IoT Based Crowd Detection and Stampede Avoidance using Predictive Analysis

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IoT Based Crowd Detection and Stampede Avoidance using Predictive Analysis

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Abstract-Stampedes are an avoidable, unfortunate cause of deaths and serious injuries and yet very common. According to investigations, victims in these situations often die (trying to stand up) from tensile stress before finally collapsing to the ground because once pressure and intensity of the throng have indeed been significantly reduced. Focused crowd control methods, improved infrastructure and marking of pressure points (entry-exit points, stairwells, etc) among many other solutions have been implemented to reduce risk of stampedes. In this proposed solution, an IOT-based system using vibration sensors will be installed under the platform using which the vibrations produced by the steps taken by persons on the platform will be measured. When the vibrations cross a certain threshold, and the risk of crowding increases, an alert will be sounded to the authorities. Data collected from the vibration sensors can be analysed to observe patterns and predict future possibilities of crowding and stampede. The proposed solution will be validated by building a working prototype using an aluminium/wooden plank and testing the IOT circuit on it by manually inducing vibrations using motors. The desired outcome is to validate the prototype and deploy it at areas at a high risk of crowding to prevent injuries and loss of life due to stampedes.

Keywords— Stampede, Vibration sensor, Machine Learning, Dataset, Logistic Regression

I.INTRODUCTION

A stampede is described as a spontaneous massive movement of a large group that repeatedly leads to injuries and deaths. Even though events with more than thousand attendees have received most of the attention, catastrophic stampedes have happened at gatherings with fewer than that proportion. The combination of dense crowding and tough points to access can create the conditions for potentially disastrous human stampedes, especially when fear is present. The bulk of human swarm fatalities are caused by devastating asphyxia, which is when breathing stops completely or partially owing to outer constriction of the chest or abdominal area. Even moderate crowds can generate significant compression forces; stresses of up to (1000 lb) 4500 N can be produced anyway by six to eight people who push in the same direction, with forces strong enough just to bend steel railings. The whole range of wounds, such as fracturing, misalignments, as well as other traumatic wounds, may very well be anticipated.

Crowds do not really stop accruing in situations that contribute to stampedes, even at local densities of up to ten individuals per square meter. This is bound to create increasing vibrations on the platform beneath which is the key to the proposed solution.

Between 2001 and 2015, stampedes at large gatherings resulted in close to 3,000 fatalities. More than 3500 incidents of stampedes took place during this period according to the NCRB. The proposed system can help save people from the risk of severe injuries/loss of life in an unlikely accident where large crowds gather with a common purpose. Stampedes can be averted, and the system can also help event organizers/authorities improve crowd management.

II. LITERATURE SURVEY

WSNs, RFID, Iot based heterogeneous solutions that mix several various sensors, and intelligent techniques are the four primary infrastructures utilized to implement crowd control and collision avoidance in limited locations. The authors of [1] employed a framework that enables mobile devices to collaborate via a smartphone app for the purpose of receiving data from sensors and providing the optimized parameters to the users. In [2] it was suggested to use a multi-path routing method for danger identification and guiding based on a cognition-based packet network with two types of WSN nodes.

In [3] the module design of the system is divided into three parts each having their own functionality all of them controlled by ATmega 328 microcontroller with Image processing algorithm used to detect the crowd behavior. In [4] proposed a multi-agent-based crowd control method. The findings demonstrate that the agents are able to both recognise and take corrective measures. In[5] proposes a navigation system that takes congestion into account. The publishers precisely evaluated the passengers' mobility, presented the emergency rescue path utilizing sensors, and decreased oscillations in navigation direction. The results of simulations demonstrated an enhancement in the travel time and directional instabilities.[6] In this publication, a brand-new mechanism for live audience densities and behavioral forecasting is put forward. The recommended method makes use of a FILR camera.

[7] By segregating series of frames and employing a feature of the optical volume estimate algorithm, the suggested technology essentially recognises a zone that is too cluttered.

