Snake-Search Bot: Design of Autonomous Search Robot for SAR Aid Process of Earthquake Victims

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Abstract— **This paper displays the description, design, and features of the Snake-Search Bot. A search robot is a robotic device used to locate people in danger or distress after a natural disaster —in this case an earthquake has occurred. This is an autonomous, low-cost, snake-like robot intended to go into the debris caused by earthquakes to identify human bodies trapped beneath, gather the data, and send the signals to a rescue team. This robot will use sensors for human life identification; it will then send alerts to the software for the rescue team to get updates on what is happening between the debris. The robot will also project a mapping system (SLAM) to facilitate the rescue process. This project is targeted at Latin-American countries, especially those most prone to earthquakes such as Mexico, Guatemala, Chile, and Peru. The robot was programmed with python on a Raspberry Pi and includes the following cameras and sensors: thermal camera, night vision camera, TF Luna LiDAR, an inertial sensor, encoder motors, seed MRH60, microphone and speaker.**

Keywords—Raspberry Pi, earthquakes, identify, SLAM, human rescue.

I. INTRODUCTION

The catastrophic earthquake in Haiti in 2010, devastating losses from the earthquakes of 2016 Ecuador, 2010 Chile, and 2007 Peru, serve as reminders of how disaster-prone some communities are. The poor are also adversely affected by earthquakes as they have the fewest resources to deal with emergencies. A 2020 United Nations survey ranked Latin America and the Caribbean as the second region most vulnerable to natural disasters. The same estimate states that between 2000 and 2020, there were 75 earthquakes in the area, resulting in 226,000 fatalities and 339,000 injuries. Significantly, the region of Central America and along the western coast of South America are among the most seismically active places in the world. This is because they are situated in the "Ring of Fire," an area for its numerous volcanoes and ongoing tectonic movements [1]. Just recently, on February 6th of 2023, a 7.8 magnitude earthquake, followed by other aftershocks and strong tremors stroke Turkey and northwest Syria. The number of fatalities has surpassed 50,000 and there were over 87,000 injured. According to reports, at least 47,000 buildings have been demolished or damaged [2]. Thus, the lack of information about where the survivors are, and their state of health, made us think about an alternative of how more people

can get saved between the same gap of a lifetime without risking more lives.

Unfortunately, many people die or are injured when poorly constructed buildings collapse in earthquakes, due to the debris, lack of oxygen, and resources however, modern robotics technology gives us nowadays the ability to create algorithms for automated driving as well as collect samples of various variables, data, and signals from the environment using sensors like thermal cameras, gas sensors, LiDAR sensors, etc. Therefore, with the help of an autonomous user-driving robot we can get to know where the human bodies are, and what their condition is— stable, injured, or dead —so the rescue team can know where to go and where to get first as some survivors need more help than others. They can know, as well, what is the best path to take provided by the data gathered by the robot through the mapping it made through Synchronous Localization and Mapping (SLAM).

With the use of SLAM, we can now create autonomous robots that can perform tasks that can be more challenging, dangerous and time consuming for humans, like locating trapped earthquake victims and working out a way how to get them out safely. Using this method shortens the execution period for searching, saves more lives because more information can be obtained in less time, and boosts productivity [3].

II. NEED STATEMENT

There is a lack of time to rescue earthquake survivors as survivors have an estimated lifetime of up to a week on average, or even more, but it also depends on their injuries and weather conditions. Rescue team members risk their lives exponentially when entering an area affected by a natural disaster; as well as many of the survivors who can be injured, suffocating, and lacking most vital resources such as water and food. For this reason, this period of one week must be used in the most efficient and effective way. In this sense, Snake-Search Bot searches and locates as many survivors as possible in the most optimized way. This robot can verify the condition of those affected, creating a map showing the location of the survivors based on the route taken by the robot, as well as pointing to indicate who needs help more urgently and where, so that the survivor can receive priority help. It is also capable of creating an optimal path for the rescue team to follow. Thus, the rescue team can go directly to the survivors without wasting time

locating people, helping the team by locating more survivors in the same period and without risking more lives in the process.

