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Analyzing the Need for an Intelligent Safety Device for Indian Women

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***Abstract*—Women safety refers to the protection of women from any forms of violence and harassment. It is becoming one of the highest concerns that shadowing the present societies around the world. In order to protect themselves from such situations, the present day women are carrying safety devices. However, the main problem with this devices are that the smart devices used by the very few women tends to raise number of false alarms and not reliable to use. Another difficulty in using smart device is its ease of use. On the other hand, the manual device need some proper training before properly using it. Hence, there is a need of safety device that can tackle all the problems. Therefore, in this study, a questionnaire survey is designed to understand the need of the women when coming to design a safety gadget that will protect them in an unsafe scenarios. The smart device needs to correctly classify an unsafe and a safe situation. For this reason, different vitals such as heart beat rate, perspiration rate, blood pressure trend and acceleration is mapped with safe and unsafe scenarios by a hyperparameter tuned Extreme Gradient Boosting (XGBoost) classifier. The data are collected by simulating different safe and unsafe scenarios for a period of two months from 12 different women. The developed model showed an accuracy, precision, recall and F1-score of 94.4%, 95.4%, 96% and 95.7% respectively. The strength of the smart safety gadget lies in its effectiveness and efficiency.**

Keywords—Women safety, smart safety device, GPS and location tracking, sending SOS signals, False alarm, Ease of using, XGBoost, Hyperparameter tuning

I. INTRODUCTION

In the present day, one of the highest concerns that shadowed the societies around the world is the woman's safety. It refers to the protection of women from various forms of violence, harassment, and discrimination. In an estimate published by the World Health Organization (WHO), 1 in every 3 women around the world is subjected to some kind of violence physically and/or psychologically [1].

However, in India 228,650 crimes against women were reported in the year 2011 which increased by 87% adding another 199,628 reports in the year 2021 [2]. Most of these crimes or harassments start with stalking either in public areas or over the internet. The National Crime Records Bureau (NCRB) stated that in 2021 around 9,285 cases of stalking were reported which is just over 1 case in every one hour [3]. The legal punishment for stalking is 3 years of prison for the first conviction and up to 5 years for repeated convictions. Although the harsh punishment is not able to check the increasing number of stalking on a daily basis. Stalking is labeled as the 'national pastime'. Thus, with the increasing number of stalking in recent years, the need for gadgets that can ensure safety when the owner feels threatened has increased exponentially.

II. LITERATURE REVIEW

There are three types of safety devices which are readily available in the market – i. Manual, ii. Android app based and iii. Sensor based Automatic device. On scrutinizing the devices, some of the interesting literatures that came out caught the attention are summarized in this section.

In the paper [4], the authors built a safety device that can send SOS messages to the authorities in the case of any emergency. The device is a sensor based gadget that can be used for surveillance of women's safety. The safety device built in paper [5], comprises of a GPS tracker that allows the exact track of the locations. In paper [6], authors have applied machine learning (ML) techniques to analyse the gait of a person. In paper [7], an IoT based safety gadgets were developed by integrating it with Deep Learning (DL) libraries such as Keras to increase the accuracy and prediction of the device built. In paper [8] present with an IoT based wearable device for gait identification. In the paper [9], a sensor based recognition system was developed that can distinguish between personal security and healthcare workers. Another IoT based device was built in paper [10] to monitor and control system for pregnant women. This device has the capability to reduce the complicacies arose in the rural places. The literature comprises of information of many devices but the most recent papers are summarized in this study.

III. SURVEY AND EXPLORATORY ANALYSIS OF THE DATA

From In this section of the study, a questionnaire survey is designed which is circulated among the girls and females of different age categories. The data collected from the survey are explored to get the insights of the features that the users wanted to be installed in the safety gadgets in order to make them feel safer.

A. The designing of the questionnaire survey

The main motive of the questionnaire survey is to bring out the most important features to be present in the safety gadgets that should make the women feel more safe and secure. In this regard, a five part questionnaire survey was designed. The first part of the survey collects the personal information such as age, qualification, occupation, their views on the crime rate against women and usage of any safety gadgets. This part will provide insight to correlate the views of women from different age categories to understand their perspective about crime against women and their knowledge of using safety gadgets.