The monitoring and management of crowd study [8] defined several characteristics of swarm movements, including orientation and velocity. Every crowd application, like as a measure of density or counting estimates, monitoring, behavior identification, categorization, and outlier detection, might well be constructed that used a separate crowd dataset with a selection of crowd attributes. Crowd data points can be gathered or created from both actual and synthetic origins. Real data is created by employing an application-driven sensor (such as a static camera) or an infrastructure-based sensor data collection method (such as social media applications). [9] This study integrates two unique crowd-counting and image segmentation architectures to create the point-to-point trainable hybridized customized topology of network, U-ASD Net.

[10] This paper reviews intelligent surveillance video analysis techniques and deep learning for crowd analysis. [11] investigated Crowd density research in computer vision counting and estimation methods. [12] This model maps the individualized turbulence intensity into a transmitted data grid, introducing informational heterogeneity into information theory to describe the level of crowd confusion. The transmitted data chart displays the level of anxiety experienced by the entire evacuative structure within a specific period of frame of time.

Depending on vibration signals, machine learning techniques for fault diagnostics, n.d.,[13] This study offers a methodical approach for evaluating prototype performance scores for defect diagnosis algorithms using machine learning based on vibration signals. Utilizing suggested assessment methodology, 4 separate classifiers—K-Nearest-Neighbor, SVMs, Random Forests, and 1-D Convolutional NN—are analytically correlated on progressively harder generalization objectives.

“Machine Learning approach to fault detection in transformers by using vibration data,” n.d., by employing SVMs, and then doing a comprehensive examination is done to determine how relevant the material is. from numerous sensors for determining the optimal volume of sensors as well as their ideal placement.

“Condition Monitoring of Railway Tracks from Car-Body Vibration Using a Machine Learning Technique,” n.d., [14] faults in track are detected via a classifier by default. To identify and separate the track flaws from the vibration of the automobile body, field testing and simulated studies utilizing SIMPACK were conducted. The final output depicts that the characterstic of fault in track is drawn via vibration of car’s body and SVM-based ML algorithms are used to classify data from the given subspace.

“Vibration Condition Monitoring Using Machine Learning,” n.d., [15] In this study, the creation and deployment of a wirelessly vibrating state surveillance system for embedded applications are discussed. A microcontroller is connected to a accelerometer, which senses tremors and sends the information remotely to a portal. It is demonstrated that the tool is capable of fault diagnosis.

III. Proposed Work

A. ***Objective of the work***

1) To devise an IOT system to detect possibility of stampedes and ensure prevention.

2) To create an alert system to be used in

conjunction with the authorities for stampede warning
3) To collect live sensor data for predictive analysis using ML algorithm.

B. Detailed Problem Statement

Stampedes are a very common occurrence which can be avoided with adequate planning and proper crowd control. However, poor crowd management at public places often leads to stampede like situations resulting in many casualties and injuries. Especially on railway over bridges where narrow entry and exit points act as bottlenecks which can lead to stampede like situations. In a stampede like situation where people force motion in a particular direction it is important to devise a system that not only monitors the situation but is able to mitigate the system as well.

Common Stampede avoidance solutions involve use of cameras which use algorithms for stampede prediction or tracking bands. However, these solutions aren't fool proof and don't necessarily help navigate and disperse crowds to avoid stampedes from occurring. It is thus necessary to develop a system that not only helps track, detect and avoid possibility of stampedes, but also involves features that help in crowd management. The data obtained from this system can further be used to improve accuracy and robustness of the proposed solution.

C. Hardware Requirements-

1. ESP32:

It is an economical open source IOT platform. ESP32 is a series of low-cost, low-power system on a chip microcontrollers with integrated Wi-Fi and dual-mode Bluetooth. It can be used to connect to the cloud and transfer data from the system after predictive analysis.

2. SW – 420 Vibration Sensor

It is a sensor with high sensitivity and it is not directional in nature. Based on a certain threshold value set by the potentiometer, it either gives a high or low output via the comparator. A number of these sensors are used to detect vibrations and predict possibilities of stampedes.