A. Social Impact

Many people find themselves trapped in the middle of debris after a building collapse on top of them because of an earthquake. For instance, the Turkey and Syria earthquake that occurred on February third. Many survivors get injured by the collapse and are not able to get through the debris and have a lack of resources such as food, oxygen, and water which makes the situation even worse because they have limited time to get rescued before those resources run out and injuries get worse. Snake-Search Bot will autonomously or user driver-controlled sneak into the debris, look for the survivors, and tell where they are located on the map.

B. Health Impact

Many of the survivors in an earthquake get injured after the collapse of buildings; of those injured many die as there is not enough time to get rescued due to the lack of information on where the survivors are and what is their condition. Snake-Search Bot will obtain information about the survivors as their heartbeat, breathing rate, and if possible, the controller will ask for their condition. All of this information will be shared with the rescue team; therefore, they can precisely know where the survivors are and what their condition is. The rescue team can prioritize survivors with more serious injuries that require special attention.

C. Societal Impact

Buildings collapse due to the lack of resources for providing safely engineered buildings and flaws that are always present. Hence, the areas that suffer the most damage from earthquakes are those from least developed countries. This is why countries such as Haiti or Turkey are more prone to people dying from earthquakes than other countries with better safety measurements for the construction of buildings.

This is something we took into consideration for the design of the robot. We understand most SAR—search and rescue—are expensive. Subsequently, the robot will follow a simple design making it affordable for countries with lower resources, but perfectly effective to develop the search mission.

The Snake-Search Bot will reduce the cost and increase reliability, saving many trapped victims subsequently.

III. MARKET SEARCH

The cost of similar prototypes in the market ranges from \$50,000 to \$150,000 versus \$1,000 for an aerial drone. Consequently, there is no cost-benefit, for a country in needs especially after having suffered a natural disaster[4]. Also, most of these robots do not have all the necessary sensors to be truly useful robot that has the skills required to save the survivors and to support the rescue team. Considering the target area and the necessary features, Snake-Search Bot offers a specific solution for this situation, where the multi-sensor robot will be able to perform several tasks at the same time , in order to finish its mission successfully. In this case, saving as many people as possible with a low-accessible approximate cost of USD \$750.

IV. COMPONENTS AND BUDGET

The components and budgeting for building the current design of the Snake-Search Bot are listed in Table 1. A Raspberry pi Fan and a 64 GB SD card.

TABLE 1
COMPONENT PRICE LIST

Component	Qty	Subtotal USD
Raspberry Pi 4	1	142
Raspberry Pi 4 Aluminum Heatsink Fan	1	10.99
SanDisk 64GB Preloaded Raspberry Pi SD card	1	25
Inertial sensor: Adafruit 9- IMU BNO055	1	34
Thermal Camera- Adafruit 3538 AMG8833	1	49
DOROTHEA Raspberry Pi Mini Camera	1	6.99
MR60FDA160GHz mm Wave Radar Sensor	1	43.99
Gas sensor:MQ-2	1	6.30
TF Luna	1	25.98
180 servo motor	1	7.5
Adafruit 16-Channel 12-bit PWM/Servo Shield	1	17.50
H-Bridges: L298N H-bridge Motor Controller	4	40
DC Motors	8	152
1kg PLC	4	92
Total		653.25

Snake-Search Bot has an approximate worth of USD 750, so far. This total includes the components and parts price listed above, manufacturing prices, and the powertrain assembly.

V. AUDIENCE

Snake-Search Bot is targeted at Latin-America countries and other low-resource, especially those most prone to earthquakes such as Mexico, Guatemala, Chile, and Peru, and other low-resource countries, such as Turkey and Syria. More than a quarter of the world's earthquakes of magnitude 8.0 or greater have occurred there since 2000. Once a disaster strikes, it is necessary for the country to have the ability to recover as soon as possible in order to avoid further problems and to recover the maximum possible population. For this reason, governments, communities, and organizations from these countries can highly benefit from the operation and implementation of this bot [5].

VI. ENGINEERING REQUIREMENTS

Snake-Search Bot must meet the following requirements to meet its purpose of getting through unknown and hard places to

reach of earthquake damages and finding the victims, providing a map along the way for a rescue team to obtain and know the localization of people and the safest route to ensure saving as many lives as possible:

Compact: The robot must have small enough measurements for it to be able to fit into the cracks of the collapsed buildings and be able to navigate around the small spaces.

Ability to avoid obstacles: The robot will be able to avoid obstacles and find the best path as it has a LiDAR sensor that can detect objects and its proximity to them.

