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RESEARCH ARTICLE OPEN ACCESS

Design and Development of Automated Personal Protective Equipment for Efficient Building Construction Safety Implementation

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Abstract:

Construction Safety is one of the major factors that affects building construction efficiency and company's integrity. Philippine government established Occupational Safety and Health Center (OSHC) under the Department of Labor and Employment to handle matters regarding safety and health at work. Standards for occupational safety and health in the construction industry are enumerated in Department Order No. 13 under Occupational Safety and Health Standards in order to provide guidelines that ensures worker safety. Written in the guidelines are the rules that construction workers must be properly oriented, instructed and trained by the safety officers and construction project manager to assure the safety of handling equipment and tools. Employees must also have personal protective equipment as protection from hazardous works in the construction. Safety Officers are required depending on the construction personnel number.

But despite the policies and standards, these guidelines are not being strictly implemented in reality. Construction works still have a high amount of accident rates and severity rate higher than other industries combined.Most common causes of injuries are Stepping on, striking against or struck by objects, falling objects.This study will introduce possible upgrades to reinforce our old methods of construction safety and ensure better implementation and communication of construction workers and safety personnel on-site using PPE equipped with Internet-of-Things Technology.This will then provide automations like real-time reporting and monitoring or fall and struck-by accidents, body and environment temperature and even hazard avoidance. Aiming to lessen accident rates and provide a safer construction workplace.

Keywords **—Automation, Arduino, PPE, Sensors, Construction Safety, Accidents**

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I. INTRODUCTION

The Philippines employs more than 2 million construction workers. Due to the nature of this industry, the workers are constantly exposed to dangerous environments and are at high risks for accidents and even death. Philippine Construction have safety standards and guidelines provided by the government and we can often appreciate in big-scale construction projects and companies but not that implemented in small-scale projects.

In my few years of experience in supervising building construction, Safety is the most neglected factor in the project. Workers often follow rules in the start but when not regularly implemented, they go back to ignoring it. That is why sometimes we tend to come up with post-solution of punishments; Examples of this are suspension, fees and termination.

As a Civil engineer with an interest with the technology and possibilities of Internet-of-Things, this study will be used as an introduction to the

wide range of aspects the Philippine construction can be improved.

What if we could prevent the problem instead of just giving punishments? What if it is possible to monitor them real-time?

II. OBJECTIVES

This study focuses on introducing automation to reinforce our construction safety methods and implementation in a way that accidental rates will be reduced.

The specific objectives aim to:

- Lessen accidents involving construction hazards using accelerator sensor attached on PPE
- Speed up rescue process using automated reporting
- Implementation of Internet-of-Things in Construction
- Introduction to wearable automated PPE

III. METHODOLOGY

Prototypes for the Automated PPE will be made using standard construction PPE equipped with sensor modules attached to the microcomputer Arduino. It is then programmed and tested for data collection, monitoring and reporting.

Major functions for certain types of accidents will be recorded as well as the wearable tech's reaction time. Additional design upgrades will be implemented for every possible development.

A. Construction of Prototype Automated PPE and Hazard Bug

The Automated PPE setup will focus on the most common accident on construction site which is "falling"; the sensor fitted is the acceleration sensor to detect both fall and impact on the wearer. Heat sensor is also provided for the setup to monitor the body temperature of the wearer. All these inputs will be reported via test message using the attached GSM Board.