3. SSD 1306 OLED Display

It is a monochrome dot matrix panel of display. It is a relatively smaller display which can be used to issue alerts and can be used in conjunction with authorities to mitigate stampede like situations.

4. MG 90 Servo Motor

It is a metal gear-based servo motor. Often emergency exits are designed to be accessed by users in an emergency themselves. By integrating the servo motors, emergency exits can be operated remotely and opened for dispersal of crowds for avoiding stampede incidents.

5. Other Components

Other components such as LEDs, buzzers are used which can be designed to operate in a set of combinations to specify varying levels of threats.

6. Basic hardware requirements

a. Jumper wires-

jumper wires are used to connect all the components with one another.

b. Breadboard-

The whole circuit is constructed on a breadboard.

c. Breadboard power supply

Through the Breadboard power supply, we can power the other hardware components which we cannot be powered directly by ESP32

D. Software Requirements-

1. Arduino IDE

Arduino IDE has a text editor which is used write the sketch for hardware implementation.

2. Jupyter Notebook

Jupyter Notebook is a Python IDE used to run a Logistic Regression model written in Python.

E. Proposed System

The proposed solution to the problem of stampede prediction and avoidance includes working with technologies such as IoT and machine learning in tandem.

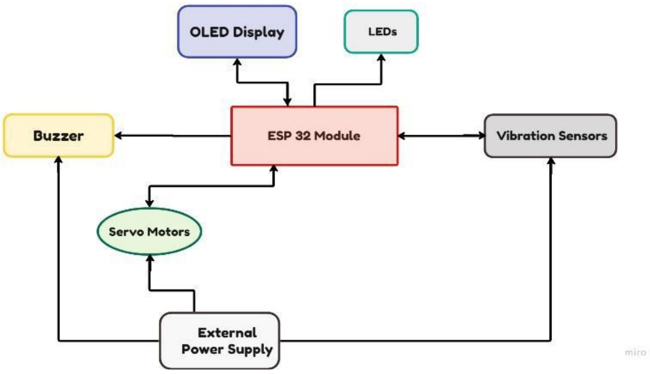

Fig. 1. Block Diagram of the Hardware Setup

The experimental set-up as described in Fig. 1. includes a microcontroller and a vibration sensor at the core of it feeding data into the ML algorithm. Since this is a rather unique solution to the identified problem, there isn't much data available on the web for us to work with and that is the ground upon which we have manually created a primary data set.

The reading of the dataset is taken by cutting up a large metal/wooden sheet into four equal pieces and sticking them back together- in order to mimic an actual large flat surface, fitting a vibration sensor onto the sheet and recording multiple individual readings from the vibration sensor across the day in random individual instants.

The dataset includes readings from four vibration sensors placed at four different corners of the platform. These values need no further processing. This dataset is a numeric dataset collected from the readings obtained from the prototype of the model, hence actual readings will be much higher. Here, the independent variables are the sensor readings from all four sensors and a dependent categorical variable describing if the readings are crossing the threshold and if a stampede situation is arising. The final dataset consists of 5000 rows and 5 columns. Since the data is pretty straightforward, the pre-processing only includes representing the categorical variable in terms of 1 and 0 where 1 represents 'yes' which means that a stampede situation is arising and 0 represents 'no' meaning that no alert needs to be sent as the situation is safe.

The machine learning algorithm proposed for predicting stampede situations in this work is Logistic Regression which is a supervised learning method for building models that perform classification tasks. It majorly calculates or predicts the probability of a binary (yes/no) event occurring. Table below depicts the data points we took and fed into algorithm.

F. ***Proposed Methodology***

The proposed system would consist of 4 levels of intimation.