Strength: The robot must have a strong enough structure to travel in and out through various collapsed buildings. The mechanical design should be resistant enough to carry itself and protect mainly the electrical components within.

Easily Deployable: The whole system should be easily transferred and stationed from place to place effortlessly, to ensure fast and optimal search.
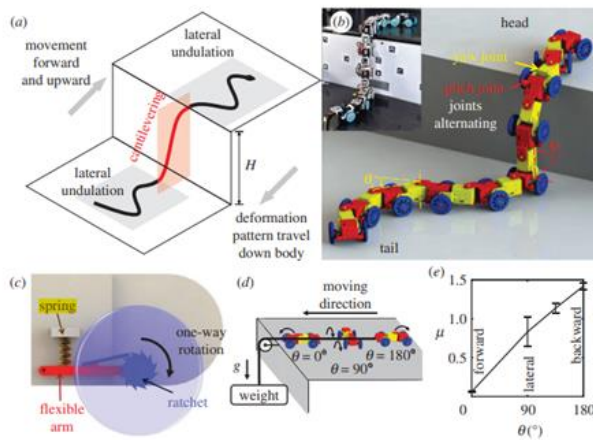

Fig. 1 Followed Mechanism [6]

Design: The robot should also be flexible and able to lift itself through obstacles to slither into the building. For this reason, we followed the mechanism shown in [6] where a suspension system, shown in Fig. 1, with a spring (shown brown) and a flexible arm connects the wheel to the body segment to add mechanical flexibility (shown in red). According to Q. Fu and C. Li, by adding a light block, the same length as the spring's natural length, oscillation was disabled in stiff robot tests. In other words, when the robot lifts itself upon steps or other obstacles, it will not fall sideways.

Autonomous: One of the major objectives of mobile robotics is to program the robots with the required autonomy for it to be able to navigate through unknown areas, providing information about the setting without the human aid. However, this robot design will have two modes, user control and autonomous control where it is able to mission on its own but is recommended to be supervised to ensure the most effective results. The robot will be able to provide mapping, decide whether something is a person, and be able to get in and out of the building by itself.

SLAM: With simultaneous localization and mapping (SLAM), it is possible to map a robot's intended path and determine its current location, even in the presence of solid components (landmarks) found in actual surroundings that depict the robot changing its path while marching [7]. The Snake-Search Bot should be able to provide localization and mapping of the building it is placed during its mission. As the robot navigates within the earthquake debris, it will be providing a map alongside, and be able to tell where in that map it identified a human body. For this design, the robot will be generating a 2D map. This way, the rescue team will know which path to take and where are humans trapped inside.

VII. DESIGN CONCEPT

The initial sketch for the overall design is illustrated in Fig. 2. The initial sketch delivered a better and more solid visualization of how the robot will appear. Consequently, the sketch provided a clearer idea before starting the CAD design, served as starter point and helped to analyze the position of each component to optimize space distribution.
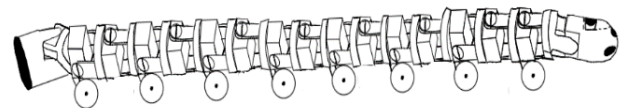

Fig. 2 Rough sketch of Snake-Search Bot main body

The robot was initially designed with 16 motors with built-in encoders, eight on each side, as shown previously in Figure 2. However, having that many motors, would drive too much power and damage the hardware and performance. For this reason, we decided to reduce the number of motors to eight encoder motors in total, four on each side. The modified sketch prior to the CAD design is shown in Figure 3.
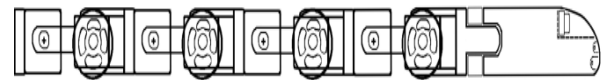

Fig. 3 Second sketch design of Search-Snake Bot

The Snake-Search Bot functions as a Search and Rescue (SAR) robot in charge of the search process to aid a rescue team find victims of earthquake damages. First, the robot will figure out obstacles inside of earthquake collapsed buildings and figure out a route to navigate the scene carefully. At the same time, the robot will be generating a 2D map of its localization and path taken to navigate the scene. Therefore, this is a robot implementing SLAM, and within that plot, it will be able to identify where are humans located using the thermal camera, respiratory heartbeat detection sensor, and microphone. An additional feature this robot will have been using a gas sensor to identity gas leaks and sending signal alerts to the rescue team so they can be aware of that. All this information will be gathered by the robot and print the information to a monitor where the rescue team will be at. Then the robot will be able to get out of the building using the same route it took to get inside. For efficiency means, the robot will be broadcasting a live

video for the team to see and ensure better performance and optimal results.

