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ROBOT BASED WIRELESS MONITORING AND SAFETY SYSTEM FOR HUMAN DETECTION IN RESCUE OPERATION OF DISASTER

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Abstract:

The robot built on the USAR team is capable of navigating the difficult terrain of a disaster site but lacks sensors for victim detection. The contribution of this work is to provide a sensor suite for human detection and Accident Detection in the urban disaster environment. Underground communication is necessary to monitor underground environmental parameter such as temperature, Humidity, toxic gas etc. and take necessary actions accordingly to avoid any types of hazard. Its purpose is to find and locate human victims who have been trapped by rubble inside damaged buildings. Conditions in a disaster area are extreme with many unknown parameters. Victims may be covered in debris, trapped in voids, or entombed, making it difficult to find them and determine their state of health. This is why it will be important to choose a set of different sensors which are complementary and able to operate in these conditions.This research consists of three main parts. The first step will be to determine the state of the art in USAR robotics, with special emphasis on sensors for victim detection. Next, a set of appropriate and complementary sensors will be selected in accordance with chosen criteria, mainly that the sensors be low-cost and lightweight.The selected sensors will be integrated with the USAR robot. This involved developing hardware and low level data acquisition software solutions. Tests will be used to determine the robustness, limitations, and accuracy of each sensor and this data will be used to develop a comprehensive system that fuses the information from all the sensors to determine the location and probability of human presence. Finally, a graphical user interface will be developed to provide useful information back to the human operator while allowing the user the power to interact with individual sensors.

Keywords — **USAR team, disaster, Accident Detection, USAR robotics.**

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I. INTRODUCTION

Many areas of world are getting affected due to natural calamity. Disasters are exceptional and unstoppable events. There is many different kind of catastrophe in natural and man-made disaster such as earthquake, wildfires, flooding, hurricane and they cause different disaster area like collapsed building, landslide or crater.

Disasters create emergency situations to provide basic services to the victims must be coordinated quickly. Many times we observe that many people dies by trapping in these disasters but the people also dies on large scale just because they did not get help at instant time or the help provided to them is late. To avoid loss of material and damaging of human health, protection system as well as faithful communication system is necessary inside the underground mines. During these emergency situations, and specially in urban disaster, many different people are deployed (policeman, fire fighters and medical assistance). They need to cooperate to save lives, protect structural infrastructure, and evacuate victims to safety.

In these situations, human rescuers must make quick decisions under stress, and try to get victims to safety often at their own risk. They must gather determine the location and status of victims and the stability of the structures as quickly as possible so that medics and firefighters can enter the disaster area and save victims. All of these tasks are performed mostly by human and trained dogs, often in very dangerous and risky situations. This is why since some years, mobile robots have been proposed to help them and to perform tasks that neither humans dogs nor existing tools can do.

1.2 SCOPE

The robot built on the USAR team is capable of navigating the difficult terrain of a disaster site but lacks sensors for victim detection. The contribution of this work is to provide a sensor suite for human detection and Accident Detection in the urban disaster environment. Underground communication is necessary to monitor underground environmental parameter such as temperature, Humidity, toxic gas etc. and take necessary actions accordingly to avoid any types of hazard. The philosophy of the USAR thesis is that the robot should be low cost, semi-autonomous, heterogeneous, and work together under a human coordinator.

1.3 MOTIVATION

Earthquake disaster mitigation requires rapid and efficient search of survivors. The magnitude of the devastation of urban environments exceeds the available resources needed to rescue victims within the critical first 48 hours. Moreover, the manner in which large structures collapse often prevents heroic rescue workers from searching buildings due to the unacceptable personal risk from further collapse. Finally collapsed structures create confined spaces which are frequently too small for both people and dogs to enter limiting the search to no more than a few feet from exterior.

II. CHOICE OF SENSORS

2.1 SENSORS CURRENTLY AVAILABLE

The main aim of the thesis is to detect a victim in an urban disaster environment. This is a very difficult task especially in the unstructured environment of a coal mining or collapsed building. The physical parameters of a victim that we can detect using different kinds of sensors are

- Vision
- Heat sensor
- Microphone
- Laser rangefinder
- Ultrasonic sensors
- Radar
- Co2 sensors
- Spo2 sensor
- Camera
- Temperature sensors
- Smoke sensor
- Radio-frequency identification

Sensor Action

There are many sensors commercially available for the human detection and all have their advantages and disadvantages. In the following part the most common sensors available for human detection are described. The most important condition for this thesis is to find a low-cost solution to put on the USAR robot.