The second part of the survey is designed to understand the reason for women to not use a safety gadget. The third part of the survey throws light upon the question that what percentage of the women actually prefer to use a safety device and its type. The fourth part of the survey is designed in such a way that it will help to understand the unnecessary features that needs to be eliminated from the device. Finally, the fifth part of the survey will help to understand the features that needs to be added in the device to make it more effective in emergency situations.

B. Data collection from the survey

The questionnaire for the survey was designed in a Google form[url:*https://docs.google.com/forms/d/e/1FAIpQLSdUiouQ6Gobg8rhtGTA8sDV6W7k8mG4t8lgtOA4ah3h8oM47A/viewform?usp=sharing*] and circulated over the different social media platforms to collect the response. The responses from the survey participants are collected for a period of one month from 15th May to 15th June, 2023. A total of 1396 participants responded the survey and their responses are collated in an excel file.

C. Data exploration of the responses

An exploratory data analysis (EDA) is conducted to understand the views of women about the reasons of crime against women and their perspective on the usage of a safety device. Figure (1) shows the age group of the respondents in the form of bar charts.

From figure 1, it is observed that the majority of respondents are from teenagers to above fifty age groups implying that the survey was respondent by all targeted age group of women. The reason for choosing the age groups from teenagers to 50 years is that, they are mostly become victim of some kind of harassment and stalking.

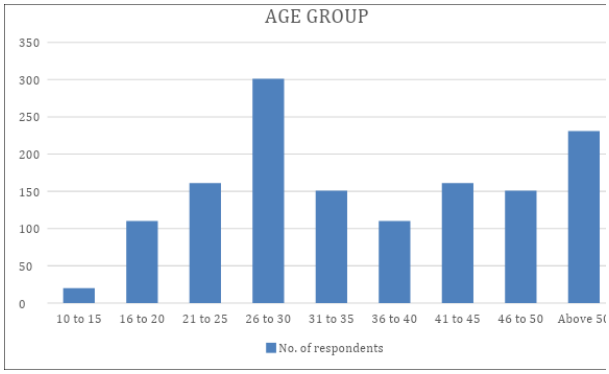


Figure 1: Bar-graph showing the age categories of respondents

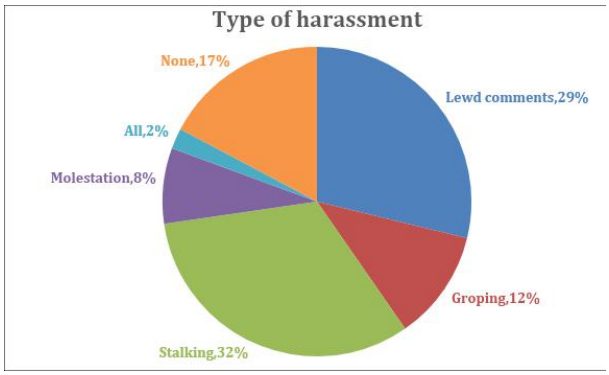


Figure 2: Pie-chart showing type of harassment faced by the respondents

In the next analysis, the type of harassment suffered by the respondents are represented as pie-diagram in figure (2). From the figure (2), it is observed that about 17% of the respondents have never faced any harassment of any kind. Out of all, stalking is the most common form of harassment faced by the respondents which is followed by lewd comments from the strangers. 2% of the respondents faced all type of harassments.

Analyzing the use of safety device, it is observed that 708 i.e. 50.7% women used a safety device and the remaining 688 women have never used it. Out of the 708 women who used a safety device 364 women used a smart device and the remaining 344 women. The details is represented in the form of a pie chart in figure (3).

