MS-Bot : Thermal Imaging capable Bots for Human Search Operations

(Rescue Robot in Chemical/Gas Industries During Gas Leakage)

[1]S. Abhinav Karthik
Dept of EIE,
Sri Sairam Engineering College,
Tambaram, Chennai-44,
Tamil Nadu, India

[2]R. Saravana Prasad
Dept of EIE,
Sri Sairam Engineering College,
Tambaram, Chennai-44,
Tamil Nadu,India

[3]S. Manibharathi
Dept of EIE ,
Sri Sairam Engineering College,
Tambaram, Chennai-44,
Tamil Nadu,India

[4]V. Pavithran
Dept of EIE,
Sri Sairam Engineering College,
Tambaram, Chennai-44,
Tamil Nadu,India

Ms. D. A. Sneha
Assistant professor, Dept of EIE
Sri Sairam Engineering College, Tambaram,
Chennai-44,Tamil Nadu,India

***Abstract*—The MS-Bot (Master-Slave Bot) is an advanced Robotic technology that is equipped with thermal detectors for detection of Humans in Human-Search operation during hazardous gas leakage in chemical industries with the integration of digital wireless camera for real time imaging. The instrument is made up of a Master robot that co-ordinates with a slave. In gas industries, during a gas leakage humans working in those dangerous conditions are prone to be attacked by those poisonous gases. Hence they inhale those toxic gases and become unconscious instantly. Most of the toxic gases are coloured and thus, creates a mist like appearance diminishing the visibility to less than 10%. Hence a robotic system that automatically conducts search operations and detects the presence of humans is needed. After searching in areas where humans cannot access, the slave robot finds for traces of humans, depending on the results from thermal imaging. This makes the controller to detect their presence and then send the information back to the Master bot. The master co-ordinates all the information from various slaves and acts accordingly to send an information to the user. It also has an inbuilt memory card that can store information, which can be used in future. The final information of the coordinates of the humans are found and fetched in the computer which is reviewed later.**

Keywords-Thermal detectors; co-ordinates; thermal imaging; master robot; slave robot

I. INTRODUCTION

This is a highly impregnable robust system that is being developed to integrate the use of robotics to save humans in danger. The basic principle used in this paper is thermal detection. Here, the presence of humans is found using the radiations emitted by humans. These are sensed by the thermal sensors equipped in the slave robot, which in turn converts it to voltage signals. There are two robots used in this system (Master robot and the slave robot). The master robot carries the slave on it to a certain point and then the slave unloads itself and then tries to detect humans. A specific case of gas leakage can in chemical industries is studied here.

II. BASIC STRUCTURE OF THE ROBOTIC SYSTEM

A. Master Robot (Primary robot)

This is the primary robot used in the system. The master robot is basically a 4 wheeled robot that is fully automated and programmed. The micro-controller used here is an ARM cortex microcontroller which facilitates the different actions performed by the robot. The program used here is a simple 'EMBEDDED C' program. The master robot carries the slave on it to a place which is not accessible by humans during the gas leakage. The master robot can carry up to 5 slave robots on it. Whenever there is a gas leakage, the gas sensors detect the presence of gas and then this sends a signal to the master bot. The master robot gets activated and then reaches the place where the gas leakage has occurred and then it unloads the slave to search for humans.

B. Slave robot (Secondary Robot)

The slave robot is a fully autonomous robot which goes in search for humans and detects it. They carry thermal sensors and also SONAR for obstacle avoidance to trace the path and detect humans. After detecting the presence of humans, the robot through a MEMS compass, notes down the coordinates and then replicates the information to the slave robot through wireless data transfer using IEEE 802.3 protocol. This is then fed into a local PC where all the details and coordinates of the humans are noted and found.

III. COMPONENTS USED

The main task of this highly impregnable robotic system is to detect the presence of humans and then at the same time feed the information to the local PC immediately so that the presence of humans can be found out easily and then rescue operation can be done immediately. The components listed out here are used in master and slave robots.

The complete co-ordination of the master and slave system will yield out maximum results and easy detection, rescue operation.

A. ARM Cortex- M3 micro controller

The ARM® Cortex®-M3 processor is the industry-leading 32-bit processor for highly deterministic real-time applications, specifically developed to enable partners to develop high-performance low-cost platforms for a broad range of devices including microcontrollers, automotive body systems, industrial control systems and wireless networking and sensors. The processor delivers outstanding computational performance and exceptional system response to events while meeting the challenges of low dynamic and static power constraints. The processor is highly configurable enabling a wide range of implementations from those requiring memory protection and powerful trace technology to cost sensitive devices requiring minimal area.