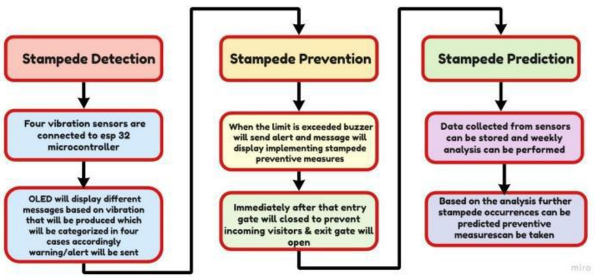

Fig. 2. Proposed Methodology for the system

There are multiple alert measures like a buzzer, multiple LEDs, OLED Panel. Using data collected from the vibration sensors, Stampede like situations can be detected and avoided and furthermore, a primary dataset is prepared using sensor data which can further be used to predict possibilities of stampedes. This is concisely depicted in Fig. 2. The 4 levels will be represented using 4 distinct colours, i.e., Blue, Green, Orange and Red.

These colours would be projected using a LED for each corresponding colour. The possibility of a stampede increases in the order of Blue-Empty, Green- Visitors approaching, Orange- Crowding underway and Red- Possibility of a stampede occurrence at its highest.

There will also be an OLED display which displays in real time the percentage of the likely occurrence of a stampede, this percentage will be calculated from the data obtained and analysed by machine learning from the sensor readings placed on the platform.

The maximum limit of each day of the week will be stored and used to analyse on which days and what specific time frames are more vulnerable to a stampede occurrence to have local authorities and approaching pedestrians aware of the situation and take necessary measures to prevent the unfortunate event of a stampede.

An additional preventive measure is to install gates operated by servo motors and controlled by the controller to regulate entry and exit of people onto the platform. These gates are especially useful in situations where the local authorities are severely outnumbered by members of the crowd. The opening and closing of the gate will depend on the data gathered and analyzed by the algorithm from the sensors fitted to the platform. This way there is even a hard bound measure installed in place in order to prevent stampedes and minimize the chance of human error and nonchalance.

As a conclusion of the basic working of the proposed system, there will be 4 primary indicators at the entry points of the platform. There will be an OLED display also installed besides the primary indicators to mention the percentage likeliness of a stampede occurring. This percentage is calculated using a ML algorithm contingent on the datapoints gathered via the sensors attached to the platform in real-time. There will be gates installed at the entry points of the platform operated by servo motors and controlled by the microcontroller which regulates the entry of pedestrians based on the percentage levels calculated by the algorithm.

IV. Experimentation And Results

A. Test Circuit

To first test the planned work, a test circuit was made and tested using a single vibration sensor.

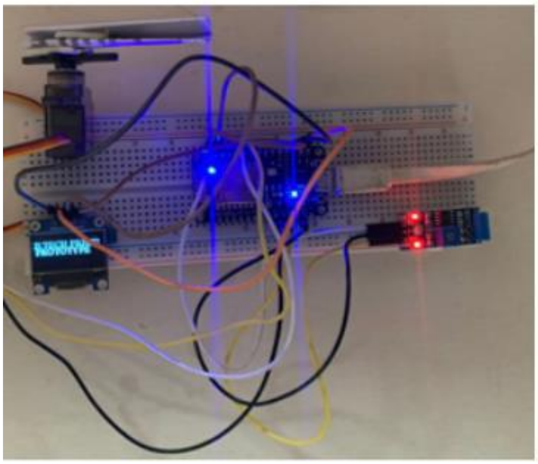

Fig. 3. Test Circuit Breadboard Connection

Fig. 3. Shows the breadboard connections for the test circuit. The sensor, when it senses high vibrations, sends the signal to the microcontroller which in turn activates the servo motor which acts as a peripheral for stampede mitigation procedure.

B. Hardware Implementation

The final hardware implementation is performed as planned and proposed in the methodology.