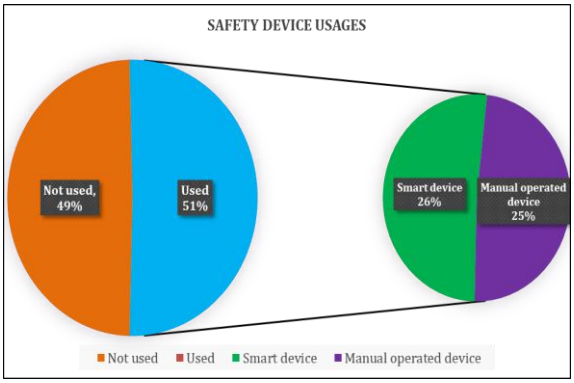


Figure 3: Pie-chart showing the breakup of the safety device usage by the respondents

The fourth part of the questionnaire survey tries to extract the disadvantageous features of the safety gadgets. All the respondents using manual operated safety devices pointed to the fact that they wanted to change the device to be triggered in order to be used. However, the respondent using the smart devices pointed out different features which either need to be installed or should be upgraded in order to enhance the usage of the device. Table 1 shows the list of features that needed for effective use of safety device. Figure (4) shows the features responded in the form of a bar graph.

Table 1: Features either need to be installed or upgraded

Features	Frequency	Percentage	Cumulative percentage
GPS and location tracking	92	25.27%	25.27%
Sending SOS signal	78	21.43%	46.70%
Informing the saved contact	65	17.86%	64.56%
False alarm	46	12.64%	77.20%
Handy and easy to use	32	8.79%	85.99%
Charging and Battery used	31	8.52%	94.51%
Water proof	20	5.49%	100.00%

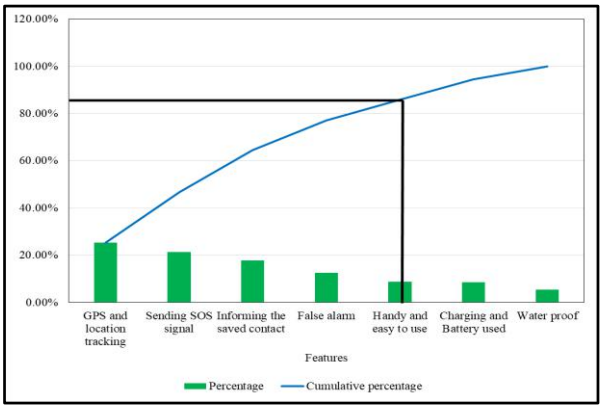


Figure 4: Cumulative frequency graph

As per the Pareto analysis, in this study those factors were targeted that were reported by 80% of the respondents who used smart safety devices. The factors that need to be either installed or upgraded in the smart safety devices are GPS and location tracking, Sending SOS signals, Informing the emergency saved contacts, False alarm and Ease of using. As per the response from the respondents, the following features were integrated in the device build in this study.

IV. DESIGNING AND BUILDING OF THE SMART SAFETY DEVICE

This section delves into the meticulous design and construction of the smart safety device, detailing each hardware component's significance and its contribution to the overall functionality of the device.

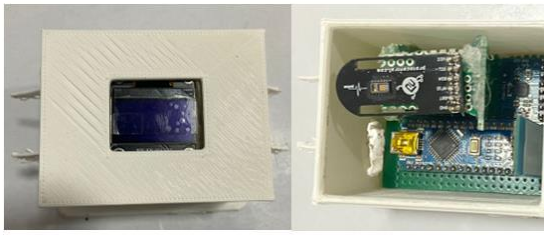
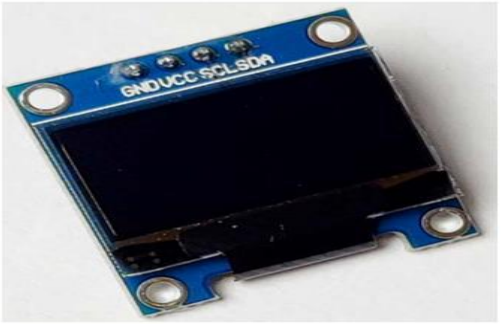


Figure 5: Hardware Setup

A. Device Components

i) 1.3-Inch OLED Display

The heart of the device is its 1.3-inch OLED display. This interface provides real-time visual feedback to the user by displaying heart rate readings obtained from the Protocentral heart rate sensor. The display not only offers health monitoring capabilities but also serves as a conduit for user interaction and alerts.



ii) Protocentral Heart Rate Sensor

The Protocentral heart rate sensor is a critical component responsible for monitoring the user's heart rate. By continuously tracking the user's cardiac activity, the device can detect any sudden or unusual deviations, potentially indicating distress or medical complications.

