *et al.* [12] utilized wearable sensors for monitoring the temperature of the human body and compared the efficacy of the sensor with other sensors such as infrared sensor (IR) and thermocouples to distinguish minimal temperature variations. Rehman *et al.* [13] proposed a contactless sensing platform for the early detection of COVID-19 by using software-defined radio technology for the detection of COVID-19 symptoms like coughing and irregular breathing.

B. Smart Bedsheets

Lokavee *et al.* [14] proposed a smart bedsheet and pillow system for monitoring posture movement as well as the respiration rate. Furthermore, Huang *et al.* [15] and Yue *et al.* [16] proposed a smart bedsheet for monitoring the sleeping posture of bedridden patients and prevent ulcers. Similarly, Matar *et al.* [17] utilized an artificial neural network for the classification of in-bed posture using the sensors embedded in a bedsheet to prevent ulcers. Furthermore, Hu *et al.* [18] also monitored the sleeping posture using a pressure-sensitive conductive sheet for real-time recognition of patients in order to improve their sleeping quality and health. Apart from this, Munidasa *et al.* [19] proposed a smart bedsheet for monitoring the movement of infants and preventing sleeping disorders.

C. Synthesis

There are various systems utilizing sensors such as temperature, oxygen saturation level, heart rate, and others for monitoring health, as shown in Table I. These systems sense

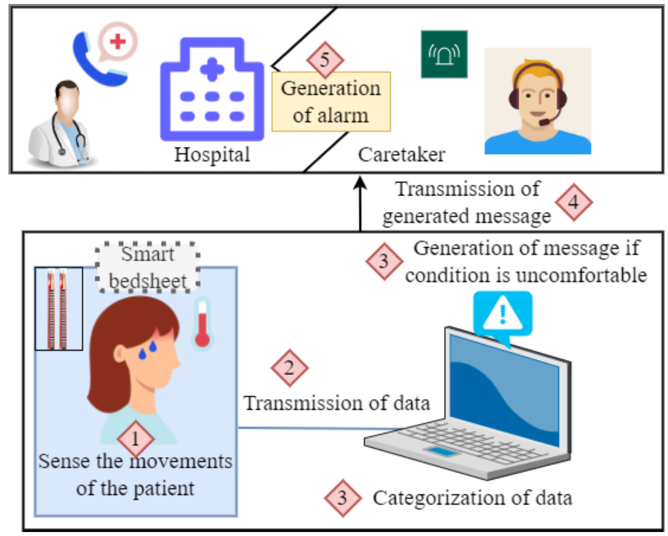


Fig. 2. Overview of i-Sheet for health monitoring.

the data related to the vitals of the patient and further monitor the health. However, to utilize these systems, the patient manually starts the sensing and allows the same to sense the data and further transmit it for monitoring. It is difficult for a patient in a critical condition or at night to start the sensing manually. Furthermore, there are various solutions based on image processing that continuously capture the images of the patient and utilize the same for monitoring the health of the patient. These solutions are costly and are not much effective at night because of occlusion. To resolve these issues, we propose a smart bedsheet—i-Sheet—that monitors the movements of the patients on the bedsheet to monitor their health. Indeed, there are various smart bedsheets available on the market; however, these are not used for monitoring the health of COVID-19 patients. The researchers utilize these bedsheets to monitor the posture of bedridden patients.

III. SYSTEM MODEL

A. Network Architecture

We propose i-Sheet to monitor the condition of the COVID-19 patients by observing their movements on the bedsheet. In order to achieve this, i-Sheet senses variations in the pressure exerted by the patients on the bedsheet. Furthermore, the sensor forwards the data to the monitoring device, which categorizes it into groups on the basis of the rate of variation in the data, as shown in Fig. 2. As a proof of concept, we utilize the K-means clustering algorithm to categorize the data into two clusters $C = \{\text{comfortable, uncomfortable}\}$. The categorization of the data into a particular group represents the condition of the patient as comfortable or uncomfortable. Furthermore, the monitoring device generates alarms to alert the caregivers or the medical officer if the patient is uncomfortable.