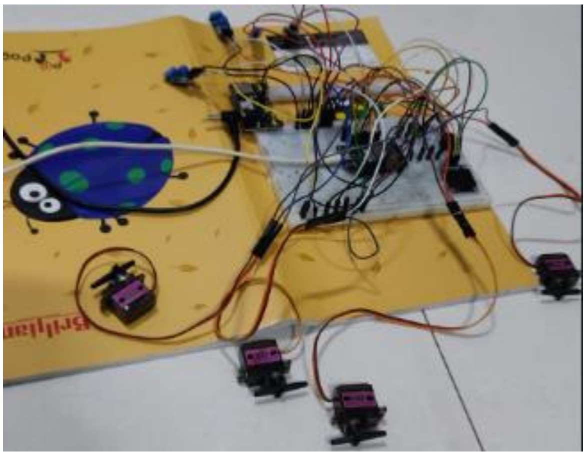

Fig. 4. Hardware Implementation with ESP 32

The circuit connections as can be seen in Fig. 4 is the ones used for the final assembly. The 4 vibration sensors act as input peripherals which sense vibrations. The OLED Panel, LEDs Buzzer act as alert measures for authorities. And the servo motors attached on the sides help are used to represent emergency exits which are automatically rotated (emergency exits open) to disperse crowds in case of high vibration readings. The setup shows positive response in peripherals as planned out in the during implementation when high vibration sensor readings are sensed.

C. Dataset Analysis

An In-house dataset has been created based on the readings from the 4 vibration sensors from the prototype. The data is numeric and the independent variables are the sensor readings from all four sensors and the output is a categorical variable indicating a stampede.

Table I. In-house dataset from Vibration Sensor Readings

	A	B	C	D	E
1	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Alert
17	16	13	15	14	no
18	15	14	4	14	no
19	15	0	0	12	no
20	15	0	8	8	no
21	7	10	13	13	no
22	9	0	0	4	no
23	16	14	13	15	no
24	691	5	14	7	no
25	15	12	0	0	no
26	15	7	0	9	no
27	15	0	10	0	no
28	15	13	12	13	no
29	15	0	13	12	no
30	15	0	0	12	no
31	4043	14	0	2	no
32	15	0	0	0	no
33	15	9	0	0	no
34	15	0	0	0	no
35	14	13	11	11	no
36	15	14	0	6	no
37	15	0	14	0	no
38	15	12	0	0	no
39	15	0	0	0	no
40	383	351	417	2	yes
41	346	2	383	583	yes
42	124	394	388	432	yes
43	383	351	417	671	yes
44	346	372	383	583	yes
45	124	394	388	432	yes
46	383	351	417	523	yes
47	346	2	383	583	yes
48	124	394	388	432	yes

For the dataset shown in Table I, Logistic Regression, a supervised machine learning algorithm has been employed to calculate the probability of a binary yes or no event. After running the model, an accuracy of 93 percent was achieved as can be seen in the classification report in Fig. 6. The Data Analysis is discussed in more detail in the subsequent section.

V. ML Applications On Vibration Sensor Data

The dataset used for the classification model for this predictive analysis task is an in-house dataset created using the prototype of the model. The reading of the dataset is taken by cutting up a large metal/wooden sheet into four equal pieces and sticking them back together- in order to mimic an actual large flat surface, fitting a vibration sensor onto the sheet and recording multiple individual readings from the vibration sensor across the day in random individual instants