iii) Accelerometer

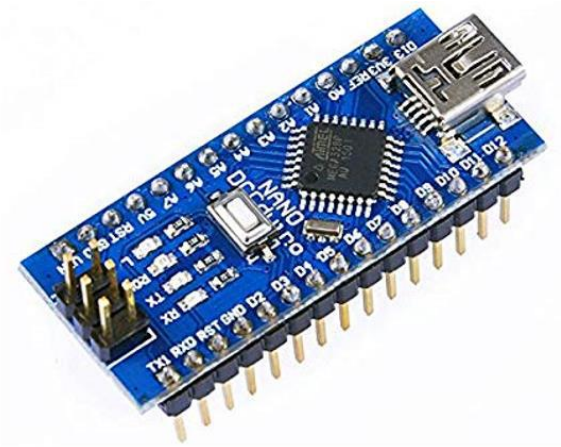
To extend the device's safety scope beyond health monitoring, an accelerometer is incorporated. This sensor detects accelerative forces and motion patterns. In situations of abrupt or irregular motion, such as a fall or collision, the accelerometer promptly triggers further actions for user safety.

iv) Buzzer

The buzzer, directly connected to the accelerometer, plays a vital role in alerting the user and those in proximity to potential hazards. When the accelerometer detects unusual motion, the buzzer emits a distinct, attention-grabbing sound that serves as an audible warning.

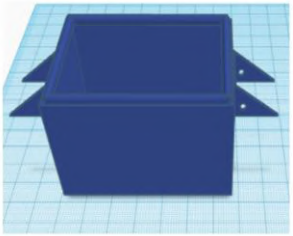
v) Arduino Nano

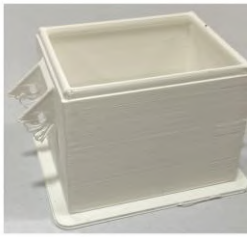
Acting as the device's computational brain, the Arduino Nano oversees data processing, logic execution, and sensor coordination. This advanced microcontroller is well-suited for IOT applications, providing the necessary power and capabilities to ensure the device responds promptly and accurately to detected events.



vi) 3D Printed Structure

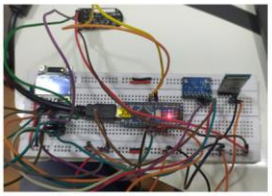
The 3D printed outer casing encapsulates the components in a durable and ergonomic design. It not only provides physical protection but also ensures a user-friendly form factor for comfortable wear or carry.





The 3D printed outer casing encapsulates the components in a durable and ergonomic design. It not only provides physical protection but also ensures a user-friendly form factor for comfortable wear or carry.

B. Functionality and Integration



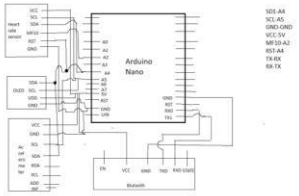


Figure 6: Hardware Functionality & Integration

i) Accelerometer and Buzzer Interaction

The accelerometer continuously monitors motion patterns. Upon detecting sudden and unusual motion, it sends a signal to the buzzer, which promptly emits an audible alarm. This immediate auditory response alerts the user and those nearby to the potential danger or distress.

ii) Mobile Application Integration

The device's capabilities are further extended through integration with a mobile application.

Figure 7: Mobile Application

When the accelerometer detects unusual motion, it transmits this information to the application. The application processes the data and, if warranted, sends notifications to designated emergency contacts. These notifications include the GPS location of the device, enabling swift and accurate assistance.

iii) Machine Learning Integration

To enhance the device's discernment of genuine emergencies from false alarms, Machine Learning (ML) models are envisaged for integration. These models will be trained to recognize intricate patterns of motion. However, successful ML integration necessitates rigorous training and validation before deployment, to ensure the models' reliability and minimize false positives.

In summary, the design and construction of the smart safety device entail careful selection and integration of hardware components to create a cohesive safety solution. Each component contributes to the device's ability to monitor health, detect unusual motion, and provide timely alerts. The subsequent section will delve into the intricate process of training the ML models, thereby elevating the device's efficacy in safeguarding user well-being.

V. MODELLING OF THE MACHINE LEARNING ALGORITHMS

In this section of the paper, the data used for training the machine learning (ML) algorithm are discussed in brief.

