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Sa. G. I. P: A Pre-development of Life Saving Intelligent Fall and Critical Event Detection System for Power Two-Wheeled Vehicle (PTW)

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ABSTRACT

Road accidents are prevalent all over the world, and many lives are lost as a result of required medical assistance failing to reach the patient on time for a variety of reasons. The majority of accidents are caused by the carelessness of drivers and pedestrians. The researchers developed a system that will determine when there is a critical event happen to a PTW rider and will protect the chest part of the rider during an accident, this will notify the authorities such as police and the hospital. In the experiment conducted, the researchers obtained 100% detection when there was a critical event within the nearest hospital to rescue the rider. The detection system is promising.

Keywords: *Accelerometer, GPS, accident detection, critical event detection, power two-wheeled vehicle (PTW)*

INTRODUCTION

The use of powered two-wheelers (PTWs) such as motorcycles is increasing, particularly in cities, because PTWs offer a solution to growing traffic congestion and parking issues. However, according to the World Health Organization's (WHO) global status report on road safety, PTW users are among the most vulnerable road users because PTWs provide less protection and stability, which frequently results in fatal accidents (Global Status Report on Road Safety, 2018). Road accidents are complex, unpredictable events. Various parameters and factors, such as weather conditions, the geometric shape of the infrastructure, the vehicle's dynamic characteristics, and the driver's behavior, can all have an impact on these types of events. To reduce the number of traffic accidents, it is necessary to first understand how and why they occur. There are numerous research tools available for this, such as naturalistic driving studies on open roads and experimental studies in driving simulators or test tracks. A driving simulator is one such tool that can be used to combat this issue. Real-world driver behavior can be modeled and simulated. Different simulation scenarios can be generated, and the factors that lead to a crash can be investigated (Martn et al., 2014). The majority of accidents involving the driver's responsibility are minor. Drivers' emotional, mental, and physical states (hurry, fatigue, illness, drunkenness, and so on) are some of the factors influencing their decisions when interacting with infrastructure and other road users. Human error, either directly or indirectly, plays a significant role in motorcycle and scooter accidents. (Treat, 1977), (Mallia, et. al., 2015). This could be because powered two-wheeler users must actively maintain their vehicle's dynamic stability. Also, in the studies conducted in Asia, 78 percent of Asians use motorcycles as their primary mode of transportation. Drowsiness is one of the leading causes of car accidents [5]. The drowsiness of the motorcycle rider causes 1% to 3% of all motor accidents (Zahng, et. al., 2016). Drowsiness can occur while driving at any time of day or night. It is primarily due to tiredness from driving for an extended period. There are several ways to avoid drowsiness, including taking a nap before driving and avoiding late-night driving. There are different ways to detect drowsiness, such as analyzing the eye and eye blinking rate. Brain signals can be used to determine the overall health of the human body. The term electroencephalography (EEG) refers to electrical neural activities in the brain (Berry, et. al., 2012). Electroencephalography (EEG) can be used to examine the brain signals associated with drowsiness. The heart rate variability (HRV) analysis based on electrocardiogram (ECG) data acquisition while a person rides at various times of the day can also be used (Jones, 2010). Although analyzing these physiological features is an intrusive method, it produces more accurate results than other methods. Because of this, as well as the limitations of other methods for motorists, such as positioning a camera for facial expression recognition is nearly impossible for a motorist wearing a helmet, this research has been done using physiological features of the motorist, namely EEG, ECG, and EMG signals for drowsiness detection and prediction. The drowsiness levels have been classified as awake, moderate, and drowsy. It is extremely dangerous to drive when a person's drowsiness level transitions from moderate to drowsy. The goal of this study is to create a system that can predict drowsy motorcycle riders and alert them using EEG, ECG, and EMG signals. The system also analyzes the motorist's consciousness and forearm muscle condition using ECG and EMG.