A. Mechanical Design

The most important mechanical characteristics of the Snake-Search Bot are the length, the diameter, the number of modules, and the resistance, which are crucial for SAR operations. Taking into consideration the necessary mechanical and operational measures, the CAD was designed in order to achieve the objective. Therefore, the Snake-Search Bot must move through a challenging environment after a natural disaster and dodge as many obstacles as possible. For this reason, the proper length and size will allow it to access and move within that environment. Also, the inclusion of the necessary sensors which will be distributed along the body and their measurements were taken into consideration respectively for its operational potential. The body also provides with the necessary protection for the electrical components to keep them from damaging or wearing out.
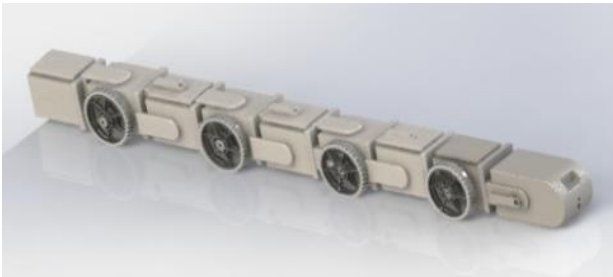

Fig. 4. Isometric View of Snake-Search Bot

As shown in Fig. 4 the model consists of multiple wagons joined together to create propulsion on its own in a spatial environment. The first wagon (head) will include the Raspberry Pi, the Thermal Camera, DOROTHEA Raspberry Pi Mini Camera, and the TF-Luna LiDAR sensor. In total, the robot measures 1100 millimeters long, 80 millimeters tall, 10 millimeters wide.

Fig 5. Side View Snake Bot

1) *Wheels:* We chose active wheels for the propulsive Snake-Search Bot due to mechanical robustness, simplicity, and increased the locomotion capability by serializing two active wheels on each wagon in between along the length of the body, making four wagons and eight wheels in total. The wheel type selected for the model is high grip wheels because they provide superior traction for robot movement. Additionally, they feature an aggressive tread pattern that provides maximum

transfer of power on the ground. The wheels are up to the challenge for high-impact and high-speed applications. In this case, these are the appropriate and useful ones to move in complicated environments. Each wheel has a diameter of 90 millimeters.

Fig 6. Close up Look of Wheel

2) *Spring system:* We decided to mount a spring between the body and the wheel which opposite to a fully rigid Snake-Search Bot, it will be able to achieve mechanical compliance, to maintain a good contact to the surface when climbing any stair or obstacle, and it will be able to traverse large steps without moving unsteadily as it climbs.

Fig 7. Spring Wheel

B. Electrical Design

The Snake-Search Bot consists of a thermal camera, day and night vision camera, inertial sensor-Luna LiDAR, SEED 60 MHz (micro-motion sensor), and 8 encoder DC motors, connected to a Raspberry Pi 4+ as shown in the diagram in Fig. 8. Following the advice of the Robotics Institute from Carnegie Mellon University, we decided to include microphones and speaker sensors, which they were missing and were widely requested [8]. This implementation provides a mean of communication between the victims and the rescue team outside the scene. For instance, if someone is speaking or asking for help, it would be easier to identify and record that data this way. Including a speaker is an effective way to let victims trapped know that search and help is on the way. A speaker and microphone provide an extra means of communication between trapped victims and the rescue team through the Snake-Search Bot.

For simplicity and clearer visualization, the encoded motors are shown separately in Fig. 9.
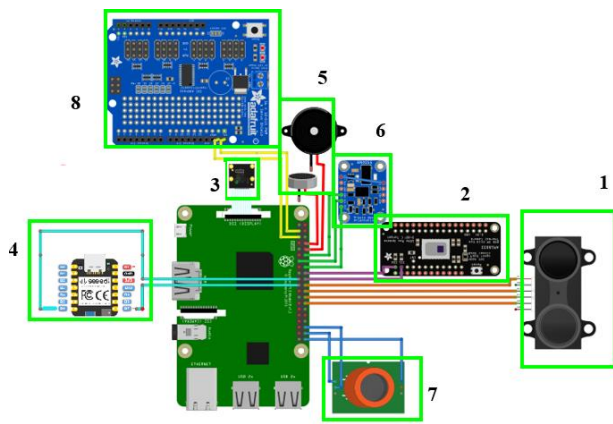
Fig. 8. Electrical Outline