B. Proposed Sensor

We design a sensor that monitors the amount of bending or deflection on the surface while the patient moves, as shown

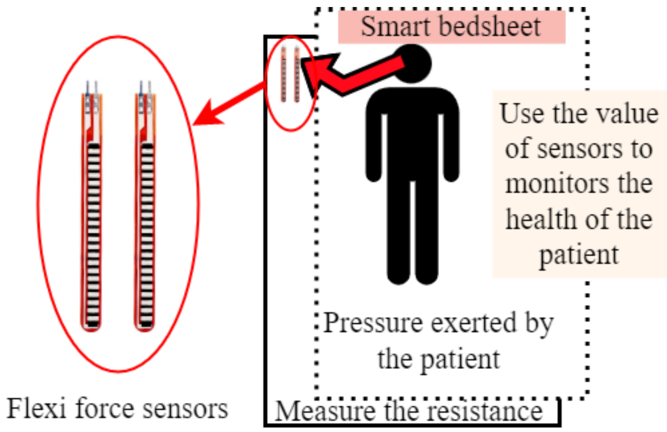


Fig. 3. i-Sheet for monitoring the health of the patient.

in Fig. 3. The resistance of the sensor varies with the bending of the sensor surface, which is directly proportional to the amount of the bend, as shown in (1). This is because with the bend, the voltage and current change, consequently resistances change [20]. The resistance of the sensor increases with the increase in the bend on the surface of the sensor, and deflection varies with the movement of the patient. We utilize the concept that the uneasiness in the condition of the patient results in more movements. These movements make deflections on the surface of the sensors and uneven changes in the values of the sensors. These changes help monitor the condition of the patient as comfortable or uncomfortable diurnally and help the caregivers to take necessary action

$$R \propto B. \tag{1}$$

Algorithm 1 Algorithm for Monitoring the Health of the COVID-19 Patient

```
Input: Data sensed by i-Sheet
Output: Health condition of COVID-19 patient
Procedure:
while i-Sheet senses data do
    Initialize i = 1;
    Initialize an array A[size=5]
    // Stores the previous five values of the
     sensors to depict the fluctuations
    Analyzes the data;
    Compare the data d_i with the data stored in array A.
    Calculate the average difference of d_i with the data in A.
    Apply K-means on the difference to categorize the data.
    while i ≤ 4 do
        a[i] = a[i + 1];
        i = i + 1;
    end
    a[i]=d_i;
    // Updation of the historical data with
     the arrival of new data
end
```

C. Power Consumption Model

The power consumption of the system depends upon the current and voltage requirement of the sensor and the monitoring devices and is given as follows:

$$P = I_s \times V_s + I_m \times V_m \tag{2}$$

where I_s is the current requirement of the sensor, V_s is the voltage requirement of the sensor, I_m is the current requirement by the monitoring device, and V_m is the voltage required by the monitoring device. Furthermore, the value of I_s depends upon the active sequence i of the sensor, the average current I_i of the active sequence, and the time duration t_i of the active sequence in the total time of T and is given as follows:

$$I_s = \left(\sum_{i=1}^{m}\left(\frac{t_i}{T} \times I_i\right)\right). \tag{3}$$

Furthermore, the total power consumption in monitoring the health of the patient is given as follows:

$$P = \left(\sum_{i=1}^{m}\left(\frac{t_i}{T} \times I_i\right)\right) \times V_s + I_m \times V_m. \tag{4}$$

D. End-to-End Data Transmission

i-Sheet generates the data due to the movements of the patients on the surface of the bedsheets and further categorizes the same to detect the condition of the patient as comfortable and uncomfortable. Based on the condition of the patients, i-Sheet sends a message packet to the caregiver (registered number), which generates alarms on the device to alert the respective individual.