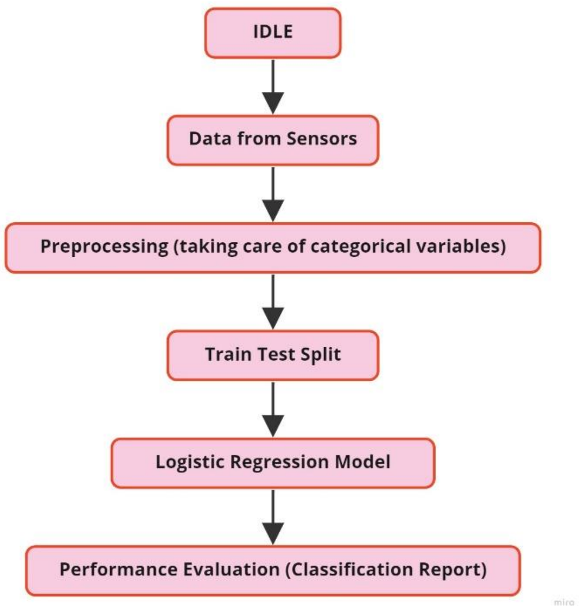

Fig. 5. Flowchart for ML Applications

Fig. 5 summarizes the process of analyzing sensor data. The dataset includes readings from four vibration sensors placed at four different corners of the platform. These values are divided into two categories where the first category includes low value readings from the sensor indicating that no alert needs to be sent as no stampede is predicted. As soon as the values start increasing beyond the threshold, they are categorized under the second situation where an alert needs to be sent as a stampede may be generated. This dataset is a numeric dataset collected from the readings obtained from the prototype of the model, hence actual readings will be much higher. Here, the independent variables are the sensor readings from all four sensors and a dependent categorical variable describing if the readings are crossing the threshold and if a stampede situation is arising. The final dataset consists of 5000 rows and 5 columns. The data is straightforward where the pre-processing is done on the categorical variable so as to fit those values in the model. The categorical variable is represented in terms of 1 and 0 where 1 represents 'yes' which means that a stampede situation is arising and 0 represents 'no' meaning that no alert needs to be sent as the situation is safe.

The machine learning algorithm proposed for predicting stampede situations in this work is Logistic Regression which is a supervised learning method for building models that perform classification tasks. It majorly calculates or predicts the probability of a binary (yes/no) event occurring.

After preprocessing the data, a train test split function is applied to it wherein the data is split as a training set and a testing set. 70% of the data goes to the training set whereas the rest goes to the testing set. A logistic regression model is then fit into the training data to train the model. The testing data is used for the performance evaluation of the model.

F1 Score : 0.9333333333333333

	precision	recall	f1-score	support
0	1.00	0.92	0.96	12
1	0.75	1.00	0.86	3
accuracy			0.93	15
macro avg	0.88	0.96	0.91	15
weighted avg	0.95	0.93	0.94	15

Fig. 6. Classification report of the Algorithm

The classification report in Fig. 6. gives the performance evaluation of the model wherein precision gives the weighted average value of 0.95 and recall gives the weighted average value of 0.93. The accuracy of the overall model obtained in terms of F1 score is 93% and the support value is 15.

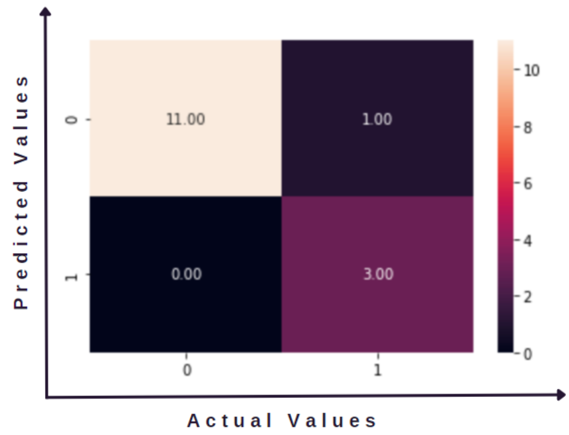

Fig. 7. Confusion Matrix for the model

A confusion matrix in terms of a heatmap is also plotted as seen in Fig. 7 to represent the performance evaluation of the model.

VI. Conclusion

Stampedes are an avoidable disaster which are very frequent due to improper crowd control measures and lack of proper infrastructure. The prototype developed uses an indirect approach by trying to measure possibility of stampede by the vibrations produced as a result of a fast-traversing of crowds over the platform. The system developed as part of this study can be used as a portable solution which can be deployed at events where temporary platforms and stages are erected for crowd management apart from the primary application in railway over bridges.

The data analysis based on the dataset formed from sensor readings further improves efficiency and reduce the number of false positive alerts from the circuit. An accuracy of 93 percent is achieved as can be seen in Fig. 6

Some limitations include risks due to complex wiring of the circuit where any error or issue in wire connections can affect performance of the system. Also, the system when deployed will require some time to gather data from the sensors and analyse the data to reduce false positives and improve efficiency. Therefore, prime efficiency is not immediately achieved after deployment.