According to the WHO Global Status Report on Road Safety 2018, there is an increasing trend in road traffic deaths in the Philippines. According to Philippine data, approximately half of these fatalities occur among vulnerable road users—motorcyclists, pedestrians, and cyclists. In addition to fatalities, road accidents injure and disable thousands of people. Road traffic injuries also cost about 2.6 percent of the country's GDP (Siecinski et. al., 2020).

Skin bruises and abrasions, hematomas, and contusions are common injuries in motorcycle accidents. When a motorcycle collides with the ground at high speeds or with friction, the rider sustains skin lacerations and bone abrasions. Skin laceration can be mildly painful in some cases but extremely painful in others (Mubashir et. al., 2013).

Body region	Vehicle occupants[a]		Vulnerable road users[b]		p^*
	$n = 678$	%	$n = 382$	%	
Head	227	34	161	42	0.005
Face	192	28	85	22	0.035
Neck	38	6	4	1	0.0001
Spine	87	13	26	7	0.0025
Thorax	205	30	104	27	0.32
Abdomen and pelvis	49	7	37	10	0.16
Upper extremity	213	31	154	40	0.004
Lower extremity	190	28	210	55	<0.0005

[a] Includes drivers, front and rear passengers.
[b] Includes pedestrians, motorcyclists, and bicyclists.
[*] p = Fisher's exact test.

Figure 1. Patients' Injury record in Hospital

Figure 1 depicts hospitalized road traffic injury patients in the United Arab Emirates from 2003 to 2006, comparing vehicle occupants and non-occupants by anatomical region (s) injured. It demonstrates that the upper extremity is the third most common region of the body where motorcycle riders are injured.

A sprained arm happens when a motorcyclist uses their arms to protect themselves during the impact of a crash. When the impact force is concentrated in the arms, they may become paralyzed and suffer nerve damage. The injury may cause damage to the brachial plexus in the upper arm. Motorcyclists are prone to injuries due to the inherent disadvantage of their bodies being exposed while riding. There is a complete lack of safety enforcement such as motorcycle airbags and protective gear. The majority of accidents occur in the musculoskeletal system, particularly the upper body.

METHODOLOGY

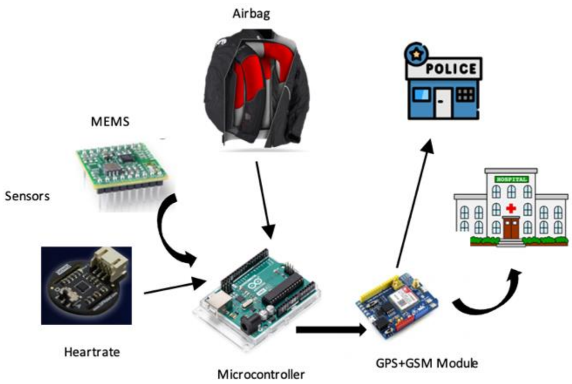

Figure 2. Sa. G.I.P System Architecture Design

Figure 2 depicts the Saving and Giving Injured Person Assistance (Sa. G.I.P for brevity) System Architecture. This system has fall and critical event detection, such as collision, which consists of an accelerometer that detects a sudden change in the motorcyclist's speed and a heart rate sensor. The Arduino analyzes the signal and determines whether or not the airbag system is activated, and the heartbeat rate determines the seriousness of the accident. The user can either cancel the automatic system notification or the system will automatically acquire the user's location and use the GPS module to locate the nearest road accident response unit. The notification system consists of a GSM module that will send SMS messages to the police station as well as the registered contact hospital.

A. Hardware Installation

This section discussed the circuitry; once the device's electronics circuitry and a detailed design of the airbag jacket are completely based on the standard requirements of the model, the device can be built.

1**. Unit/Device Testing**: In this stage is a test phase where each component of the device is tested to ensure that the components are working properly as per specification.

2. Integration Testing

In this phase, testing of the individual software components is conducted to verify the interaction between various software components and to expose faults or defects in the interaction between integrated units.

3. System Testing
After the integration testing on the components, they are readily available for system testing. The airbag jacket undergoes this test to evaluate if the system complies with the specified requirements.