A. Machine learning (ML) algorithm

Machine learning (ML) is a branch of science that involves the application of mathematical algorithms to find the pattern between the data [11]. ML is used for both regression and classification of the output data. In this study, the aim is to develop a smart safety device for women. This safety device is able to classify between scenarios where the user is in danger and a normal scene. One of the best ML model for classification is XGBoost (Extreme Gradient Boosting). It is a popular and powerful machine learning algorithm known for its efficiency and performance in structured/tabular data analysis and prediction tasks. It falls under the category of ensemble learning methods, specifically gradient boosting frameworks, which build a strong predictive model by combining the predictions of multiple weaker models [12].

The key advantage of using XGBoost in classification is its gradient boosting, which involves iteratively adding weak learners (usually decision trees) to the ensemble. Some other advantages of using XGBoost are Regularization, Gradient and Hessian, Feature Importance, Cross – Validation, Handling Missing Data, Parallelization [13]. Moreover, XGBoost is applied in a wide range of areas where the general ML model perform weakly.

B. Data Acquiring

In order to train the XGBoost algorithm, the data used are acquired by simulating a normal scene and where is in danger and recording the vitals in that circumstances. A woman in danger scenario is simulated by when she is harassed by stranger in public late at night, she is groped by men, and she is scolded or dominated by men for no reasons. A normal scenario is simulated by when she is alone in office late at night, when she missed her bus, when she is travelling alone with the few male and strangers in public transport. The different values of data acquired in this manner are used for training the XGBoost classifier.

The vitals that showed a spike in the normal data when someone feels in danger are blood pressure, heart beat, and perspiration. Above that, the acceleration data are also considered for this study which is due to the reason that when a woman feels danger, she will run tends to run away from it. As a result, there is a sudden change in the acceleration. The output for the data collected in a binary label. If a women feels danger then the output is labelled as yes whereas the output is labelled as no if danger is felt during the scenario simulations. In this way, a total of 925 data were collected from 12 women over a period of 2 months from 10th May till 15th July, 2023.

C. Splitting of Data

The data collected were split in the ratio of 75:25 where 75% of the data are used for training the XGBoost classifier and the remaining 25% data were used for testing and validating the trained model. Out of 925 data, 694 data were used for training and the remaining 231 data are used for testing.

D. Modelling of the XGBoost classifier

For modelling the XGBoost classifier, the data collected and standardized are fitted into the algorithm. The training data are used to develop the model whereas the testing data are used for validating the model. The flowchart for developing XGBoost classifier is shown is shown in figure 5.

i) Training the XGBoost algorithm

For developing the XGBoost classifier Pandas, NumPy, seaborn, matplotlib and scikit-learn are

among the Python libraries imported. Standardization of the data are performed by removing the mean and further scaling it to unit variance. After these procedures, the dataset is finally subjected to the XGBoost classifying algorithms.

ii) Testing the XGBoost algorithm

The model developed by the training data is tested and validated in this section. The 231 test data are used for this purpose. The heatmap for the confusion matrix for the testing and validation data is shown in figure 6.

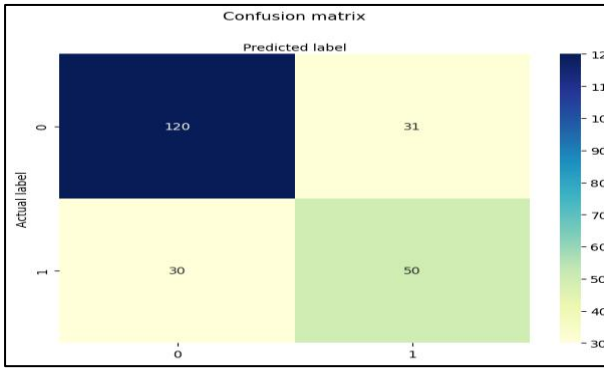


Figure 8: Heatmap of the confusion matrix

In the figure 6, the normal label is indexed as 0 and the dangerous scenario is indexed as 1. From the figure 6, it is observed that the developed model is able correctly predict the 120 out of 151 normal scenarios and 50 out of 80 unsafe scenarios. On the other hand, the model raised false alarm for 31 times and failed to classify an unsafe scenario for 30 times. The values of the testing accuracy, false negative, true positive and F1-score are tabulated in table 2.