Going forward, cameras and computer vision techniques can be introduced to further improve the robustness and efficiency of the system

References

[1] M. F. Mohamed, A. E.-R. Shabayek, and M. El-Gayyar, ‘‘IoT-based framework for crowd management,’’ in Mobile Solutions and Their Usefulness in Everyday Life. 2019, pp. 47–61.

[2] H. Bi and O. Akinwande, ‘‘Multi-path routing in emergency with healthaware classification,’’ in Proc. 2nd Int. Conf. Inf. Commun. Technol. Disaster Manage. (ICT-DM), Nov. 2015, pp. 109–115

[3] Shah, S.K. and Kulkarni, S., 2015. A review: monitoring and safety of pilgrims using stampede detection and pilgrim tracking. International Journal of Research in Engineering and Technology, 4(04), pp.328-332 .

[4] Ahuja, G., & Karlapalem, K. (2015, May). Managing Multi Robotic Agents to Avoid Congestion and Stampedes. In AAMAS (pp. 1883-1884).

[5] Y. Chen, L. Sun, F. Wang, and X. Zhou, ‘‘Congestion-aware indoor emergency navigation algorithm for wireless sensor networks,’’ in Proc. IEEE Global Telecommun. Conf., Dec. 2011, pp. 1–5.

[6] Abuarafah, Adnan Ghazi, Mohamed Osama Khozium, and Essam AbdRabou. "Real-time crowd monitoring using infrared thermal video sequences." Journal of American Science 8, no. 3 (2012): 133-140.

[7] NMAMIT, Nitte. "An Automated System for Detecting Congestion in Huge Gatherings." International Journal of Computer Applications 975: 8887.

[8] A. Draghici, M.V. Steen A survey of techniques for automatically sensing the behavior of a crowd ACM Computing Surveys, 51 (1) (2018), pp. 1-40, 10.1145/3129343.

[9] A. Hafeezallah, A. Al-Dhamari and S. A. R. Abu-Bakar, "U-ASD Net: Supervised Crowd Counting Based on Semantic Segmentation and Adaptive Scenario Discovery," in IEEE Access, vol. 9, pp. 127444-127459, 2021, doi: 10.1109/ACCESS.2021.3112174.

[10] Sreenu, G., and Saleem Durai. "Intelligent video surveillance: a review through deep learning techniques for crowd analysis." Journal of Big Data 6, no. 1 (2019): 1-27.

[11] S. A. M. Saleh, S. A. Suandi, and H. Ibrahim, ‘‘Recent survey on crowd density estimation and counting for visual surveillance,’’ Eng. Appl. Artif. Intell., vol. 41, pp. 103–114, May 2015, doi: 10.1016/j.engappai.2015.01.007.

[12] R. Zhao et al., "Macroscopic crowd panic quantification model of crowd evacuation based on information entropy," 2019 IEEE 3rd Information Technology, Networking, Electronic and Automation Control Conference (ITNEC), 2019, pp. 388-392, doi: 10.1109/ITNEC.2019.8729160.

[13] T. W. Rauber, A. L. da S. Loca, F. de A. Boldt, A. L. Rodrigues, and F. M. Varejão, “An experimental methodology to evaluate machine learning methods for fault diagnosis based on vibration signals,” Expert Systems with Applications, 30-Sep-2020.

[14] A. Tavakoli, L. D. Maria, B. Valecillos, D. Bartalesi, S. Garatti, and S. Bittanti, “A machine learning approach to fault detection in transformers by using vibration data,” IFAC-PapersOnLine, 14-Apr-2021.

[15] I. Amihai, R. Gitzel, A. M. Kotriwala, and D. Pareschi, “An industrial case study using vibration data and machine learning to predict asset health,” IEEE Xplore, Jul-2018. [Online]. Available: https://ieeexplore.ieee.org/document/8452671. [Accessed: 12-Nov-2022].