2.2. Solution Chosen for A Human Detection Set Of Sensors

The results of the research obtained above, it can be seen that one sensor is not enough to detect the presence of a victim in a disaster area. We need a set of several sensors which measure different physical human characteristics that can be put on the USAR robot. Here are the most important criteria for sensor selection for our application

- Low cost
- Small size
- Low weight
- Simplicity (easy to interface)
- Robustness

Interesting advices about sensors and their applications in USAR. They explain that video camera are essential for USAR robot since they permit the workers to navigate and see the site via tele operation, but for victim identification digital thermal camera appear much better. Motion detection is also a good solution for victim detection. Better view of the environment should be seen with Omni-cam or fish eye camera.

2.2.1.CAMERA

We need a vision sensor to have a robust solution. This is a powerful sensor because it gives a lot of information and is useful both in human detection and navigation. We decide to use a USB camera because of low cost, small size and ease of use. Moreover it already exists some software to acquire the image.

Figure 2.1: Webcam Philips ToUCam Pro

2.2.2. IR CAMERA

An IR camera is a powerful sensor to detect human presence in different kinds of environmental conditions. Then, a lot of searches were done to find a product not too expensive and that could be use on a robot.

We believe the best camera for this application is the IR camera 2000b by Raytheon Infrared. This is one of the cheapest with interesting characteristics and small size (see the specifications below and the datasheet in Appendix A).

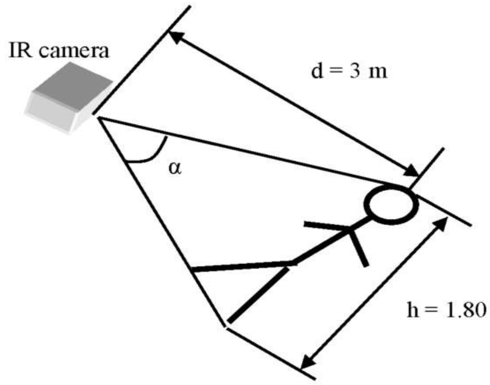


Figure 2.2: How to Choose the FOV of the IR Camera

2.3 RFID Component Parts

Tag or Transponder

An RFID tag is a tiny radio device that is also referred to as a transponder, smart tag, smart label or radio barcode. The tag comprises of a simple silicon microchip (typically less than half a millimeter in size) attached to a small flat aerial and mounted on a substrate. The whole device can then be encapsulated in different materials (such as plastic) dependent upon its intended usage.

Figure 2.3: Interrogator

Chips Available

There are two basic types of chips available on RFID tags, Read-Only and Read-Write

Read only chips are programmed with unique information stored on them during the manufacturing process – often referred to as a 'number plate' application. The information on read-only chips cannot be changed.

With Read-Write chips, the user can add information to the tag or write over existing information when the tag is within range of the reader. Read-Write chips are more expensive that Read only chips. Applications for these may include field service maintenance or 'item attendant data' – where a maintenance record associated with a mechanical component is stored and updated on a tag attached to the component.

RFID Tag

An RFID tag is a microchip combined with an antenna in a compact package; the packaging is structured to allow the RFID tag to be attached to an object to be tracked. "RFID" stands for Radio Frequency Identification.
The tag's antenna picks up signals from an RFID reader or scanner and then returns the signal, usually with some additional data (like a unique serial number or other customized information). RFID tags can be very small - the size of a large rice grain. Others may be the size of a small paperback book.

Active Tag (Active RFID Tag)

An RFID tag is an active tag when it is equipped with a battery that can be used as a partial or complete source of power for the tag's circuitry and antenna. Some active tags contain replaceable batteries for years of use; others are sealed units. (Note that It is also possible to connect the tag to an external power source.)

Advantages of active RFID tags

- It can be read at distances of one hundred feet or more, greatly improving the utility of the device
- It may have other sensors that can use electricity for power.

III. MICROCONTROLLER AND ROBOT TELEOPERATION

All the sensors selected below are implemented on the USAR robot. This robot, with two bicycles wheels, use a differential drive by varying the speeds between the left and right wheels. The solution provides to the robot a great mobility. With its two high power motor wheel controlled by a PID, it can climb ramps too. It has also a pan tilt head for the camera.