4. Operation and Deployment:
Once all the tests are done and the design specifications for every part of the system are met, the device can now be deployed to the market or for further research and development.

5. Validation
If the device's requirements are not met in each testing phase or the results are not acceptable, the designers can retest another design that will perfectly fit the device's objective. The preceding processes are then repeated for testing the new design.

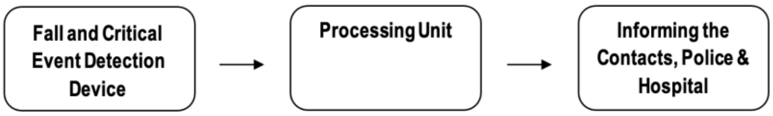

Figure 3. Sa.G.I.P. System Workflow

Figure 3 depicts the device's system architecture design. When the fall and critical event detection device detects a sudden change in the motorcyclist's speed, the signal is processed to determine whether or not the system should be activated. The user has the option of canceling the automatic system notification, or the system will automatically acquire the user's location and locate the nearest road accident response unit. The system will notify the authorities as well as the designated contact person. When the information is sent to the appropriate authorities, the user will be notified.

In the studies conducted (Bonjyotsna et al., 2014), there is a two-way step to determine whether or not the accident occurred. The first is through an accelerometer, which detects any sudden tilt of the vehicle in the event of an accident. The heartbeat sensor will then detect the user's heartbeat rate and determine the seriousness of the accident or fall. Based on the changes in the heartbeat, a message is sent to the control room and emergency contacts, along with a location map, and will send a text message to the nearest medical help center, along with the location using GPS, saving valuable time. The heart rate sensor effectively eliminates false alarms.

Another basis of this study is that early fall detection was developed by Bhardwai et. al. (2018) to prevent old people from having injuries from their accidental falls. Progress in technology brings more possibilities to help us protect the elderly. Low power consumption components make it possible to realize wearable monitoring devices. MEMS (microelectro mechanical systems) sensors have simplified the design and implementation of the sensor system. A location-based service (LBS) makes it easier to locate the elderly for health monitoring. Besides these, mobile computing makes remote health monitoring easier to implement.

A fall and collision detection sensor is a device that consists of three-dimensional microelectromechanical systems (MEMS) accelerometers, gyroscopes, a Bluetooth module, and a Microcontroller Unit (MCU). The unit records human motion information and falls with the use of high-speed cameras. With the aid of gyroscopes, lateral falls can be determined. The unit includes a human motion database that contains falls and other normal motions (walking, running, etc.) that are set up. The response time for the mechanical trigger is 0.133 s, which is enough time for compressed air to be released before a person falls to the ground (Inio et al., 2018).

1. **Methods to Activate the Sensor**
   The researchers used the Microelectromechanical Systems (MEMS), which contains a gyroscope and an accelerometer to measure movement and acceleration. A force will occur when a mass is moving in a particular direction with a particular velocity and an external angular rate is applied.
2. **Acquiring Location**
   The Global Positioning System (GPS) is a satellite-based navigation system made up of at least 24 satellites. GPS works in any weather conditions, anywhere in the world, 24 hours a day, with no subscription fees or setup charges.

Mathematical Computation

$$d = 2r \text{ arcsine } \left(\sqrt{\text{hav}(\text{œÜ}_2-\text{œÜ}_1)+\cos(\text{œÜ}_1)\cos(\text{œÜ}_2)\,\text{hav}(\text{Œª}_2-\text{Œª}_1)} \right)$$

$$= 2\arcsin\left(\sqrt{\sin^2(\text{œÜ}_2-\text{œÜ}_1)/2+\cos(\text{œÜ}_1)\cos(\text{œÜ}_2)\sin^2(\text{Œª}_2-\text{Œª}_1)/2} \right)$$

Coordinates of Chinese General and Medical Hospital

(ϕ1, λ1) = (14.625933°,120.988059°) = (0.255270687025,2.111639985142)

Coordinates of motorcycle accident

(ϕ1, λ1) = (14.625808°,120.987940°) = (0.255268505364,2.1116379082)

$$2(6.371) \text{ arcsine } \left(\sqrt{\sin^2(0.25527-0.25526)/2+\cos(0.25526)\cos(0.25527)\sin^2(2.111637)} \right) /2$$

d = = 64.97168 m

Calculating the value of Pseudo range:

The pseudo-range is the "distance" between the GPS satellite at some transmit time and the receiver at some receive time. The time that the signal is transmitted from the satellite is encoded on the signal, using the time according to an atomic clock onboard the satellite.