Table 2: Summary table

Testing accuracy (%age)	Precision (%age)	Recall (%age)	F1-score (%age)
73.6%	80.0	79.5	79.7

iii) Hyperparameter tuning

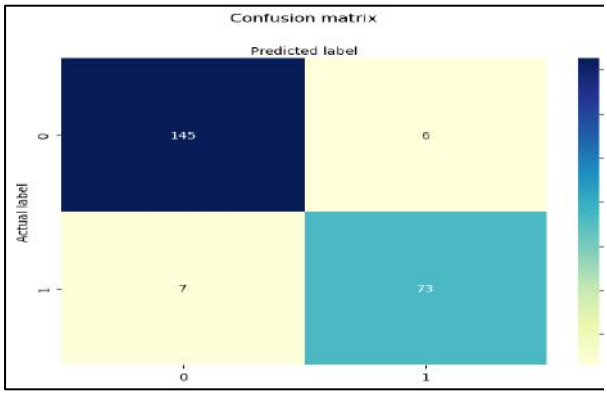


Figure 9: Heatmap of the confusion matrix after hyperparameter tuning

In this step hyperparameter tuning is done to nullify the error caused due to overfitting and also to increase the accuracy of the models. The heatmap for the confusion matrix for the testing and validation data is shown in figure 7.

From figure 7, it is observed that the XGBoost model after hyperparameter tuning is worked better than the previous which can be determined by more number of number of correctly classifying normal and unsafe scenarios and also by raising less number of false alarms. After hyperparameter tuning 145 out of 151 scenarios are correctly classified as normal and 73 out of 80 scenarios are correctly classified as unsafe scenarios. Furthermore, the hyperparameter tuned XGBoost model raised false alarm for 6 times and for 7 times the model failed to classify an unsafe scenarios. The values testing accuracy, precision, recall and F1-score for the hyperparameter tuned XGBoost classifier is tabulated in table 3.

Table 3: Summary table after hyperparameter tuning

Testing accuracy (%age)	Precision (%age)	Recall (%age)	F1-score (%age)
94.4	95.4	96.0	95.7

E. Discussions

In this study, some of the important points observed are as follows:

1. About 87.8% of the women feels that there is an increase in crime against women, whereas 2.2% of the women feels that the crime against women has decreased.
2. About 52% of the women feels that the culprits has no fear of law and so they can act in any way with women. Furthermore, 21.6% of the women thinks that men treats women as sex objects and as a result of which crime against women is increasing.
3. When faced with harassment, 59.4% of the women did not file a police complaint thinking that it would not serve any purpose of it.
4. About 50% of the women uses safety device as a means of protection for any kind of harassment.

5. However, 25% of the women who carry safety devices feels secure with it.

6. Some of the common features that they wants to be in the safety device includes are:

i) GPS and location tracking,

ii) sending SOS signals,

iii) informing the emergency saved contacts,

iv) lesser number of false alarm and v) easy using.

CONCLUSION

The main aim of the paper is to develop a smart safety device that is more accurate and easier to use. In order to fulfill the aim of the study, a five part questionnaire survey is designed to understand the basic needs of the women that they wants to be installed in the safety device. From the survey it was confirmed that they want smart device with GPS and location tracking, sending automated SOS signals, informing the emergency saved contacts, lesser number of triggering false alarm and easy usage. In order to install the features in the safety device, it is necessary to train the device to detect an unsafe scenarios. In this direction, the vitals that showed a spike in reading when felt unsafe are considered as the input parameters which are heart beat rate, perspiration rate, blood pressure trend and acceleration. The inputs are mapped with the labels as safe and unsafe. XGBoost classifying model is developed with the data acquired. The model showed an accuracy, precision, recall and F1-score of 73.6%, 80%, 79.5% and 79.7% respectively. The parameters of the model is further hypertuned in order to nullify the error caused due to overfitting and also to increase the accuracy. After hyperparameter tuning, the model showed an accuracy, precision, recall and F1-score of 94.4%, 95.4%, 96% and 95.7% respectively. The developed classifying model is embedded in the safety device along with the features to develop a new highly efficient and effective smart device that can easily classify a safe and unsafe scenarios with more accuracy.

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