Design and Development of an Advanced Affordable Wearable Safety Device for Women: Freedom Against Fearsome

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A R T I C L E   I N F O

A B S T R A C T

Harassment and violence against women have become one of the social security problems in Bangladesh. In this paper, we aim to develop safety devices for women named BOHNNI and BADHON which resemble legitimate jewelry. We used a microcontroller for the hardware device to make it most decisive and less immoderate. BOHNNI, a locating device, is the imitator of a locket including a voice recognizer, Bluetooth, Arduino, GPS, and GSM module. BADHON which imitates a bracelet is a rescue device for the victim whenever she thinks of herself being in a very deliberate situation. Both devices are activated by the user's voice commands and also by a manual switch. The devices are aesthetically designed which will make the users enthusiastic to wear them. The device will generate messages to the predefined relative's numbers with the victim's location and relevant surrounding information. The device can also be used as a self-defending weapon as it can produce a shock up to 10 mA with an interval of two seconds which can temporarily paralyze or freeze a person. After calculating, we have obtained the lowest response time of BOHNNI and BADHON which is 1.95s, and the highest accuracy level of 91.67% in different situations that ensure the superlative performance level of our devices. We found our device as an all-in-one device that combines all the features in it regarding safety.

1. Introduction

Bangladesh has met the eligibility requirements for shifting from 'Least Developed Country' to 'Developing Country' status, the UN says [1]. Women's empowerment is also on the rise, but incidents of various forms of violence against women, including dowry torture, sexual assault, abduction, and rape continue to take place extensively in Bangladesh. The "State of Rights Implementation of Women Ready Made Garment Workers" study, conducted by Karmojibi Nari and Care Bangladesh, shows that about 12.7% of workers face sexual harassment in their workplaces [2]. Around 94% of women face harassment in public transport [3]. Bangladesh Mahila Parishad (October 2019) statistics indicated that in the last year at least 3,918 women have been victims of various forms of violence across the country [4]. [4]. Surviving in these situations becomes a great challenge for women. By adopting modern technology and devices to protect

them from their oppressors, the defense strategy used by women needs to be revolutionized [5]. This current situation has encouraged us to come up with a solution to harassment and violence against women. This work has been done to ensure safety for women moving alone. It is not the only solution to a problem but also comes with wearable safety products. These are very handy safety devices that can be used by any woman. GPS and GSM modules are used to give alert calls and messages to the victim's previously established numbers and nearest police station numbers including the instant location and that location can be tracked immediately or later using our device "BOHNNI" and "BADHON". The devices that we have built can be activated by using vocalized passwords which ensures the surety of access to the devices in any critical situation. It is very easy to operate and anyone can operate it as it can be used manually or by using voice commands. This product is multi-functional. It makes it easier and faster to catch the criminals as the lowest response time of BOHNNI and BADHON is 1.95s and also works as a self-defender. The highest accuracy level of 91.67% was obtained in a

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different situation that ensures the performance level of our devices. It is intelligent enough because it can understand the user's voice command and can be used by people of any age. Materials used there are recyclable. We have maintained the safety of the user while designing the device with polymer plastic material to protect the user from accidental shock. The notable accomplishment of our design is the shocking module which can give a shock to the harasser up to 10 mA with an interval of 2 seconds which help the victim to escape from the location. We believe that this device can bring a huge change in violence and harassment against women. It can be a blessing for women and also develop their social norms in our country.