E. Health Monitoring by i-Sheet

We monitor the health of the patient by using the proposed i-Sheet. We utilize the data sensed by i-Sheet to determine the condition of the patient. The fluctuations in the data are the main source that helps in categorizing the health of the patient. For instance, if the fluctuations are not very high, then the condition of the patient is normal; otherwise, the condition is abnormal, as shown in Algorithm 1. Furthermore, we compare the recent data value with the historical data to determine the fluctuations. As a proof of concept, we use the K-means clustering algorithm to determine the category of the data and further the category of the patient. Furthermore, on the basis of the condition of the patient, the monitoring system alerts the caregiver as well as the medical officials.

Apart from this, the complexity of the proposed algorithm for a single iteration is $O(n^2)$, where n is the size of the input data. The algorithm continuously senses the data, and for each data point, the complexity of the algorithm is equivalent to that of K-means, which is $O(n^2)$.

IV. Performance Evaluation

A. Experimental Setup

In this section, we evaluate the efficacy of the proposed i-Sheet in monitoring the health of the patient. In order to test the effectiveness of i-Sheet, we connect it with Arduino Uno to collect the data sensed by it (sampling rate is 1 kHz) and further categorize it into groups on the basis of the fluctuations in the values of i-Sheet. Furthermore, we generate a client–server model in which the server sends the alert to the client (caregiver) on the detection of the abnormal condition

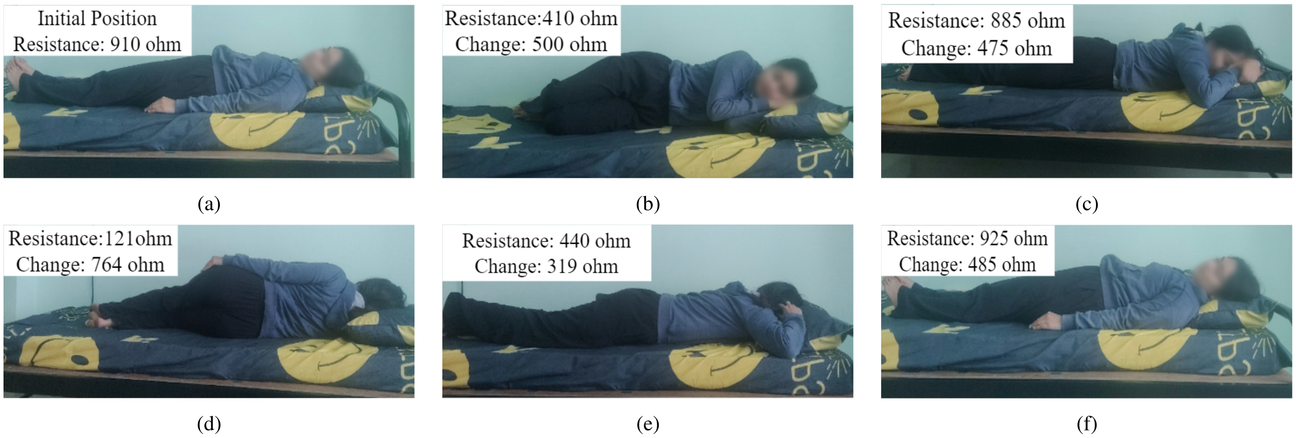


Fig. 4. Patient posture in an uncomfortable condition. (a) 12 A.M., (b) 12:10 A.M., (c) 12:20 A.M., (d) 12:30 A.M., (e) 12:40 A.M., and (f) 12:50 A.M.