The ARM Cortex-M3 board has an Harvard architecture and it has separate INSTRUCTION and DATA buses that allow parallel fetching and data storage. The cortex board has a three stage pipeline network with branch speculation. The basic process involves: Fetch, Decode and Execute. It has an integrated bus matrix with a special configurable Nested vectored Interrupt controller. The board also has advanced debugging and traces components. The Cortex-M3 core contains a decoder for traditional Thumb and new Thumb-2 instructions, an advanced ALU with support for hardware multiply and divide, control logic, and interfaces to the other components of the processor. The Cortex-M3 processor is a 32-bit processor, with a 32-bit wide data path, register bank and memory interface. There are 13 general-purpose registers, two stack pointers, a link register, a program counter and a number of special registers including a program status register.

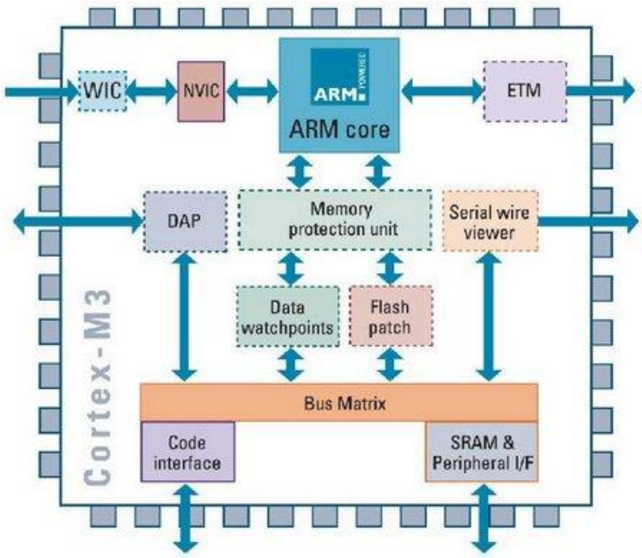

Fig 1. Basic block diagram of the ARM Cortex - M3 board

The Cortex-M3 processor supports two operating modes, Thread and Handler and two levels of access for the code, privileged and unprivileged, enabling the implementation of complex and open systems without sacrificing the security of the application. Unprivileged code execution limits or excludes access to some resources like certain instructions and specific memory locations. The Thread mode is the typical operating mode and supports both privileged and unprivileged code. The Handler mode is entered when an exception occurs and all code is privileged during this mode. In addition, all operation is categorized under two operating states, Thumb for normal execution and Debug for debug activities. The Cortex-M3 processor is a memory mapped system with a simple, fixed memory map for up to 4 gigabytes of addressable memory space with predefined, dedicated addresses for code (code space), SRAM(memory space), external memories/devices and internal/external peripherals. There is also a special region to provide for vendor specific addressability.

B. Thermal Detectors (Omron D6t-44L MEMS thermal sensors)

The basic idea is to sense the presence of humans. This is achieved by this sensor. This is a high sensitivity sensor that detects the surface temperature of a radiating body. This is different from traditional pyroelectric sensors which detect only change of signal (i.e. moving bodies, not the stationary one).The D6T series sensors are made up of a cap with silicon lens, MEMS thermopile sensor chips, and dedicated analog circuit and a logic circuit for converting to a digital temperature value on a single board through one connector. This sensor works on the Seebeck Effect. The silicon lens collects radiated heat (far-infrared ray) emitted from an object onto the thermopile sensor in the module. The radiated heat (far-infrared ray) produces an electromotive force on the thermopile sensor. The analog circuit calculates the temperature of an object by using the electromotive force value and a measured temperature value inside the module. The measured value is outputted through an I2C bus which can be used for further processing using STM32L-Discovery Board. D6T-44L-06 has sensor chip arrays of 16 channels (4x4).Each channel corresponds to a pixel (as shown in the figure below) and measures temperature independently. In the Field of view of the sensor that includes all the pixels, whenever an object appears the temperature of corresponding pixel changes. By mounting the signal processing circuit closely to the sensor chip, a low noise temperature measurement is realized

C. SONAR(For obstacle detectionand avoidance)

The SONAR is placed in the slave robot for avoiding any obstacles in its path. The SONAR sensor used here is an Ultrasonic transducer. An ultrasonic transducer is a device that converts energy into ultrasound, or sound waves above the normal range of human hearing. While technically a dog whistle is an ultrasonic transducer that converts mechanical energy in the form of air pressure into ultrasonic sound waves, the term is more apt to be used to refer to piezoelectric transducers or capacitive transducers that convert electrical energy into sound.

Piezoelectric crystals have the property of changing size when a voltage is applied; applying an alternating (AC) across them causes them to oscillate at very high frequencies, thus producing very high frequency sound waves. The location at which a transducer focuses the sound can be determined by the active transducer area and shape, the ultrasound frequency, and the sound velocity of the propagation medium.