2. Related Works

The project described in [6] developed a wearable device for the protection of women by analyzing physiological signals in association with body position. Galvanic skin resistance and body temperature are analyzed as the physiological signals. Real-time monitoring of data is obtained by wirelessly sending data to an open-source Cloud Platform. In critical situations, this device sends notifications to designated individuals. A proposal is available in [7] anticipated "FEMME" as a safety device specifically designed for women in situations of threat. Using Bluetooth, both the device and the smartphone are synced. With instant location information, it can record audio, give an alert call and message to the pre-set contacts. A hidden camera detector is a visible feature here as well. A smart Intelligent Security System was proposed in [8]. The system features a band on the wrist associated with a pressure switch. The screaming alarm and tear gas mechanisms are appointed for self-defending purposes. This system also sends the appropriate locations and messages to the emergency contacts and uses live streaming video to figure out the assaulter [8]. It was aimed to create a common system that incorporates a wearable computer and acts as a safeguard for women facing any danger in [9]. Body area sensors, Bluetooth communication, GPS, SMS and MMS, Internet connection, and a mobile database system are used for the composition of this system. Another proposal named "Suraksha" is developed in [10] to flash a warning to provide the police with an immediate location of the distressed victim so that the incident could be prevented easily. A smart intelligent device is proposed in [11] where a wearable smart band and a secret webcam linked via Bluetooth are integrated into the device. Women's information such as call log, messages, motion, pulse measurement, blood oxygen levels, heartbeat rating can be tracked by the application. It automatically generates signals to the predefined smartphones and the nearest police stations when the SOS present in the smart band is pressed continuously. A smart women's security system using Radio Frequency Identification (RFID) and Global Positioning System (GPS) was established in [12]. In scanning the information, the RFID reader is used and assigns that information to the microcontroller. In [13], the team developed a device that can use GPS to track the location of women and send emergency messages using GSM. The pulse sensor checks the victim's pulse and the device also sends the current GPS location to the ambulance every 10 seconds in the form of SMSs in abnormal health situations. The authors in [14] developed a device that will be clipped to the user's footwear and can be carefully triggered four times by tapping one foot behind the other. A device is

developed in [15] that reads and creates patterns such as body temperature and pulse rate automatically during running, including temperature and pulse sensors. If the readings are higher than normal readings, more than one person will automatically get a call and message. In non-dangerous conditions, data is first collected by sensors to train the algorithm. A passive continuous monitoring system is proposed in [16] using both survivor-attached biosensors and machine learning techniques. According to the current status of wearable and biomedical device technology, the monitoring structure of the system supervises a lot of bio-signals. In [17] a system is designed to detect location with GPS and GSM mechanisms to pass the current location to any of the trusted contacts as a Google map link and services are provided from that moment on to track the locations to save the individual. A wearable system was designed in [18] that resembles a normal watch with a button that can be pressed in an unpleasant situation to activate the system. Using a Global Positioning System (GPS) sensor, the system monitors the victim's location. The system also includes a screaming alarm using a real-time clock. A smart band is developed in [19] that gets activated to send the GPS location to the ICE contacts and police control rooms by tapping on the screen twice. A micro USB charge is supported by the device and two metal points generate the shock on the top of the band screen. A project 'watch me' is developed in [20] for a purpose whenever a woman or child wearing a smartwatch called 'watch me' is exposed to sexual or vulnerable assault, the device works. It will automatically make a call to the registered contacts of the victim and will also detect the nearby police station via GPS / GSM to make a ring there so that police can arrive at the spot soon by tracking the GPS. The developers in [21] developed a female safety jacket that flashes a warning giving the police an instant location of the distressed victim so that the incident can be avoided and the culprit captured. An efficient woman's security recognition system has been introduced in [22] consisting of an ARDUINO NANO Controller, a Bluetooth module, a Taser, and a versatile Android. It monitors the victim's location using GPS and sends emergency messages via GSM. An electronic device including biometric touch sensors has been developed in [23] that generates extremely high voltage pulses at around 3 KV range. The high voltage causes body pain, numbness, and balance loss. From its use, no permanent injury is noticed. For women, a self-defense system using Raspberry-pi 0 controller and GSM, GPS, Temperature sensor, Heartbeat Sensor has been developed by [24]. The location of a place via GPS is indicated by a single click on this device and a message consisting of the location URL is sent to the registered contacts to assist them in dangerous situations. In terms of latitude and longitude, a rapid response mechanism was developed by [25] that helps women when they press the button attached to the device and the location information is sent as an SMS alert to a few predefined emergency contacts. A smart security wearable device for women was implemented by [26] in the form of a smart ring (SMARISA) comprising Raspberry Pi Zero, camera, buzzer, and button. The victim can activate the device by clicking on a button that fetches her current location and also captures the attacker's image.