FIG. I
PROTOTYPE TESTING OF AUTOMATED HARDHAT SETUP

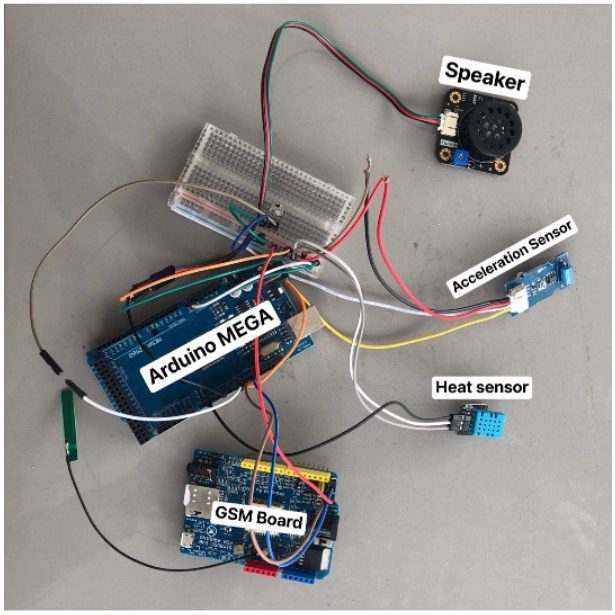
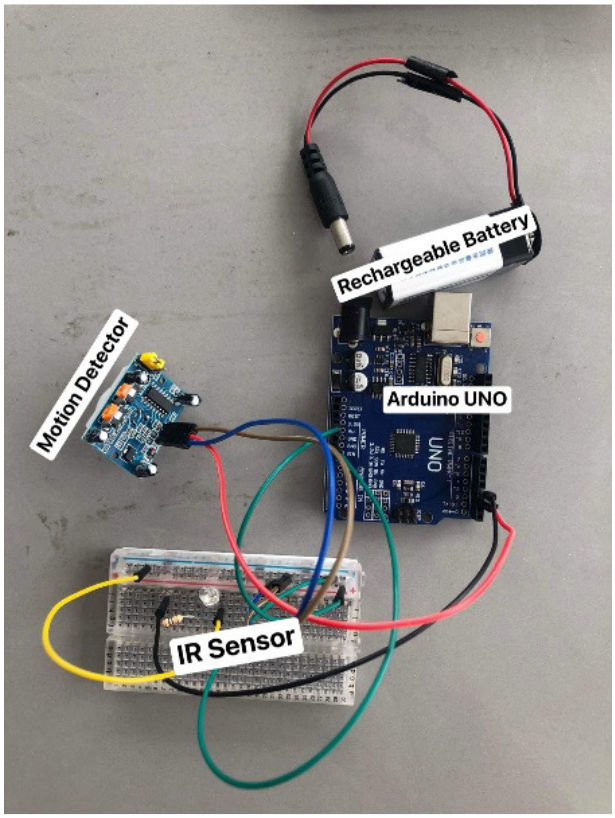


FIG. III
PROTOTYPE TESTING OF HAZARD BUG SETUP



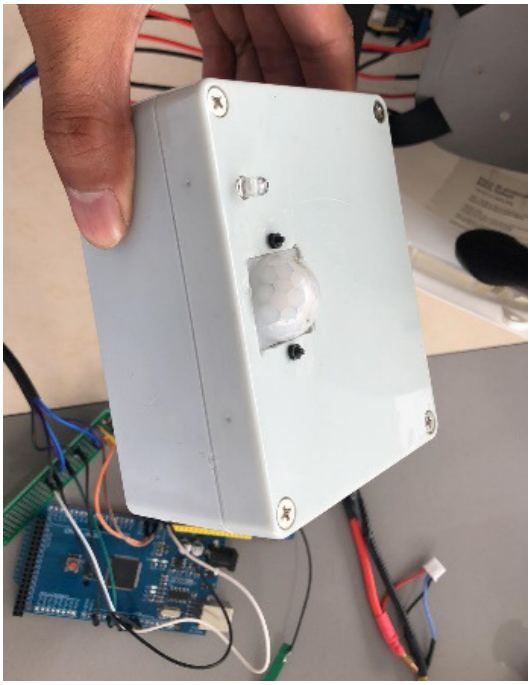
B. *Assembly of setup for Hardhat, Hazard Bug and Vest*

Assembling the setup starts with the Hardhat which will hold most of the sensors needed for the project. IR receiver is placed on top of the hat to provide wide clearance of receiving signal from the *Hazard Bug*. Mini Speaker is placed inside the hardhat on the right side to provide better response to alarm. Heat sensor is then placed inside the hardhat on the level of the wearer's forehead to provide constant scanning of the worker's body temperature. All cable lines are bundled and fix into one single cord that will run on the back side of the hard hat and placed perfectly so it won't provide discomfort to the wearer.