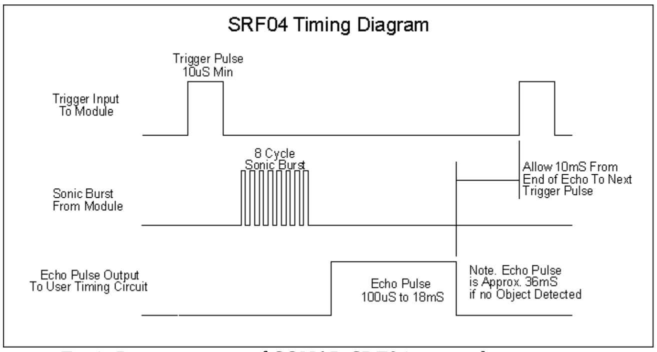

Fig 2. Representation of SONAR SRF04 timing diagram

Since piezoelectric crystals generate a voltage when force is applied to them, the same crystal can be used as an ultrasonic detector. Some systems use separate transmitter and receiver components while others combine both in a single piezoelectric transceiver. Non-piezoelectric principles are also used in construction of ultrasound transmitters. Magneto-strictive materials slightly change size when exposed to a magnetic field; such materials can be used to make transducers. A capacitor microphone uses a thin plate which moves in response to ultrasound waves; changes in the electric field around the plate convert sound signals to electric currents, which can be amplified.

D. Wireless communication (IEEE 802.15.4 Network)

IEEE standard 802.15.4 intends to offer the fundamental lower network layers of a type of wireless personal area network (WPAN) which focuses on low-cost, low-speed ubiquitous communication between devices. It can be contrasted with other approaches, such as Wi-Fi, which offer more bandwidth and require more power. The emphasis is on very low cost communication of nearby devices with little to no underlying infrastructure, intending to exploit this to lower power consumption even more. The basic framework conceives a 10-meter communications range with a transfer rate of 250 Kbit/s. Tradeoffs are possible to favor more radically embedded devices with even lower power requirements, through the definition of not one, but several physical layers.

Lower transfer rates of 20 and 40 Kbit/s were initially defined, with the 100 Kbit/s rate being added in the current revision. Even lower rates can be considered with the resulting effect on power consumption. As already mentioned, the main identifying feature of IEEE 802.15.4 among WPANs is the importance of achieving extremely low manufacturing and operation costs and technological simplicity, without sacrificing flexibility or generality. Important features include real-time suitability by reservation of guaranteed time slots, collision avoidance through CSMA/CA and integrated support for secure communications. Devices also include power management functions such as link quality and energy detection. IEEE 802.15.4-conformant devices may use one of three possible frequency bands for operation (868/915/2450 MHz).

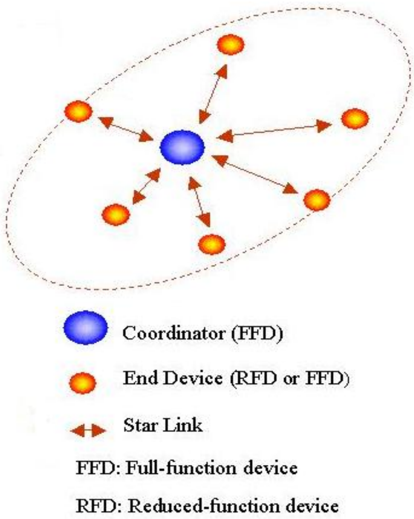

Fig 3. Representation of IEEE 802.15.4 network

IV. STANDARD WORKING PROCEDURE OF THE SYSTEM

A. Initiating the Master Robot

In case of a gas leakage in a Chemical power plant or a gas station, the gas sensor placed gets activated. This activation triggers an alarm and at the same time sends a signal to the master control robot placed in that particular area. The detected gas signal is converted into voltage pulses and then sent to the master robot. The master robot comprehends the signal and then it gets activated. There are two methods of activation here. It can be either wired or wireless mode of communication to the master depending on the hardware required in the plant.

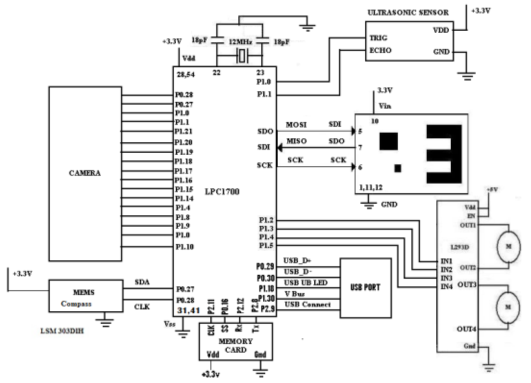

Fig 4. Circuit diagram of the Master robot

B. Locomotion of the Master-Slave robot

Once the signal is received by the master robot, the inbuilt programming is loaded into the main memory of the ARM Cortex M3 board and the master moves in the direction of the gas leakage area. The master robot is not designed to traverse all the places, so it goes to a certain point and then it unloads the slave. The slave is all on its own and then it travels to intricate places where the master cannot enter and performs its duties.