> [16] Pseudo range = (time difference) x (speed of light)
> Time difference = receiver clock reading at reception – satellite clock reading at transmission
> speed of light = 3 x 10^8 m/s

3. Notification system

The researchers use the Short Message Service (SMS), which is GSM's text messaging component that enables mobile devices to exchange short messages. The frequency that a GSM module uses depends on the SIM card inserted into the module. The path loss exponent varies according to the location of the antenna and the distance between two transmitters.

4. Critical Event Detection

The proponents used pressure sensing textile, which is a fabric that has a surface transformed into a textile area that has sensing properties. It detects the part of the body that is severely injured [16].

$$\text{Applied pressure} = \frac{\text{Force}}{\text{Area}} = \frac{\text{mass (g) x acceleration (cm/s}^2\text{)}}{\text{area (cm}^2\text{x k)}}$$

4.1 Airbag Activators

Another worker was able to inflate their airbag system. They used a mechanical release mechanism that includes a cross-shaped punch mounted on a launcher consisting of a spring and a locking switch. When the locking switch is pressed by an actuator, the compressed spring extends, and the punch accelerates toward the pressurized CO2

4.2 Fall Signal Processing Techniques

A wearable airbag that uses both acceleration and angular velocity signals to trigger inflation. The system consists of a jacket, a fall detection sensor, an inflator, and an airbag. There were several methods to determine the fall: contact with the ground and the detection of free fall. adaptive restraint system based on precrash classification of occupant posture. The system has achieved a classification accuracy of approximately 98%. The tracking system has demonstrated the ability to detect the dangerous proximity of the occupant relative to the airbag within only 7 milliseconds. The selection of patches and the estimation of their parameters are achieved through a boosting algorithm.

4.3 Application of the Automatic Airbag System

Another field where the airbag is now used is in the anti-drowning systems for swimmers. If the body wearing this system has been unmoving for a prolonged period while submerging or when the pressure sensors and MEMS detect abnormalities in the swimmer's relative pressure, the airbag system is activated.

Testing and Results

The Data and Results

Table 1
Sample Trials of MEMS Data Calibration

LINE	AXIS		DIFFERENCE		STATUS
	x	y	X	y	
1	1788	4140			currentState = 1
2	1840	3908	52	-232	currentState = 1
3	2056	3136	216	-772	currentState = 1
4	1920	2776	-136	-360	currentState = 1
5	1736	3208	-184	432	currentState = 1
6	1908	3352	172	144	currentState = 1
7	2080	3128	172	-224	currentState = 1
8	1456	2320	-624	-808	currentState = 1
9	**3228**	**-5636**	**1772**	**-7956**	**AIRBAG YYYY**
10	5472	-7864	2244	-2228	currentState = 1
11	4224	-7692	-1248	172	currentState = 1
12	1224	-7460	-3000	232	currentState = 1
13	1576	-9996	352	-2536	currentState = 1
14	4216	-7244	2640	2752	currentState = 1
15	-312	-7980	-4528	-736	currentState = 1
16	588	-7596	900	384	currentState = 1
17	-1784	-9760	-2372	-2164	currentState = 1
18	1828	-6260	3612	3500	currentState = 1
19	3328	-9708	1500	-3448	currentState = 1
20	4076	-10440	748	-732	currentState = 1
21	868	-6672	-3208	3768	currentState = 1
22	1604	-5348	736	1324	currentState = 1
23	**3068**	**-13084**	**1464**	**-7736**	**AIRBAG YYYY**
24	1416	-7636	-1652	5448	currentState = 1
25	1892	-7704	476	-68	currentState = 1
26	2080	-9688	188	-1984	currentState = 1
27	2092	-8548	12	1140	currentState = 1
28	416	-7796	-1676	752	currentState = 1
29	1188	-8948	772	-1152	currentState = 1
30	2516	-7524	1328	1424	currentState = 1
31	-2708	-4544	-5224	2980	currentState = 1
32	3068	-7092	5776	-2548	currentState = 1