1) TF-Luna LiDAR sensor: The LiDAR sensor is connected as shown in Fig. 8.1, where the SCL and SDA pins are connected to the GIPO pins of the Raspberry pi 8 and 7, respectively. The Vin and Ground are connected accordingly to the corresponding expected pins. This sensor is the one responsible to provide localization and trace mapping back to the software of the Raspberry Pi. However, since this is 1D LiDAR, it will need the aid of an electromechanical system to produce a 2D map. Since the Snake-Search Bot will be slithering into the scene, it will provide with the necessary displacement to output a 2D map.

2) Thermal camera module: The thermal camera module AMG8833 is shown in Fig 8.2, is connected from its SDA and SCL pins to the GIPO pins 22 and 24 of the Pi. This sensor identifies differences in temperature, and since the human body is approximately 37ºC, it will show the difference between that thermal change and the surroundings.

3) Raspberry Pi camera: The DOROTHEA mini camera works in lighted and dark surroundings well enough for it to project imaging of the scene where the robot will be. This allows the rescue team to have a clearer idea of the picture inside buildings. The camera will be connected to the Raspberry Pi CSI camera connectors as shown in Fig. 8.3

4) Respiratory Heartbeat Detection sensor (MR60FDA1): This sensor is connected, as shown in Fig. 8.4, from its D7 and D6 pins to the GIPO 9 and 10; respectively. The 5V pin and Ground are connected accordingly to the corresponding pins of the Raspberry Pi. This is the Seed Studio MR60FDA1 60MHz mm Wave sensor, and it is crucial since it can detect heartbeat; hence, human life.

5) Speaker and microphone: The microphone sensor is connected to GIPO pin 4, and the speaker sensor is connected to GIPO pin 17. The speaker is meant to play a recorded message from the rescue team, letting victims know there is help coming in the way in case anyone is able to hear it. The microphone is there in case the robot is able to catch sounds or speaking from the victim. This system is shown in Fig. 8.5.

6) Inertial sensor: From Fig. 8.6, it is visualized that the inertial sensor is connected from its SDA, SCL and Reset pins to the GIPO pins 18, 27 and 23; respectively. The inertial sensor will provide the x and y coordinates of the robot, to know its location.

7) Gas sensor: The gas sensor MQ-2 is placed in case there is a gas leak, so the robot can send a signal alert to the team, letting them know of the hazard. The MQ2 sensor detects smoke, liquified natural gas (LNG), butane, propane, methane, alcohol, and hydrogen in the air. Its connection goes from its A1 pin to GIPO pin 16. Its B1 pin to the GIPO 20, and its H2 pin is connected to GIPO 21, as displayed in Fig.8.7.

8) Encoded motors: The Snake-Search Bot provides eight DC encoded motors using the 4416 Adafruit Industries LLC DC Motor Gearmotor for the snake-robot wheels. These motors come with rotary encoders, which are useful for the tracking and localization process of the robot. They work alongside the inertial sensor. As mentioned earlier, for simplicity reasons, the encoded motors are shown separately in Fig. 9. Here the motors are connected to the H-bridge controllers: L298N H-bridge Motor Controller. The H-Bridges (shown in red) are connected to the servo shield (shown in blue), and then the servo shield is the one connected to the Raspberry Pi as shown in Fig. 8.8
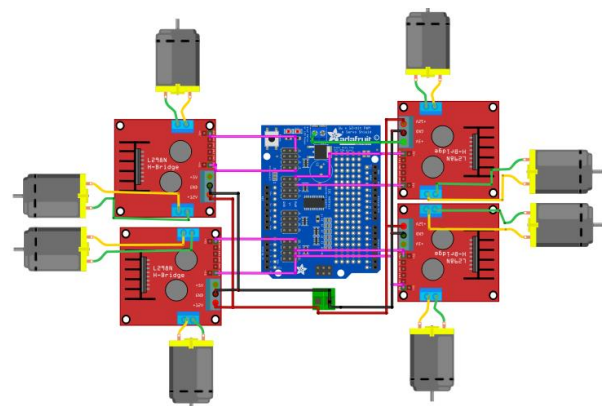