The controller board of the robot is a Stayton board made by Intel. This family board offers several benefits for embedded systems including robotics. Specifically, it is designed to optimize low power consumption and high performance processing for a wide range of wireless networking applications. It currently runs version 2.4.19 of Linux. The main characteristics of this board are listed below:

- 400 MHz PXA250 XScale processor (new chip family based on the ARM architecture)
- 64 MB SDRAM
- 32 MB Flash EPROM
- USB host and slave interfaces
- 2 PCMCIA slots
- Seri

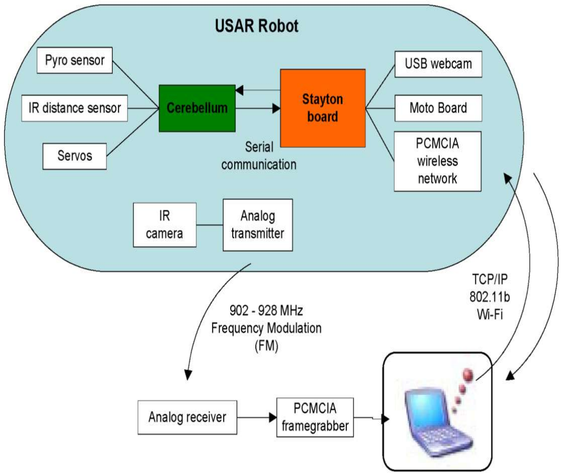


Figure 3.1 : USAR Robot's Configuration And Connections

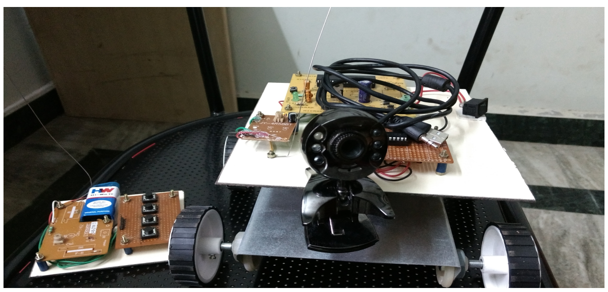


Figure 3.2: Hardware For USAR Robot Tele-operation

Tele-operation

There are several negative aspects associated with strictly autonomous approach that traditionally has existed within the robotics field. Robots have been found to lack both the necessary perception and decision making capabilities required to operate in the real world environment. Therefore a lot of the research efforts was directed towards tele-operation(i.e., robots and humans working together), rather than robots that are working entirely on their own.

IV. HUMAN DETECTION TECHNOLOGIES AND RESEARCH

4.1 PYROELECTRIC SENSOR

The pyroelectric sensor is connected to the digital port of the Cerebellum and the digital port value is read to know if the sensor has detected something (state 1) or not (state 0). The sensor can only be read once a second (bandwidth = 1Hz) to let the amount of charge on the sensitive crystalline material decrease (see datasheet in Appendix A).

4.1.1. Results for pyroelectric sensor

Different kinds of experiments are done to determine the sensitivity of this sensor. First the sensor is placed on the robot in a fixed position and the robot remained in place. A human stand in different places in the field of view of the sensor and gestures.

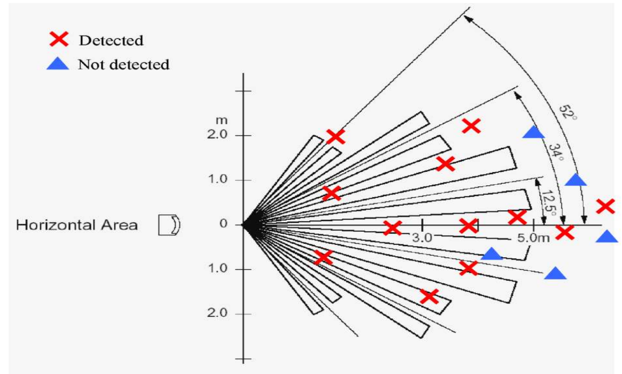


Figure 4.1: Pyroelectric Sensor Field Of View With The Fresnel Lens

4.2 USB CAMERA

4.2.1. USB Camera Software

The pictures are captured with the Philips ToUcam USB camera. The software to acquire data from the device and convert it to a picture is Vidcat. This is a free software for Linux written in C code.

The data is captured in YUV format and converted in RGB. The picture is then compressed in JPEG format to be sent through the TCP/IP protocol to an external computer for visualization. As the Stayton board has limited computing power, only basic image processing is done directly on the robot.

4.2.2. USB Camera Processing

There are different ways to process pictures to extract information about human presence. Color detection, motion detection and human body modeling are the most common ways. The first image processing used on the robot which does not require large amounts of computation is motion detection. Two images are subtracted with a threshold to filter noise and avoid little light changes between the two images. To characterize the motion, the percentage p of the "moving"pixels in the image compared to its size is calculated; the mean value m of the difference of each pixel between the two images is also calculated.