For all sections of women in Bangladesh, a user-friendly mobile-based approach 'BONITAA' was developed by [27] with several unique features, primarily aimed at supporting victims of rape by facilitating their ways to obtain justice with legal solutions,

physical and mental support, etc. Another mobile app 'SafetiPin' was introduced by [28] where the device can gather crowd-source data and information on insecurity in cities using several features such as GPS navigation, digital camera, high-speed internet connectivity, and many more. The team in [29] created a women's security Android application. Using the Wikitude SDK, the women's safety app can be integrated with augmented reality that helps to place articles and reviews related to the current location. A smartphone application prototype was introduced in [30], which is primarily a safety decision aid designed to help women estimate the risk in their abusive relationships, set safety priorities, and develop a personalized safety plan. A "Virtual Friendly" device was created by [31], consisting mainly of GPS, GSM modem, microcontroller, RF transceiver, temperature sensor, voice recognizer to provide trouble-safety. The GPS receiver obtains location information in the form of latitude and longitude from satellites. The temperature sensor senses the temperature of the body and sends an SMS alert in the event of a low temperature. A portable device was developed by [32] incorporating a pressure switch that gets activated by compressing it. The pressure sensor senses the pressure instantly and a conventional SMS, with the location of the victim being sent to phone numbers stored in the device followed by a call to their parents/guardians [32]. A smart device is developed by [33] that can be clipped to a woman's footwear and can be discreetly triggered within 5 seconds by tapping her feet 10 or more times. It will also sense the unnatural rise or fall of her heartbeat and the values will be displayed on the smartphone of the victim.

Figure 1: Circuit Diagram of BOHNNI and BADHON

3. Materials & Methods

3.1. Hardware Components

Materials that have been used to produce these devices are non-toxic, heat & current resistant. The core of the device is embedded with the PCB circuit board consisting of the circuit of GSM, Bluetooth, Arduino, voice recognition module, and camera module. The primary components of the circuits are the voice recognition module which is used to capture the user's voice & turning on the operation of the device, Arduino to send messages & location to the programmed numbers, GSM Module which is used to send messages & location to the programmed numbers, Bluetooth Module to send & receive a signal during the operation of the device and lastly the Camera Module to save pictures during the operation of the device.

3.2. Design

The circuit is designed in Proteus software. The microcontroller is the processing unit that processes all data from the sensor and voice recognition module. It also sends the necessary command to GPS and GSM units.

We have designed the initial outer designs of the device BOHNNI in SolidWorks that is represented below in Figure 2:

Figure 2: 3D Design of BOHNNI & BADHON

3.3. Fabrication of Prototype

'BOHNNI' and 'BADHON' are fabricated initially on breadboard connecting all parts including Arduino, LED, voice recognition module, Bluetooth module, GSM, and a GPS module. 'BADHON' consists of a shocking module, Arduino, a Bluetooth device, a video camera, and a buzzer. Initially, the video camera was not used in the prototype. During mass production or making a real-time product, the video camera will be included. A visual representation of our prototype 'BOHNNI' and 'BADHON' are given below in Figure 3 and Figure 4:
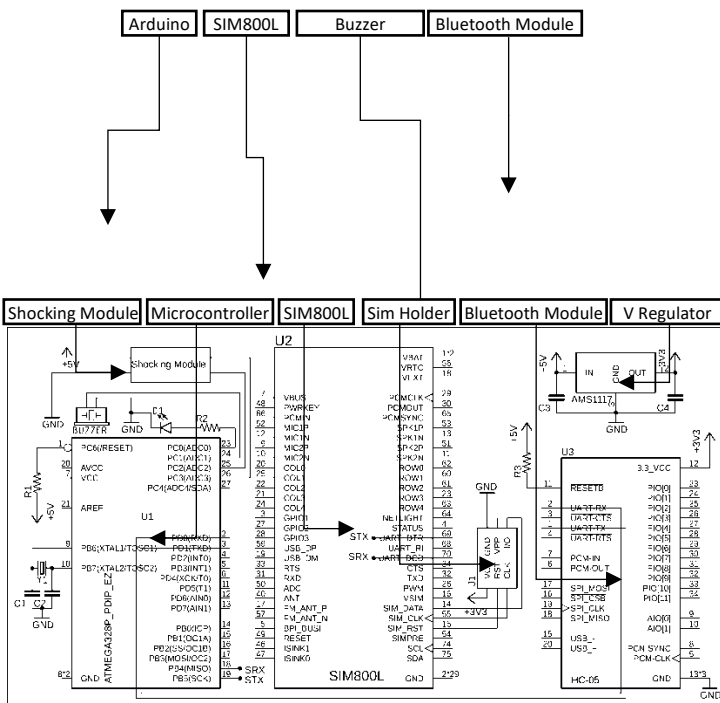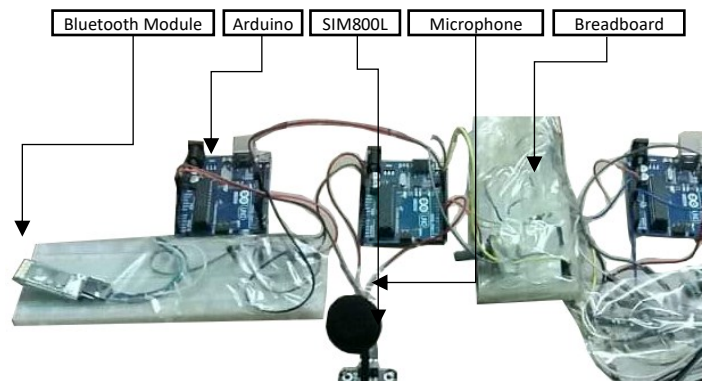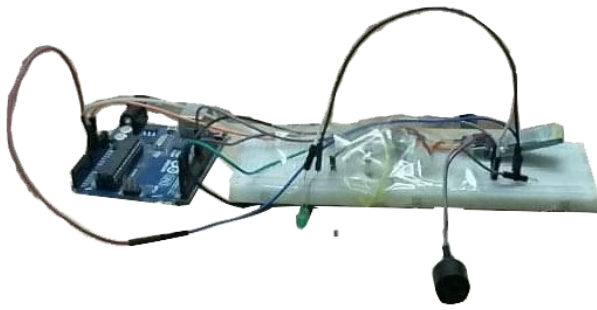