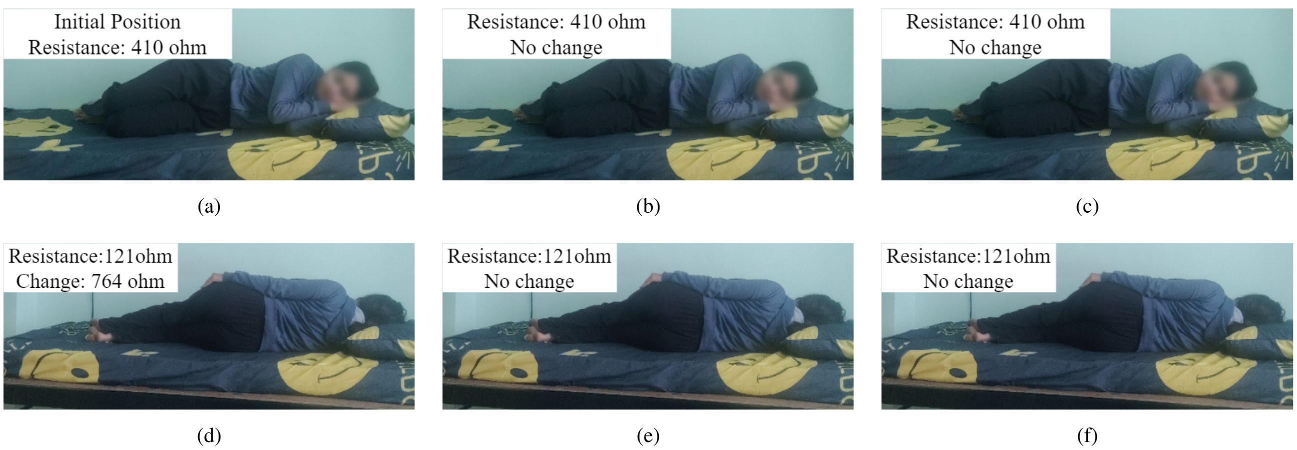


Fig. 5. Patient posture in a comfortable condition. (a) 2 A.M., (b) 2:10 A.M., (c) 2:20 A.M., (d) 2:30 A.M., (e) 2:40 A.M., and (f) 2:50 A.M.

of the patient. Apart from this, we also check the efficacy of i-Sheet under various temperature conditions as well as at various times of the day. For this, we set the temperature of the room at various degrees such as 10 °C, 20 °C, 30 °C, and 40 °C. Apart from this, we iterate our experiments to record the observations at different times of the day, such as 4 A.M., 8 A.M., 12 P.M., 4 P.M., 8 P.M., and 12 A.M. Furthermore, we also check the effectiveness of i-Sheet by increasing its sensing area. As a proof of concept, we perform our experiments over the data of 1 h (3.6 M data values) to check the efficacy of i-Sheet.

B. Results

1) Analysis of Human Posture: As a proof of concept, we capture the instance of person movements during sleep by considering a random person infected with the COVID-19 virus. We observe the person for 1 h during his sleep and observe that when a person feels discomfort, he makes movements when compared to the person sleeping comfortably, as shown in Fig. 4. Furthermore, as shown in Fig. 5, when the person sleeps comfortably, he only changes his gestures two times when compared to the situation when he feels discomfort. As the person moves, i-Sheet monitors these movements by detecting the variations in pressure exerted by the patient. We comment that the proposed i-Sheet identifies the discomfort felt by the patient during sleep efficiently.

2) Accuracy of i-Sheet: We perform the categorization of the condition of the patient based on the data sensed by i-Sheet. We observe in Fig. 6 that only 0.9375% i-Sheet is not able to monitor the discomfort accurately if we use K-means and the fuzzy C means clustering algorithm. Intuitively, this is because of the abrupt change in the pressure exerted by the patient in normal conditions. However, 99.0625% time i-Sheet monitors the true condition of the patient. As shown in Fig. 6(a) and (d), there are only three instances where the patient is in a comfortable situation; however, i-Sheet detects it as discomfort. We observe significant detection of discomfort faced by the patient. This is because i-Sheet detects all the abrupt fluctuations in the pressure exerted by the patient and accordingly categorizes the condition of the patient. Furthermore, as shown in Fig. 6(b) and (c), the accuracy of detecting discomfort is 96.56% and 92.18% when we use DBSCAN and affinity propagation, respectively. We infer that the K-means and fuzzy C means clustering algorithms are best suitable for i-Sheet. Indeed, the fuzzy C means clustering algorithm adds an external computation overhead, making K-means best suitable for the proposed smart bedsheet.