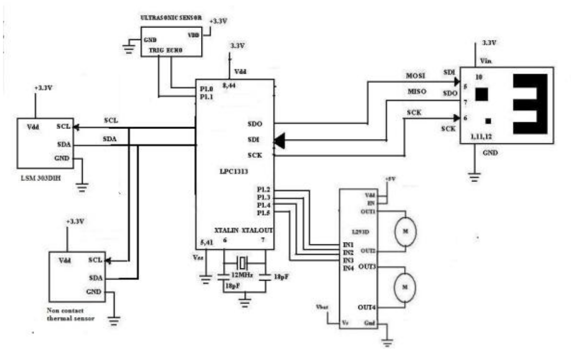

Fig 4. Circuit Diagram of the Slave Robot

C. Slave Unloading and Thermal Detection

The slave automatically gets unloaded after the master reaches a certain point. The microprocessor of the slave shall be programmed as such to unload it perfectly from the master robot. The slave has inbuilt search algorithms and it also equips a SONAR for obstacle avoidance. It effectively surpasses all obstacles and keeps the thermal sensors ready to detect any presence of humans. Once detected, this information is transferred to the master robot, which stores the information in a memory card which can be retrieved later on.

D. Final co-ordinate location and rescue operation

The master robot gets the presence of the slaves (Co-ordinates) through the MEMS compass placed, whose working is already discussed above. These co-ordinate information are stored in the master robot's secondary storage memory, from which the later information can be traced. Thus, after finding the co-ordinates, humans manually go and carry out the rescue operation.

V. CONCLUSION

The goal of this proposed project is to build a robotic system that can be used to identify unconscious humans who are victims to poisonous gases during a gas leakage. A classical study into the Bhopal Gas tragedy was done and it was found that around 75 employees of the gas station remained unconscious for around 3 hours and no help was bought since the area was covered with the mist of gas. This highly impregnable robotic system proves to break all limits and helps us to find the casualties in times of need and danger. The master-slave combination of robots help in faster navigation, easier tracing and a high speed data transfer can be achieved in here. The system is also equipped with a web cam that is integrated with the microprocessor, which regularly takes photos of the area which will be of much use in the later stages of investigation. The proposed system can be quipped in all chemical and gas industries. The future scope in this project is that on how first aid treatment to the victims can be provided to the casualties by the robots itself.

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VII. REFERENCES

[1] Guoxian Zhang, Gregory K. Fricke, and Devendra P. Garg, “Spill Detection and peremeter surveillance via distributed swarming agents” IEEE/ASME, Transcations on Mechatronics, Vol 18, No.1: February 2013

[2] Mohammed Talha and Rustam Stolkin, "Particle Filter Tracking of Camouflaged Targets by Adaptive Fusion of Thermal and Visible Spectra Camera Data" IEEE/ASME, Transactions on Mechatronics, Vol 21, No.1:January 2013

[3] Alper Aydemir, Andrzej Pronobis, Moritz G¨obelbecker, and Patric Jensfelt, " Active Visual Object Search in Unknown Environments Using Uncertain semantics" IEEE/ASME, Transcations on Mechatronics, Vol 29, No.1: August 2013

[4] Ahmet Yazici, Gokhan Kirlik, Osman Parlaktuna, and Aydin Sipahioglu," A Dynamic Path Planning Approach for Multirobot Sensor-Based Coverage considering Energy Constraints" IEEE/ASME, Transcations on Mechatronics, Vol 44, No.3: March 2013

[5] H. Yamaguchi, T. Arai, and G. Beni, “A distributed control scheme for multiple robotic vehicles to make group formations,” *Robot. Auton. Syst.*, vol.36, no. 4, pp. 125–147, 2001.

[6] M. Buehler, K. Iagnemma, and S. Sanjiv, “The 2005 DARPA Grand Challenge: The great robot race,” in *Springer Tracts in Advanced Robotics*, vol. 36.Berlin: Springer-Verlag, 2007.

[7] J. L. Gross and J. Yellen, *Graph Theory and Its Applications*. Boca Raton, FL, USA: CRC press, 2006.

[8] B. Siciliano and O. Khatib, *Handbook of Robotics*. Berlin, Germany: Springer-Verlag, 2008.

[9] ARIA. (2009). *Mobile Robots' Advanced Robot Interface for Applications* Available: http://robots.mobilerobots.com/wiki/ARIA

[10] R. Murphy, *Introduction to AI Robotics*. Cambridge, MA, USA: The MIT Press, 2000.