Figure 3: Prototype of BOHNNI
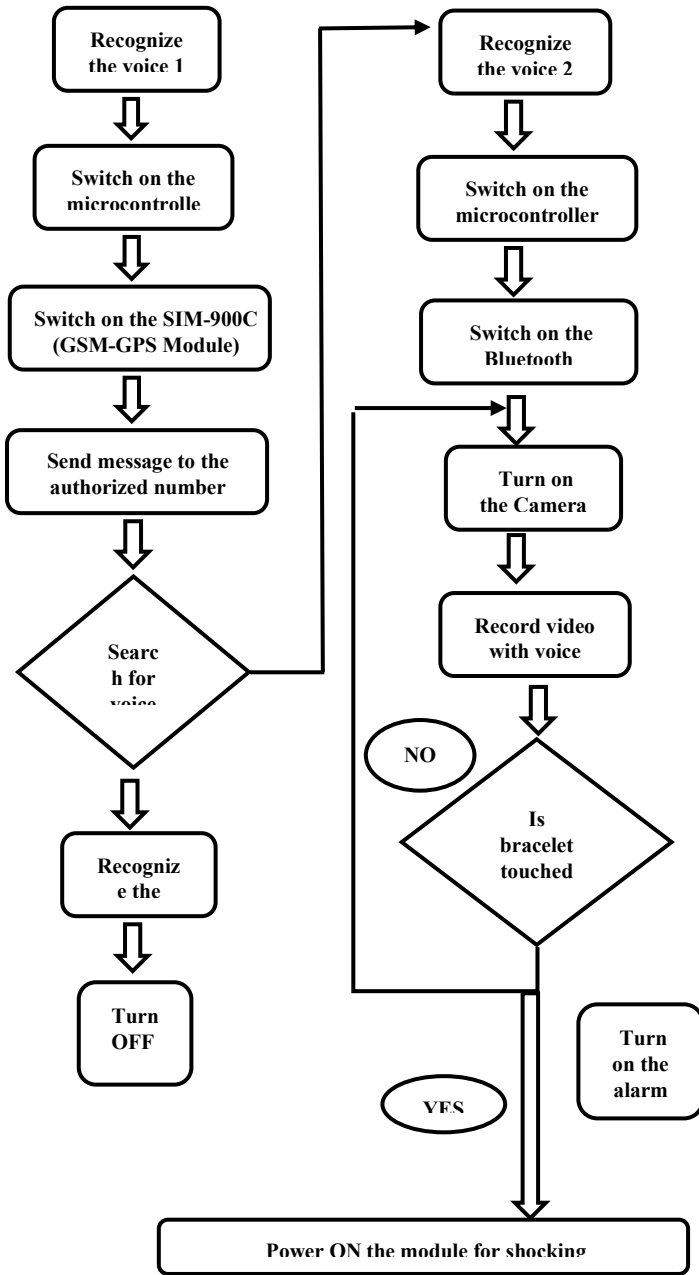
Figure 4: Prototype of BADHON

Figure 5: Flow chart of the operating process of BOHNNI and BADHON

3.4. Working Procedure

For WOMEN we are introducing a system that resembles some normal jewelry like locket (BOHNNI) and bracelet (BADHON). BOHNNI is a locating device including a voice recognizer, Bluetooth, Arduino, GPS, and GSM module. The device will be activated using the voice password set by the user. As it activates it will send messages to the user's family member's numbers which were previously set by her and the nearest police stations with the link of her location. This will provide vital protection to the victim. BADHON which reassembles a bracelet activates another voice password set by the user. It is a rescue device for the victim if she is in a very critical situation. This device includes a shocking module, Arduino, Bluetooth device, video camera, and a buzzer. Using another voice code in BOHNNI will activate the device BADHON. After it activates, the video camera will capture video of the victim's surroundings as it can be used as evidence in the future. The shocking system will be activated which can give a shock to the harasser up to 10mA (10 mA) with an interval of 2 sec which can make him paralyze or freeze his muscle for few minutes and help the victim to escape from the location. As the device will be made of polymer plastic the user will not be affected by the shock. It also has a buzzer that activates when it is touched. Then the buzzer will buzz 120 decibel sound to attract people from further. This device can also be used for children when aesthetically designed which will make the children enthusiastic to wear them. In this way, the guardian can always be aware of their child when they are not with them.

4. Results & Discussion

4.1. Design of Experiments

The design of the experiment runs by putting BOHNNI and BADHON together in different combinations. In table 1, for the first five rows, BADHON was placed on the right arm where BOHNNI was placed on the left arm, right wrist, left wrist, neck, and chest respectively. For the next four rows, BADHON was placed on the left arm where BOHNNI was placed on the right wrist, left wrist, neck, and chest respectively. Again, for the next three rows, BADHON was placed in the right wrist and BOHNNI was placed on the left wrist, neck, and chest respectively. For the last two rows, BADHON was placed in the left wrist and BOHNNI was placed in the neck and chest respectively. In this total of 14 rows, BOHNNI and BADHON were subjected to different combinations to check the response time of each for every possible combination. The experimental design has been formatted in Table 1 below.