4.2.3. USB Calibration

There are several changing parameters for motion detection

- Distance between camera and the moving object
- Kind of motion
- Delay between two pictures
- Difference between the value of the pixel in each pictures

4.3 MICROPHONE

4.3.1. Microphone Software

The sound data is acquired using the built in microphone of the Philips ToUcam Pro USB camera. Free software, VSR, which is running under Linux and use the OSS library sound, records sound from the camera to a wave file. This software, written in C, stores data from the device in a shared memory buffer, while two other threads convert the data to wav format and write it to the disk.

4.3.2. Microphone Processing

The most common way to do sound processing is to work under the frequency domain using the Fourier transform. This method is computationally expensive and requires powerful hardware for use in real-time. A sampling rate of 8000 Hz for 30 ms (240 samples) is necessary to classify the human voice. A Fast Fourier Transform (FFT) with a 200 MHz processor and a buffer of 100 samples takes about 150 ms.

4.3.3. Microphone Calibration

To determine the threshold and duration that characterize human noise, the system must be calibrated. This is accomplished by recording the ambient noise for several seconds and setting the threshold slightly above the upper limit of the amplitude during this time. Further calibration depends on whether or not the sound to be detected is known.

4.4 IR CAMERA

4.4.1. IR Camera Software

The tLib, from the VRAI-Group at EPFL, is used for the processing of the infrared images. This image processing library was written specifically for real time object tracking and contains a lot of functionality.

It is very efficient, easy to use, and portable. It can take multiple sources as input. However, it requires significant computing power and needs to be run on an external computer rather than on the Stayton board on the robot. The analog transmitter sends the output of the infrared camera to an external computer with a frame grabber. The infrared camera is used to detect humans in the environment by looking for hot spots that correspond to skin and by looking for motion of that spots.

4.4.2. IR Camera Processing

The image provided by the infrared camera is in grayscale. White corresponds to warm object and black to cold object, clothing on a human body has different levels of gray, but, most importantly, human skin is uniform bright white. Some objects in the environment can be seen as well and objects that came into contact with a human remain warm for some time.

V. DATA FUSION

5.1 Process Of Data Fusion

Data fusion is the process of combining information from different sources to provide a robust and complete description of an environment or an interest feature. The fusion of the data may be complicated due to the fact that each sensor has its own performance characteristics and its own level of precision, and because different sensors may detect different physical phenomena. Every sensor has different advantages and disadvantages depending of the environmental conditions. Reliable results can not be found with only one kind of sensor. Multiple sensors are used to improve the robustness of the final result. Fusing the data of each sensor yields results that are less dependant on the weaknesses of any single sensor.

There is different way to apply sensors fusion:

- Probabilistic method (Bayes therorem, Log Likelihood, mutual information, Fuzzy logic...)
- Multi sensors estimation (different form of Kalman filter)

5.2 Solution Selected

Almost all sensor fusion approaches use the probability density function of each sensor. In our case we have different sensors with different kinds of data (binary or discrete). We do not have an exact model so we will use a fusion method with confidence values. Each sensor is assigned a confidence marker indicating the certainty of the measurement value for this sensor.

5.3 Results

Results of different measure in various environments are shown in this chapter, to see how the sensors are reacting to various situations and what the result of data fusion is.

For every experiment, the robot is doing a 180° turn around itself in seven steps. At every step, data from every sensor are taken. Motion is calculated in the normal view; in IR view, the size of the blob and its motion are computed; state of the pyroelectric sensor is read. At the end of the panorama, sound is recording and voice detection is performed. Then the probability to have a human is computed for every step with all the data of the sensor stored in memory.

At the end, the user can see three pictures that show the direction where there is the highest probability to have a human. On these pictures the motion is displayed in red to know which part in the image is moving. A green rectangle is also displayed to locate the warmest object in the normal view.

5.4 Strength and Weakness Of Fusion

According to these experiments, data fusion is essential to have good results for human detection. Using only one sensor would involve many false results that can not be differentiated with right on then, using multiple sensors as we do, decrease the number of these false results.

The relation between the sensors i.e. their confidence value is very dependant of the environmental condition. It is difficult to find a way, or an exact method to proceed for chosen this value.

It needs a lot of tests and experiments and of course the more we know where the robot will evolve, the easier the choice of these values will be.

To improve the result of fusion, it is necessary to link spatially the measurement of each sensor to know if a measurement corresponds to the same object than the other measurement with another sensor. It can be done specially with the motion detection and the infrared picture.