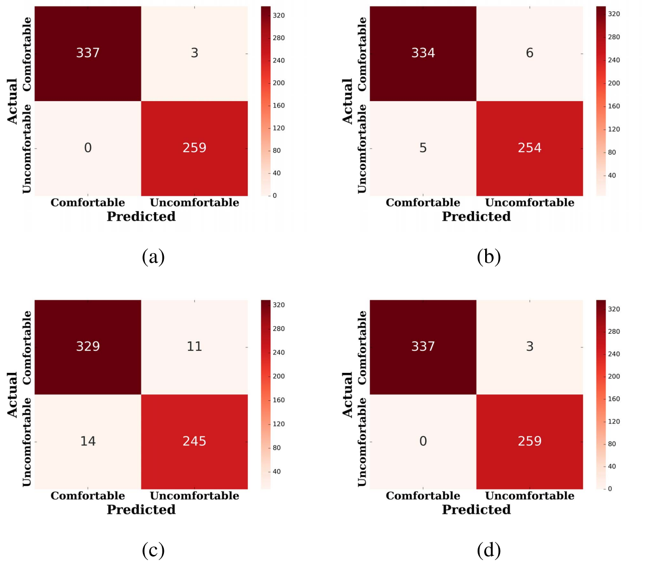


Fig. 6. Accuracy of i-Sheet using clustering algorithms. (a) K-means. (b) DBSCAN. (c) Affinity propagation. (d) Fuzzy C means.

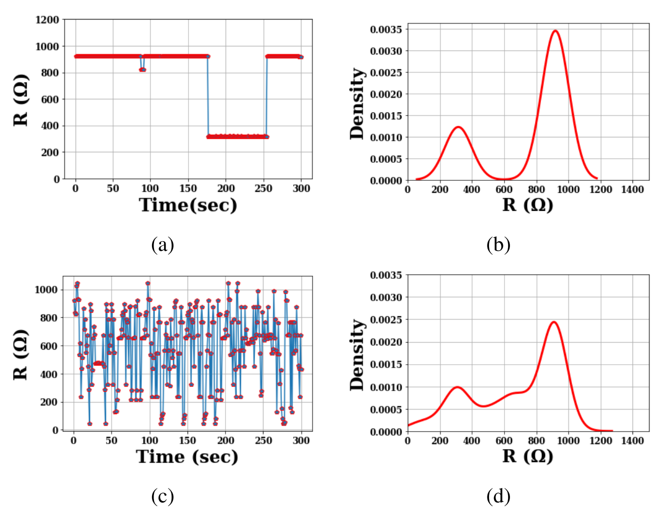


Fig. 7. Data analysis of i-Sheet, where R is the resistance. (a) and (c) Data sensed by i-Sheet during comfortable condition. (b) and (d) Density plot of data during comfortable condition.

3) Data Analysis of i-Sheet for Comfortable Patient: We observe the data sensed by i-Sheet for 1 h and observe the values of resistance. As shown in Fig. 7(a), the resistance of i-Sheet does not vary significantly for 170 s. For the first 170 s, the value of resistance lies in the range of 910–925 Ω and does not vary significantly. This is because the patient does not make any movement, which results in constant pressure on the bedsheet, and indeed the resistance also does not vary. In addition, due to the movement made by the patient at the 170th s, there is a variation in the pressure and consequently in resistance. The value of resistance from 170 to 260 s lies in the range of 310–330 Ω and further changes to 910 Ω. This is because, in a comfortable position, there is less variation in the position of the individual, and the values of most of the data points lie in the same region. Furthermore, as shown in Fig. 7(b), the density of the data points only lies