Table 1: Different combinations and placements of BOHNNI and BADHON

Right Arm	Left Arm	Right Wrist	Left Wrist	Neck	Chest
BADHON	BOHNNI	--	--	--	--
BADHON	--	BOHNNI	--	--	--
BADHON	--	--	BOHNNI	--	--
BADHON	--	--	--	BOHNNI	--
BADHON	--	--	--	--	BOHNNI
--	BADHON	BOHNNI	--	--	--
--	BADHON	--	BOHNNI	--	--
--	BADHON	--	--	BOHNNI	--

--	BADHON	--	--	--	BOHNNI
--	--	BADHON	BOHNNI	--	--
--	--	BADHON	--	BOHNNI	--
--	--	BADHON	--	--	BOHNNI
--	--	--	BADHON	BOHNNI	--
--	--	--	BADHON	--	BOHNNI

Response times have been calculated by following the combinations of BOHNNI & BADHON's placement & placed in Table 2.

Table 2: Response time for different placement combinations of BOHNNI and BADHON

Right Arm	Left Arm	Right Wrist	Left Wrist	Neck	Chest	Total Response Time (s)
0.55	1.45	0	0	0	0	2
0.56	0	1.85	0	0	0	2.41
0.58	0	0	1.85	0	0	2.43
0.57	0	0	0	1.4	0	1.97
0.56	0	0	0	0	1.4	1.96
0	0.58	1.85	0	0	0	2.43
0	0.56	0	1.85	0	0	2.41
0	0.57	0	0	1.4	0	1.97
0	**0.55**	**0**	**0**	**0**	**1.4**	**1.95**
0	0	0.59	1.85	0	0	2.44
0	0	0.57	0	1.4	0	1.97
0	**0**	**0.55**	**0**	**0**	**1.4**	**1.95**
0	0	0	0.57	1.4	0	1.97
0	**0**	**0**	**0.55**	**0**	**1.4**	**1.95**

The total response time for BOHNNI and BADHON was obtained by adding the response time of BOHNNI and BADHON for each combination. From table 2, we have obtained the lowest response time that is 1.95s.

Findings from this data are the precise locations to place the device in the body. We found three locations with the minimum response time. Those combinations are-

- Right Wrist (BADHON) & Chest (BOHNNI)
- Left Wrist (BADHON) & Chest (BOHNNI)
- Left Arm (BADHON) & Chest (BOHNNI)

From these findings, we have designed our devices so that they can be worn on the wrist & chest to obtain the least response time.
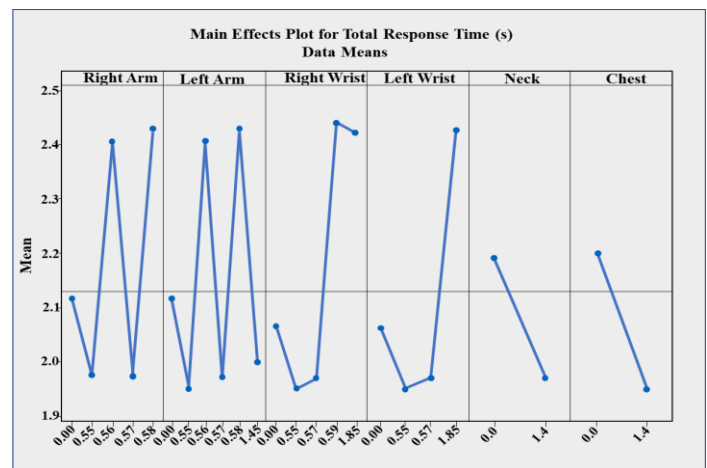