The testing shows that the 5000 difference over x and y was not proper for street calibration as it can trigger when the motorcycle runs over roadblocks such as humps and steep roads. The sensors were recalibrated with the x difference set at 5000 while the difference was set at 8000.

Table 2
Recalibration

LINE	AXIS		DIFFERENCE		STATUS
	x	y	x	y	
1	-4144	-2500			currentState = 1
2	-3648	-2568	496	-68	currentState = 1
3	-4540	-180	-892	2388	currentState = 1
4	-3684	-1564	856	-1384	currentState = 1
5	-3496	-1512	188	52	currentState = 1
6	-5364	-3032	-1868	-1520	currentState = 1
7	-4780	-548	584	2484	currentState = 1
8	-6064	-1008	-1284	-460	currentState = 1
9	-5556	-160	508	848	currentState = 1
10	-6440	-228	-884	-68	currentState = 1
11	-6568	1428	-128	1656	currentState = 1
12	-6332	16	236	-1412	currentState = 1
13	-4784	452	1548	436	currentState = 1
14	-3996	20	788	-432	currentState = 1
15	-4392	-828	-396	-848	currentState = 1
16	-4096	-644	296	184	currentState = 1

Recalibrating the sensors show that it works better as the airbag did not activate when driving in normal conditions and even when there are road blockages. The system worked well and can be tested for its efficiency.

Fall Detection Head-on Collisions

These types of accidents typically occur when a car crosses the center line and hits an oncoming motorcycle. Motorcycle riders caught in this type of accident are thrown in front of the motorcycle because of the obstruction in front due to inertia. A driver can lose control in this manner because of impairment, such as drunk driving, drugged driving, or fatigued/drowsy driving. In many cases, a driver who is distracted by texting or talking on a cell phone can cross the centerline and cause a head-on collision.

Table 3
Summary of Trials

TRIAL	FALL/COLLISION DETECTION TIME	FALL/COLLISION DETECTION
1	460 ms	Success
2	400 ms	Success
3	370 ms	Success
4	350 ms	Success
5	460 ms	Success
6	400 ms	Success
7	1100 ms	Failed
8	700 ms	Success
9	300 ms	Success
10	290 ms	Success
11	340 ms	Success
12	350 ms	Success
13	450 ms	Success
14	400 ms	Success
15	460 ms	Success
16	1200 ms	Failed
17	370 ms	Success
18	420 ms	Success
19	300 ms	Success
20	600 ms	Success
21	280 ms	Success
22	430 ms	Success
23	350 ms	Success
24	450 ms	Success
25	650 ms	Success
26	1100 ms	Failed
27	300 ms	Success
28	400 ms	Success
29	550 ms	Success
30	500 ms	Success

Average Fall Detection Time = 419.33 ms

Table 6 shows how long it takes to detect a fall or collision. It can be seen that three of our trials for a head-on collision failed to detect the client's fall while wearing the jacket. The accuracy is based on the standard "Restraint Device: Supplemental Restraint System (SRS) Airbag- Toyota-global.com, the time it takes for the airbag to finish deploying is approximately 1 second." As a result, if the time

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it takes for the Sensor to detect the fall or collision was longer than 1 second, the trial was considered invalid.