Fig. 9. Encoder's Outline

C. Program

The programming for the robot is developed using the Raspberry Pi OS based on Linux, and it was programmed using python 3.9.2. The Raspberry Pi microprocessor was chosen because of the complexity of the program since it will be performing more than one task and basing decisions on that. Also, in addition to its autonomy, we need it to be able to take decisions on its own. For instance, the robot is not only required for it to give a map, but also to identify if an object is a human or not and locate where the map the body is found. Another reason, and the most important one, is that since Raspberry pi acts as a computer when plugged in to peripherals, it will run the sensors and output the data and signals gathered into a software. It will be able to provide mapping and a route, identify humans withing the building, indicate where the victims are located, project a video of the scene through a camera, play a recorded message in case victims are able to hear, have a microphone in case the victims are speaking or making sounds, and sending alert signals of caution, such as if there is a gas leak identified.

The Snake-Search Bot code is first initialized by importing the libraries for each sensor and camera respectively, then by

stating all the variables needed to store the different kinds of data needed. The autonomous mode starts by getting data from the TF Luna sensor to start mapping the area on a 2D mapping array, initializing the motors, and getting to know which path is free for the Snake-Search Bot to go through the area, in case there is no feasible path in front of the Snake-Search Bot will go around the area until a path is found; while this is happening the Snake-Search Bot will look for gas leaks on the ambient so the rescue team can get to know if they need special suits for the environment, the PIR system will compare data from the built-in encoders form the motors to correct any possible lost in velocity caused by different factors in any of the eight motors of the Snake-Search Bot which can cause that the robot does not have the right precision of heading straight because with the pass of the time a difference in angle can be noticed; at the same time, the SLAM system will be working o project mapping of its route and indicating where in the map it has found victims. Finally, at the same time, the broadcast system will be working for the user to be able to see what the camera and thermal camera are projecting and to have communication between the user and any possible survivors.
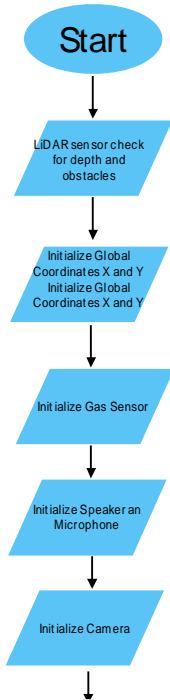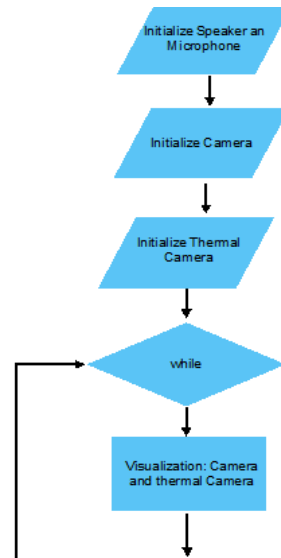

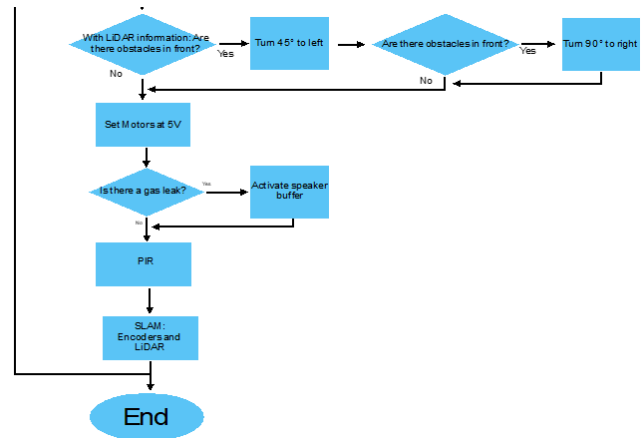Fig. 11. Flow diagram for Search-Snake Bot Part 2