Figure 6: Main effect plots for Total Response Time

Table 3: The response of the device in different situations

Ser No	Different Situation	Tested Times	True (+)ve	False (-)ve	Sensitivity	% of Error
1.	Inside a room	12	11	1	0.92	**8.33%**
2.	Inside a bus	12	8	4	0.67	**33.33%**
3.	Inside a CNG	12	9	3	0.75	**25.00%**
4.	Inside a car	12	11	1	0.92	**8.33%**
5.	Walking on the street during morning	12	10	2	0.83	**16.67%**
6.	Walking on the street during noon	12	9	3	0.75	**25.00%**
7.	Walking on the street during night	12	10	2	0.83	**16.67%**
8.	Walking on the street during midnight	12	11	1	0.92	**8.33%**

% of Error= (1-Sensitivity) ×100 %

4.2. Accuracy calculation

Sensitivity analysis is the study of how to divide and allocate the uncertainty in the output of a mathematical model or system (numerical or otherwise) into its inputs to different sources of uncertainty. Uncertainty analysis, which focuses more on quantifying uncertainty and propagating uncertainty, is a related practice; ideally, uncertainty and sensitivity analysis should be performed in tandem. We have checked the sensitivity and percentage of error in various situations. The formula of Sensitivity (S_n) [34] is given below,

$$S_n = \frac{\text{True positive}}{\text{True positive} + \text{False negative}}$$

The obtained results using the Sensitivity formula are given in Table 3.

We have also obtained a bar diagram regarding the results. Here we have shown the percentage of error and accuracy in different situations.
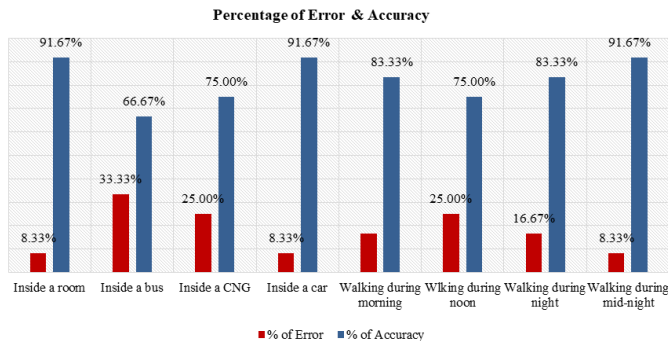

Figure 7: Bar chart of percentage & accuracy

From the chart, we found out 91.67% accuracy occurred during three situations. Those are: -

a) Inside a room
b) Inside a car
c) Walking on the street during mid-night

Other situation's accuracy is higher than the error percentage which indicates the feasibility of the device.

4.3. Comparative Analysis

We have made a comparative analysis with two of the existing works "Suraksha" [10] and "Watch Me" [20]. The major achievements of our design that distinguish itself from others are the shocking system which can give a shock to the harasser up to 10 mA with an interval of 2 sec which can make him paralyze or freeze his muscle for few minutes and help the victim to escape from the location and also the fact that we have taken the safety of the user under account while designing the device with polymer plastic material to protect the user from the shock.

Table 4: Comparative analysis with existing works

Device	Suraksha	Watch Me	BOHNNI and BADHON
Country	India	India	Bangladesh
Features	Voice recognition, GSM/GPS module, Switch, force sensor.	Pulse rate sensor, motion sensor, GSM/GPS module, alarm.	Voice recognizer, GPS, GSM, buzzer, video camera, shocking system.
Product Components	Miniature device which can be embedded in jewelry or mobile phone etc.	Smartwatch	Wearable Locket, a bracelet made of polymer plastic.
Application	The device will activate by voice command or switch or if thrown by	The sensor of the device will activate when the targeted heart rate for the targeted time is	The device will activate using the voice password set by the user. After activation, it will send messages to

	force then it will send an alert message to the police and registered number.	achieved, then will produce an alarm sound and send a notification to the cops and registered numbers.	the user's emergency numbers and nearest police stations with the link of her location.
Limitations	There is no such feature to attack the attacker and also the device needs to be set with accessories.	The device is physically dependent.	Physical modifications can be done to ensure durability and the size of the locket can be reduced to some extent.