FIG. IIIII
HARDHAT WITH INSTALLED SENSORS

The *Hazard Bug* is the external part of the setup; housing a motion sensor to detect incoming workers. IR Transmitter are placed beside the motion sensor to provide wide clearance of signal when transmitting. All will be processed using Arduino Uno and will be powered by 12V Li-Ion Battery. *Hazard Bugs* will be regularly charged every 3rd day and are strategically placed near hazard prone areas.

FIG. IVV
HAZARD BUG SETUP



Hardhat setup will be connected to the worker's vest where the Arduino Mega are placed. It will also hold the GSM Board for sending SMS and all will be powered by a 2 cell 7.4V Li-PO Battery which are charged every end of the work hours.

FIG. V
AUTOMATED PPE FEATURES INFOGRAPHIC

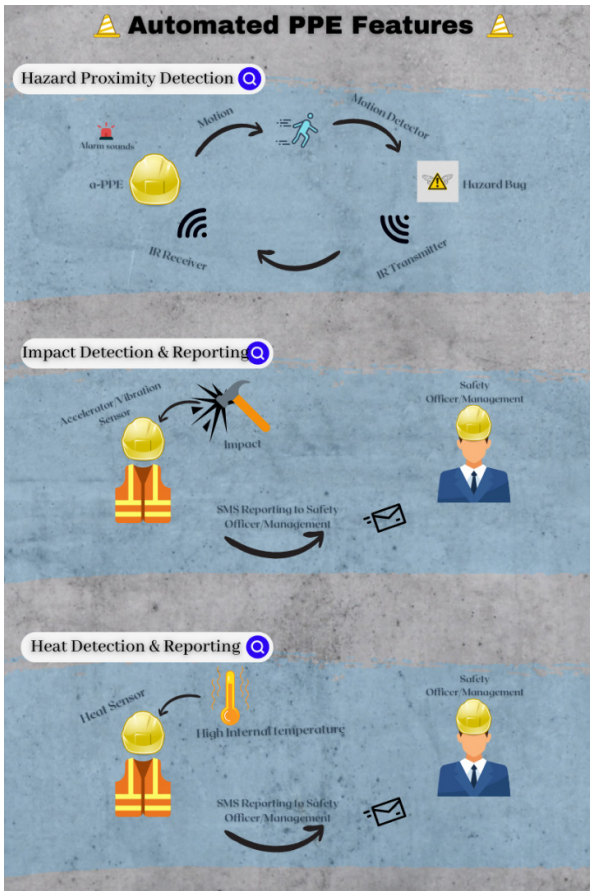


FIG. VI
ARDUINO IDE CODE INTERFACE

FULLSEQUENCE

```
#include "SPI.h"
#include <IRremote.h>
#include "DHT.h"
#define DHTTYPE DHT11
#include <SoftwareSerial.h>
#define DHTPIN 2


DHT dht(DHTPIN, DHTTYPE);

SoftwareSerial SIM800C(10,9);

int receiverpin = 7;
int vs =8;
int buzzer = 5;
int Buzzer;

IRrecv irrecv(receiverpin);
decode_results results;

void setup() {
  SIM800C.begin(9600);
  dht.begin();
  pinMode(receiverpin, INPUT);
  pinMode(vs, INPUT);
  pinMode(buzzer,OUTPUT);
  Serial.begin(9600);
  irrecv.enableIRIn();
  beep(50);
  beep(50);
  beep(50);
  Serial.begin(9600);
  delay(1000);
}
```

```
void loop() {
  irReceive();
  //readTemp();
  //vibrationSensor();
  if(Buzzer==1){
        int i=0;
    for(i=0; i<=5; i++){
    beep(200);
    }
    Buzzer=0;
    results.value=0;
  }
}
void beep(unsigned char delayms){
  analogWrite(5, 20);
  delay(delayms);
  analogWrite(5, 0);
  delay(delayms);
}

void vibrationSensor(){
  long measurement =vibration();
  measurement/100;
  if (measurement > 30000){

    SendVS();
  }
  delay(5000);
}

long vibration(){
  long measurement=pulseIn (vs, HIGH);  //wait for the pin to
  return measurement;
}
```