Some parameters like confidence value are difficult to set because there is no precise method to calculate them. The function fi(x) or lookup table could also be improved by having more possibilities of output value depending of the input. The result would be more precise and would have better resolution compare to every step. But we have to keep in mind that the Stayton board cannot use floating number, thus this improvement is limited.

VI. INTERACTION BETWEEN USER AND ROBOT

Currently, in the heart of the USAR thesis is RETSINA. This is an intelligent multi-agent System. The goal is to create a system where humans, software agents and robot can work together in teams to coordinate information, goals, plans and tasks in order to provide aid as quickly and safely as possible in the event of an urban disaster. The human must be able to work with a team of heterogeneous robots. experiences to determine the capabilities of humans working with USAR robots show that, the data the robots present to the human operator is very important in determining the success of the mission. Information must be distilled so that the human can make quick decisions.

6.1 User Interface for the Sensors

Our approach is to have the robot complete a panorama of the environment, fuse the information from all of its sensors, and provide back to the human the three highest probabilities where a human may be found along with pictures of each location. The user can then select the interesting directions and tell the robot where to move.

The user interface for the sensors must support following commands

- Change the parameters of each sensor manually
- Calibrate each sensor in an independent way
- Use each sensor in an independently and receive their information
- Survey the environment around the robot with all the sensors together and provide back any interesting information

6.2 USER MANUAL

First the user has to open the video Client application on the external computer. In 4) the port is chosen and then Start is pressed. Then the user has to start the executable file humanDet on the robot with the IP address of the external computer and the port to open. The connection between the robot and the external computer is established. Then the user has three possibilities: calibrate the sensors in 2), move the pan tilt head in 3), change manually the confidence of each sensor in 7) or send a command on the robot to perform an action in 6).

Calibrate the sensors

The user can choose between sound and motion calibration. For sound calibration he can put a threshold value manually in the field and then select the Calibrate button or execute an automatic calibration clicking only on Calibrate. For motion calibration, the user first selects a time delay between the pictures acquisition and an offset for the difference between these two pictures. After that, Calibrate is selected and the user can choose between an automatic or manual calibration.

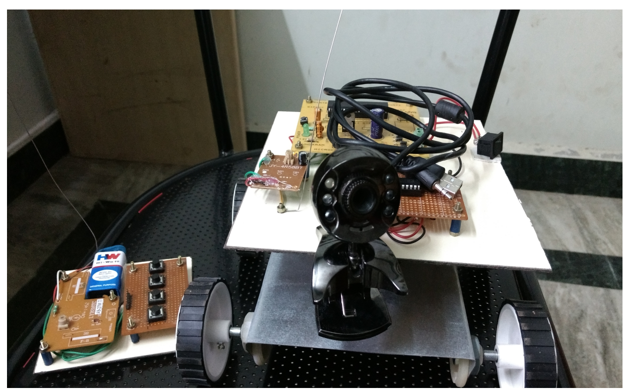
Move the pan-tilt head

The user first enters a value between 0 and 255 in the pan and tilt fields and then clicks on Move to change the pan-tilt head position on the robot.

Change manually the sensor confidence

The user first enters a value between 0 and 100 in the sensor field of which he wants to change the default value. Then he clicks on send to send these values to the robot.

HOW IT WORKS



CONCLUSION

The goal of this thesis was to provide a sensor suite for human detection in the urban disaster environment. Many researches were done to survey the state-of-the-art in USAR robotics with special importance on sensors for victim detection. A list of all the currently available sensors was established to know which kind of sensor it was possible to use for victim detection.

In this scheme, a real-time computer vision system for human detection, tracking, and verification in uncontrolled camera motion environment has been presented. The efficiency was achieved via a multi-threaded design with efficient inter-thread communication, and the usage of a highly optimized software library. The system has demonstrated a satisfactory performance on highly challenging video sequences. Our short term plan is to further optimize our system and experiment with other algorithms. Our long term plan is to extend the system to analyze human activities and evaluate threats.

A development project of Infrared (IR)-based pedestrian detection system implementation was described. The detection was developed using the available detection algorithms on a laptop platform with Laptop, and its detection result was interfaced to external, low-end microcontroller via serial communication link. The detection performance of the developed system in analysis showed, in both all images.

For our application and compare to existing thesis, the following sensors were chosen with low-cost and lightweight as main criteria:

- USB camera with build-in microphone
- Pyroelectric sensor
- Infrared camera

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