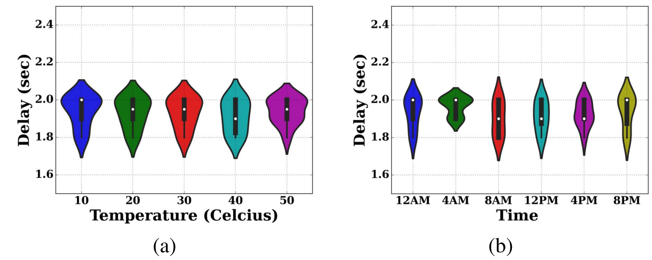


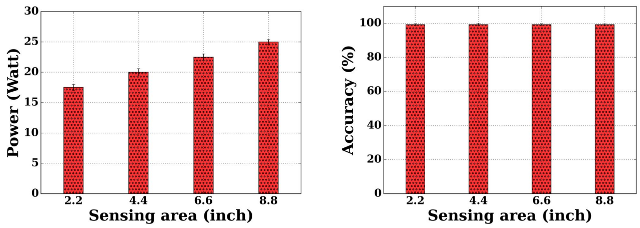
Fig. 8. Delay in health monitoring with external environmental conditions. Change in delay with (a) temperature and (b) time.

in the range of 910–925 and 310–330 Ω. We infer that i-Sheet is able to detect even the small movement made by the patient and proves effective in detecting the condition of the patient.

4) Data Analysis of i-Sheet for Uncomfortable Patient: We perform experiments to detect the nature of i-Sheet when the patient feels discomfort in breathing. We observe that the data sensed by i-Sheet varies abruptly, and there is no particular trend in it. As shown in Fig. 7(c), the values of the resistance sensed by i-Sheet lie between 40 and 1000 Ω. However, there is no particular variation or value of resistance that i-Sheet detects whenever the condition of the patient is not well. Furthermore, as shown in Fig. 7(d), the density of the data points lies in the range of 0–1300 Ω nonuniformly. Intuitively, these variations in the value of i-Sheet are because of the movement made by the patient due to the discomfort and variations in the pressure exerted by the same.

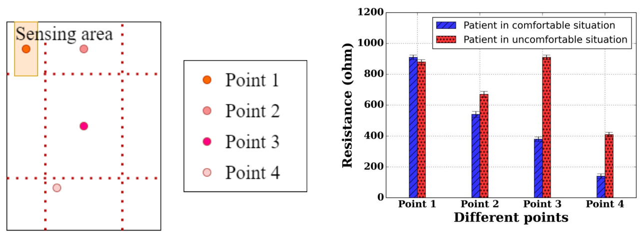
5) Delay in Health Monitoring: Categorization of data to monitor the condition of the patient involves extensive computation. Fig. 8 depicts the delays involved in monitoring the condition of the patient at different phases of the day. We observe that the delay involved in data sensing and alarm generation is negligible. However, the significant delay involves the categorization of data to monitor the health as comfortable or uncomfortable. Furthermore, the delay remains almost constant, which is 2 s, irrespective of the daytime and the external environment condition, for example, temperature. i-Sheet is not sensitive to temperature, which results in a constant sampling rate as well as the range of data which further results in constant delay in monitoring the health. Fig. 8 does not depict the correlation between the delay and temperature, however, shows that i-Sheet is insensitive to temperature. We observe that the overall delay in monitoring the state of the patient is very diminutive and acceptable. This diminutive delay helps in monitoring the condition of the patient and taking preventive steps on time. This further helps in preventing the condition of the patient from deteriorating.