C. Programming of Code for the Arduino micro-computer

Next to assembling of parts is then focused on programming of code for the setup to work and function as needed. Individual parts and sensor are first coded and tested to check the condition and upgrade to better parts if necessary. 3 main features of the project are then assembled and tested with code separately until we reached a good working condition.

Wrapping up every feature took combining all parts and programming the code; Both the automated PPE setup and the Hazard Bug. Debugging and testing took a lot of trial and error until it worked but still needs future cleaning up.

FIG. VII
SCHEMATICS OF AUTOMATED PPE

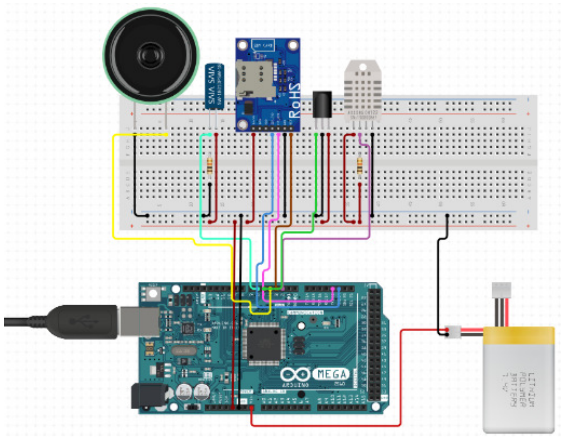


FIG. VIII
SCHEMATICS OF HAZARD BUG

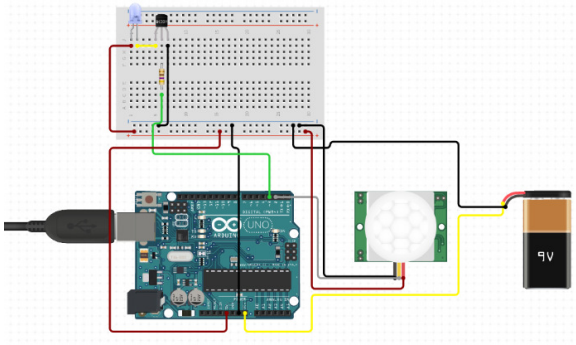


FIG. IX
ANNUAL ACCIDENT REPORT TABLE

Project Name: **Construction of 5 Storey Multi-Purpose Building**
Project Location: **Brgy. Pinagsama Phase 1, Taguig City**
Contractor: **C.B. Garay Builders Inc.**

ANNUAL ACCIDE

Worker Accidents without aPPE:	11
Worker Accidents with aPPE:	3

Month	Week	Day	Date	Injury	Property damage	Accident type
January	1	M	1 03 2022			fall from height
		T				
		W				
		TH				
		F	1 07 2022			strucked-by
		S				
	2	M				
		T				
		W				
		TH				
		F	01/14/22			Slipped
		S				
	3	M				
		T				
		W				
		TH				
		F				
		S				
	4	M				
		T				
		W				
		TH				
		F	1/28/22			fall from height
		S				
February	1	M				
		T				
		W				
		TH				
		F				
		S				
	2	M				
		T	2 08 2022			Slipped
		W				
		TH	2 10 2022			Slipped
		F				
		S				
	3	M				
		T				
		W				
		TH				
		F				
		S				
	4	M				
		T				
		W				
		TH				
		F				
		S				
March	1	M	3 07 2022			fall from height
		T	3 08 2022			strucked-by
		W				
		TH				
		F				
		S				
	2	M				
		T				
		W				
		TH				
		F	3/18/22			strucked-by
		S				
	3	M				
		T				
		W				
		TH				
		F				
		S				
	4	M				
		T				
		W				
		TH				
		F				
		S				