Fig. 12. Flow diagram for Search-Snake Bot Part 3

The Snake-Search Bot code is first initialized by importing the libraries for each sensor and camera respectively, then by stating all the variables needed to store the different kinds of data needed. The autonomous mode starts by getting data from the TF Luna sensor to start mapping the area on a 2D mapping array, initializing the motors, and getting to know which path is free for the Snake-Search Bot to go through the area, in case there is no feasible path in front of the Snake-Search Bot will go around the area until a path is found; while this is happening the Snake-Search Bot will look for gas leaks on the ambient so the rescue team can get to know if they need special suits for the environment, the PIR system will compare data from the built-in encoders form the motors to correct any possible lost in velocity caused by different factors in any of the eight motors of the Snake-Search Bot which can cause that the robot does not have the right precision of heading straight because with the pass of the time a difference in angle can be noticed; at the same time, the SLAM system will be working o project mapping of its route and indicating where in the map it has found victims. Finally, at the same time, the broadcast system will be working for the user to be able to see what the camera and thermal

Fig. 10. Flow diagram for Search-Snake Bot Part 1

camera are projecting and to have communication between the user and any possible survivors.

VIII. PROGRAM DISCUSSION

The program for the thermal sensor starts by first importing the needed classes defined by the raspberry pi standards, in this case math, time, and OS then by importing the installed libraries "pygame", "numpy", "griddata", and "Color", for this specific sensor. The temperature range for the thermal sensor is fixed, in this case, the minimum temperature to be recorded is 26 °C and the maximum temperature to be recoded is 32 °C. The grid is created; the grid size is 8x8 for this case in which a grid-eye is being utilized. The color ranges are defined to differentiate the different temperatures that the thermal sensor is detecting, in this case, the blue areas reflect the colder regions as the red areas detect the warmer regions, and the background color is indigo which means that any area being displayed with this color is outside of the defined range. A function is initialized for the constraint and for the map. Finally, a while loop is created so the thermal sensor updates the information as is being received with a sleep or refresh time of 0.1 seconds which means that every 0.1 seconds the array with the different temperatures is being updated and therefore the map that the user is visualizing is being updated as well.

Shown below in Fig. 14 is a sample of one of the codes, and part of the overall program for the robot design.

```
1  from Adafruit_AMG88xx import Adafruit_AMG88xx
2  import pygame
3  import os
4  import math
5  import time
6
7  import numpy as np
8  from scipy.interpolate import griddata
9
10 from colour import Color
11
12 MINTEMP = 26
13
14 MAXTEMP = 32
15
16 COLORDEPTH = 1024
17 os.putenv('SDL_FBDEV', '/dev/fb1')
18 pygame.init()
19
20 sensor = Adafruit_AMG88xx()
21
22 points = [(math.floor(ix / 8), (ix % 8)) for ix in range(0,64)]
23 grid_x, grid_y = np.mgrid[0:7:32j, 0:7:32j]
24
25 height = 240
26 width = 240
27
28 blue = Color("indigo")
29
30 colors = list(blue.range_to(Color("red"), COLORDEPTH))
31
32 colors = [(int(c.red * 255), int(c.green * 255), int(c.blue * 255)) for c in colors]
33
34 displayPixelWidth = width / 30
35 displayPixelHeight = height / 30
36 lcd = pygame.display.set_mode((width,height))
37
38 lcd.fill((255, 0, 0))
39
40 pygame.display.update()
41 pygame.mouse.set_visible(False)
42
43 lcd.fill((0,0,0))
44 pygame.display.update()
45
46 def constrain(val, min_val, max_val):
47     return min(max_val, max(min_val, val))
48
49 def map(x, in_min, in_max, out_min, out_max):
50     return (x - in_min) * (out_max - out_min) / (in_max - in_min) + out_min
51
52 time.sleep(.1)
53
54 while(1):
55
56     pixels = sensor.readPixels()
57     pixels = [map(p, MINTEMP, MAXTEMP, 0, COLORDEPTH -1) for p in pixels]
58
59     bicubic = griddata(points, pixels, (grid_x, grid_y), method = 'cubic')
60
61     for ix, row in enumerate(bicubic):
62         for jx, pixel in enumerate(row):
63             pygame.draw.rect(lcd, colors[constrain(int(pixel), 0, COLORDEPTH -1)], (displayPixelHeight
64
65     pygame.display.update()
```

Fig. 13 Sample Code for Thermal Sensor in Python

As the range is being fixed from 26°C to 32°C, the thermal sensor is just going to display human beings as any other temperature is going to be outside this fixed range which also means that if the program displays any other color than indigo a human is being detected.