6) Power Consumption in Health Monitoring: We observe the power consumption by i-Sheet in monitoring the condition of the patient. We perform 50 iterations to observe our readings. We observe that the power consumption increases with the increase in the sensing area. As shown in Fig. 9(a), we observe that i-Sheet consumes 17.5 W of power whenever the sensing area is 2.2 in and increases to 30% when we increase the sensing area by 75%. We infer that the consumption increases with the increase in the sensing area.



(a) (b)

Fig. 9. Variation in power and accuracy with sensing area. Change in (a) power and (b) accuracy.



(a) (b)

Fig. 10. Resistance across different points of i-Sheet. (a) Various points on i-Sheet. (b) Resistance across different points.

7) Accuracy With Sensing Area: We observe the accuracy in monitoring the condition of the patient with the increase in the sensing area. We perform 40 iterations to record our observations. From Fig. 9(b), we observe that the accuracy does not change with the increase in the sensing area. Intuitively, this is because even a small sensing area can detect the movements made by the COVID-19 patient and categorize the condition of the patient as comfortable or uncomfortable.

8) Resistance Across i-Sheet: We observe the resistance across various points of i-Sheet. We perform 30 iterations to record our observations at four different points, as shown in Fig. 10(a). When the patient is in a comfortable situation, we observe that the resistance decreases as we move away from the sensing area. However, in an uncomfortable situation, no particular trend can be seen. This is because the pressure exerted in the uncomfortable condition is not stable. The value of resistance at point 1 is 910 and 880 Ω in comfortable and uncomfortable situations, respectively, as shown in Fig. 10(b). We infer that the pressure exerted is not stable in an uncomfortable situation.

C. Verification

To check the efficacy of i-Sheet, we utilize two test scenarios.

1) Discomfort in Sleeping: i-Sheet monitors the movements made by individuals due to the discomfort felt by them during sleeping. We observe 100% true positives.

2) Health Monitoring: i-Sheet monitors the health of the individuals remotely by sensing the movements made by them on its surface. For 30 test runs, we utilized i-Sheet to monitor the health (when the individual is not well) and observed 100% true positives.

D. Discussion and Limitations

We propose a smart bedsheet for monitoring the health of the individuals remotely. The bedsheet senses the movements made by individuals on its surface and categorizes their condition as comfortable or uncomfortable. We also look into the efficacy of i-Sheet under different environmental conditions and observe that it is independent of various operating conditions. We observe that i-Sheet is efficient in detecting the condition of patients with 99.06% of the accuracy and with a 2-s delay.

The limitation of the proposed bedsheet is that it does not categorize the movements made by the individuals intentionally and due to discomfort. i-Sheet gives a large number of false negatives if the movements are intentional and not due to discomfort.

V. Conclusion

In this article, we proposed a smart bedsheet—i-Sheet—to remotely monitor the health of the COVID-19 patients. i-Sheet effectively monitored the health of the COVID-19 patients irrespective of the time and outside environmental conditions. It is independent of these features and provides the health monitoring of the COVID-19 patients based on their pressure on the bedsheet. It operated in three phases: 1) sensing the pressure exerted by the patient on the bedsheet; 2) categorizing the data into groups (comfortable and uncomfortable) based on the fluctuations in the value of the data; and 3) alerting the caregiver about the condition of the patient. In the first phase, i-Sheet sensed the movements made by the patients on its surface. In the second phase, we utilized the fluctuations in the value of data sensed by i-Sheet to categorize it into groups. As a proof of concept, we utilized the K-means clustering algorithm to categorize the condition of the patient on the basis of sensed data. Finally, in the last stage, we informed the caregiver about the health of the patient. We also showed experimental results to prove the efficacy of i-Sheet in monitoring the health of the patient.

In this work, we abstained from categorizing the movements done by the patients due to other factors such as intentional movements, bad dreams, and others. However, we only focused on the healthcare issues faced by the patients to categorize the data. In the future, we aim to categorize intentional movements made by the patient. Furthermore, we also aim to detect the position of the individual on the sheet, which further prevents the fall from the bed by generating alarms.

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