Month	Week	Day	Date	Injury	Property damage	Accident type
April	1	M	4 04 2022			strucked-by
		T				
		W	4 06 2022			strucked-by
		TH				
		F				
		S				
	2	M				
		T				
		W				
		TH				
		F				
		S				
	3	M				
		T				
		W				
		TH				
		F				
		S				
	4	M				
		T				
		W				
		TH				
		F				
		S				
May	1	M				
		T	5 03 2022			Slipped
		W				
		TH				
		F				
		S				
	2	M				
		T				
		W				
		TH				
		F				
		S				
	3	M				
		T				
		W				
		TH				
		F				
		S				
	4	M				
		T				
		W				
		TH				
		F				
		S				
June	1	M				
		T				
		W				
		TH				
		F				
		S				
	2	M				
		T				
		W				
		TH				
		F				
		S				
	3	M				
		T				
		W				
		TH				
		F				
		S				
	4	M				
		T				
		W				
		TH				
		F				
		S				

D. *Accident response and Reports comparison*

With the automated PPE prototype working, candidate for the experiment is then chosen and by the records of our safety officer, the worker with the most offense and accident reports in our construction site has been chosen and with his approval. Data from January to last week of April are then tabulated because this will be the baseline of the worker. Testing duration from 1st week of May up to last week of October are then recorded with him wearing the automated PPE every day at work

NT REPORT: 2022

Month	Week	Day	Date	Injury	Property damage	Accident type
July	1	M				
		T				
		W				
		TH				
		F				
		S				
	2	M				
		T				
		W				
		TH				
		F				
		S				
	3	M				
		T				
		W				
		TH				
		F				
		S				
	4	M				
		T				
		W				
		TH				
		F				
		S				
August	1	M				
		T				
		W				
		TH				
		F				
		S				
	2	M				
		T				
		W				
		TH				
		F				
		S				
	3	M				
		T				
		W				
		TH				
		F				
		S				
	4	M				
		T				
		W				
		TH				
		F				
		S				
September	1	M				
		T	9 06 2022			fall from height
		W				
		TH				
		F				
		S				
	2	M				
		T				
		W				
		TH				
		F				
		S				
	3	M				
		T				
		W				
		TH				
		F				
		S				
	4	M				
		T				
		W				
		TH				
		F				
		S				

Month	Week	Day	Date	Injury	Property damage	Accident type
October	1	M				
		T				
		W				
		TH				
		F				
		S				
	2	M				
		T				
		W				
		TH				
		F	10/14/22			Slipped
		S				
	3	M				
		T				
		W				
		TH				
		F				
		S				
	4	M				
		T				
		W				
		TH				
		F				
		S				

After 6 months there has been a significant result of only 3 accident reports compared to 11 accident reports before the use of the new PPE.

IV. CONCLUSIONS

This research aims to improve the construction safety system by introducing Internet-of-Things in construction industry and by implementing it using wearables for the PPE. With this, it aims to lessen common accidents and speed up rescue processes.

While the research and testing of the automated PPE prototype turns out to be helpful by decreasing significant amount of accident for the worker and also greatly provide a faster and almost real time response for the safety officer and management, it also provides new insight into adding features for different situations that are not focused on the setup.

The project did succeed of introducing and opening the doors of construction industry for more automation using Internet-of-Things and wearable technology for further advancement of not only the construction safety side but the whole project management itself. To better understand and develop the implications of these results, futures research and studies could address wide varieties of sensor and programming for further improvement of features and uses of automated Personal Protective Equipment.

This research really did hope to close the gap between the uses of technology and common construction practices that requires improvements.

ACKNOWLEDGMENT

This endeavor would not have been possible without my Advisors and Professors for the Knowledge and expertise they shared.

I am also grateful to my classmates for providing inspiration. Thanks, should also go to my research assistants for their advice and suggestions.

Lastly, I would be remiss in not mentioning my partner for her belief in me which kept me going forward.

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