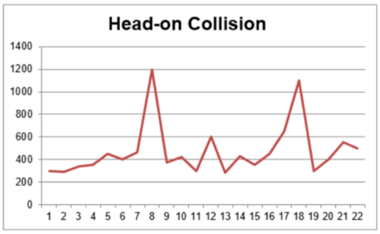

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Figure 4. Summary of the trials conducted for Head-on Critical Event Detection

Rear-end Critical Event

Rear-end accidents occur because another vehicle mostly larger is following a motorcycle too closely, or “tailgating” the motorcycle. Because of their lighter weight, motorcycles stop more quickly than larger vehicles

Table 4
Critical Event Detection Testing

TRIAL	FALL/COLLISION DETECTION TIME	FALL/COLLISION DETECTION
1	700 ms	Success
2	270 ms	Success
3	240 ms	Success
4	400 ms	Success
5	360 ms	Success
6	1200 ms	Failure
7	230 ms	Success

The table shows the time it takes to detect a fall or collision. It can be seen that two of our trials for Rear-End collision have failed to detect the fall of the client that is wearing the jacket. The accuracy is based on the standard "Restraint Device: Supplemental Restraint System (SRS) Airbag- Toyota-global.com,

The time it takes for the airbag to finish deploying is approximately 1 second. "Therefore, if the time it takes for the sensor to detect the fall or collision was longer than 1 second, the trial was considered failed."

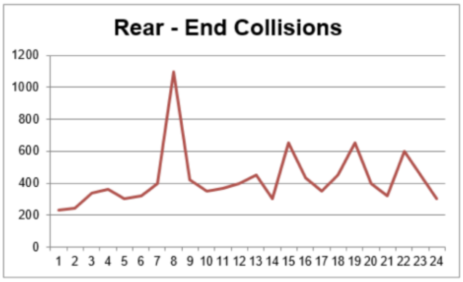

Figure 5. Summary of the trials conducted for Rear-End Fall/Critical Event Detection

Table 5
Left Side Fall Collision

TRIAL	FALL/COLLISION DETECTION TIME	FALL/COLLISION DETECTION
1	230 ms	Success
2	470 ms	Success
3	280 ms	Success
4	340 ms	Success
5	290 ms	Success
6	220 ms	Success
7	260 ms	Success
8	240 ms	Success
9	290 ms	Success
10	300 ms	Success
11	420 ms	Success
12	500 ms	Success
13	1100 ms	Failure
14	300 ms	Success
15	600 ms	Success
16	450 ms	Success
17	350 ms	Success
18	1100 ms	Failure
19	400 ms	Success
20	300 ms	Success
21	650 ms	Success
22	500 ms	Success
23	320 ms	Success
24	450 ms	Success
25	600 ms	Success
26	540 ms	Success
27	300 ms	Success
28	450 ms	Success
29	400 ms	Success
30	350 ms	Success

The table shows the time it takes to detect a fall or collision. It can be seen that in two of our trials, the left-side collision failed to detect the fall of the client who was wearing the jacket. The accuracy is based on the standard "Restraint Device: Supplemental Restraint System (SRS) Airbag-Toyota-global.com, The time it takes for the airbag to finish deploying is approximately 1 second." Therefore, if the time it takes for the sensor to detect the fall or collision was more than 1 second, the trial was considered failed.

Sample of Results of Choosing the Nearest Hospital

Name of Hospital	Latitude	Longitude	Distance (Km)
Chinese General and Medical Hospital	**14.625933**	**120.988059**	**1.19**
Jose R. Reyes Memorial Medical Center	14.614239	120.981956	1.89
Del Los Santos Medical Center	14.620029	121.017568	4.39
University of Santo Thomas Hospital	14.611493	120.990161	2.50
Manila Doctors Hospital	14.581955	120.982954	5.46

CONCLUSION

This research provides preliminary development of intelligent critical event detection and information to medical rescue teams within seconds of an accident, which can be very helpful and lifesaving. It has the potential to significantly reduce the response time of medical teams while also saving victims' lives. This system detects an accident using accelerometer and vibration sensor data and sends an alert message via GSM along with the location via GPS. Using GPS, the alert message is sent to the nearest medical center. A "cancel" option is also provided in the application, which is active for 10 seconds only in the event of false alarms or if the user does not require immediate assistance. It can be canceled through the user's phone. Accident detection and alert systems are very important these days, and this project aims to develop a low-cost solution for the benefit of society.

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