4.4. Mass Production Plan

Mass production plan for BOHNNI & BADHON starts with internal components placement. In BOHNNI, five components are needed to place into the inner circuit. From Fig 8 below, we can see the total weight of the components of BOHNNI is 26.1 gm & the outer portion of BOHNNI is made of a polymer of rubber and plastic for anti-shocking weighing 7.25 gm. The total weight of BOHNNI including all of its components is 33.35 gm which is much lower than the necklace that women usually wear.

From Fig 8, we can find the area of every component which defines the feasibility of mass production of this device. The device BADHON's weight & size is quite similar to the regular smartwatch and so we have not designed the positions of placement of its components but it will be made of polymer plastic to protect the user from getting sudden shocks.
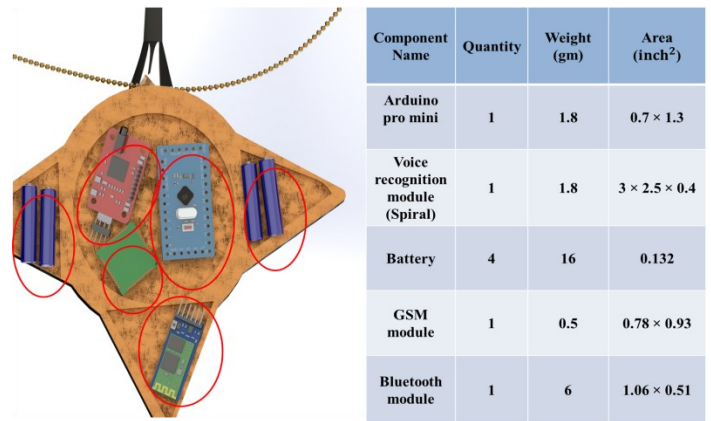

Component Name	Quantity	Weight (gm)	Area (inch²)
Arduino pro mini	1	1.8	0.7 × 1.3
Voice recognition module (Spiral)	1	1.8	3 × 2.5 × 0.4
Battery	4	16	0.132
GSM module	1	0.5	0.78 × 0.93
Bluetooth module	1	6	1.06 × 0.51

Figure 8: Inner components of BOHNNI including weight and size

5. Conclusions

In this twenty-first century, our country is experiencing a notable change in society because of women's empowerment. But the bitter truth is that these women are continuously being harassed every day and everywhere. So, women's safety issue has become a matter of great concern nowadays. For women, there are several safety devices available, but affordability for all has yet to be achieved. Keeping that in mind, we have designed our "BOHNNI" & "BADHON" to prevent harassment in our country. This device is simple structured, inexpensive, and feasible as well. This safety device is much more user-friendly & accurate during critical situations than other existing devices. It is very lightweight

and as it resembles jewelry, it can easily remain hidden from the attacker. We built the prototype & tested it during several situations. Our findings are the accuracy of the device which indicates the feasibility of using it. Our products- "BOHNNI" & "BADHON", will ensure a safe environment for women and children in all situations by providing the hidden camera, GPS and GSM module, shocking device, and voice recognizer. In our paper, we presented only the proto-type of a wearable safety locket and bracelet. Various health and activity monitoring sensor belts are already available on the market, but the design of an integrated safety device is completely different as very accurate calculations and designs are mandatory. Therefore, future work will aim to present both physical and appropriate modifications of the devices to improve their durability and prevent any damage to the hardware. With additional study and innovation, our project can be sufficiently competent to reduce the rate of crime against women and children.

Conflict of Interest

Acknowledgment

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