For the SLAM implementation, LiDAR sensor and the inertial sensors are run, and the data of the distance gathered by the LiDAR, and the angle obtained by the inertial sensor is enough information to plot a 2D map of the route the robot is taking. The data obtained by these sensors (distance and degrees) is read by Python Compiler and plotted using some embedded libraries. The TF-Luna has a range of 0.2m-8m, a resolution of 1 cm, frame rate of 1-250 Hz, and an accuracy of ±6 cm (0.2 m - 3.0 m) ±2% (3.0 m - 8.0 m) [9].

As the robot moves the TF-Luna LiDAR will simultaneously begin developing its array by emitting its laser signal. Eventually, the information gathered will be used to plot the map. For this process, the Python libraries *Matplotlib* and *Pandas* are needed first. They are downloaded using "sudo apt install python3-matplotlib python3-tk" for matplotlib, and "sudo apt-get install python-pandas" to install the pandas library. The *pandas* library will serve for data acquisition and matplotlib to generate and plot the map.

IX. DISCUSSION

As of the current model of the Search-Snake Bot, there are some improvements that can be made to provide more efficient results. For instance, the thermal and DOROTHEA cameras used for this study should be instead switched to MLX90640 IR Array Thermal Imaging Camera and the Raspberry Pi NoIR module, respectively. The MLX90640 provides a better resolution than the AMG8833 and it has a range of -40 to 300°C. The NoIR camera is a better choice than the DOROTHEA because it can provide a better image in the darkness, and collapsed buildings are not expected to have a great light source due to the debris and dust.

As mentioned previously, the initial robot design had a total of 16 motors with built-in encoders, but the current design has only eight because 16 motors were going to take too much power. To maintain the length, we decided to intercalate the motors between the wagons because the snake-like robot needs impulse form the rest of its body to climb up obstacles. In this case, for example, a large step would not be a problem for the robot to climb.

Implementing the spring in between the wagons, is crucial to add stability to the system, because otherwise, without it, while climbing an obstacle, it tilts to the side and falls.

The speaker and microphone are placed to have extra means of communication with the inside. Perhaps, not all victims will be speaking; nevertheless, there is always the possibility that a victim inside a collapse is in perfect capabilities of providing extra information important to know that the robot may not catch.

X. PRODUCT TESTING AND ANALYSIS

The Snake-Search Bot is currently in its development phase awaiting funding to start building a physical and working prototype. After the prototype has been fully assembled, tests on a variety of terrains, and a simulated earthquake environments with improvised victims will be done to evaluate

the robot's signals and agility to make any necessary alterations if needed. The Snake-Search Bot will then be expected to be tested in a real collapsed building situation sent with the team and professional supervision to verify the effectiveness of the data gathering, navigation, and SLAM performance.

XI. FUTURE WORK

For future work on this design, some improved systems could be incorporated to make the robot more efficient and provide better outcomes. One of the new concepts that can be integrated into the current design is changing the TF-Luna LiDAR, for a 3D LiDAR. This way, the robot could output a 3D map, for better visualization of the scenes inside collapses. The implementation of the 3D LiDAR would raise the cost of the original design by USD80-USD150, depending on the sensor chosen. However, an issue would be its size. Since most 3D LiDAR sensors are even bigger than a Raspberry Pi; hence, the overall size of the robot would have to increase as well.

Other changes may include, using change some models of the chosen sensors with others of higher range or with more accurate data gathering. Nevertheless, it must be taken into consideration its compatibility with Raspberry Pi.

XII. CONCLUSION

The Snake-Search Bot is a robot design that focuses on locating earthquake victims trapped in collapsed buildings. It optimizes the search process, saving more lives in less time. It is a low-cost design in comparison with the market which makes it affordable for organizations and communities in Latin America where earthquakes have a major impact, produce more damage, have higher rates of fatalities, and communities have less resources.

Snake-Search Bot takes away the risk of scrabbling and searching unknown and unstable scenes due to delicate and dangerous state of earthquake collapses, while incrementing the survival rate of the victims since the process can be done with less time and more caution. The robot also reduces the possibility of leaving victims behind. It makes the process of search and rescue, less tedious, more efficient because the robot can reach small places and crack openings that humans or search dogs cannot. This makes the Snake-Search-Bot ideal for search and rescue operations.

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