Intelligent Autonomous Environmental Monitoring Based on the AMBOA Robot Sensory System

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Abstract— **The monitoring, control or adjustment of dynamic environmental change is becoming a high priority within systems requiring constant twenty four hour observation such as server rooms, warehouses, greenhouses, utility stations and bio-systems to name a few and all of which may require dynamic supervision of humidity, temperature, gas levels, air-flow, barometric, ambience, intruder detection, the list appears endless yet all of are able to be accessed according to an assortment of modes, Wifi, cloud, with appropriate control methods accessible. The paper presents modification to an existing system enabling an autonomous robot to monitor a selected environment, proposals for working principles and assumptions of efficacy. It is presented that the fully autonomous robot (AMBOA), represents an inexpensive yet robust solution for both private and industry applications.**

Index Terms - Robot, Autonomous, Environment, Sensors, Cloud Computing, Neuro Guidance

I. Introduction

The main contribution of the paper orbits around the modification requirements necessary to convert the Ambient Obstacle Avoidance, (AMBOA) Robot [1] and in Fig.1, for utilization as an intelligent environmental monitoring solution enabling fast and reliable detection and correction of anomalies within a selected arena. There are of course limitations within various environments themselves and the robot platform must be designed with those limitations in mind [2] and as an extreme example of this the Bio-hybrid Micro-robot described in [3]. Advances in robotics and specifically mobile robotics, presents opportunities previously unexamined. The distinction between Industrial (fixed) robotics, Service robots and Industrial Service Hybrids (ISH) [4], indicates an evolutionary change in the ways we may utilize them within industries. Fast and reliable monitoring and detection within closed environments, or hazardous environments, investigations of both static and dynamic environments and the control of production environments such as in aquaculture, hydroponics, aquaponics or the more advanced bio-systems within agriculture [5] is an essential part of the future of the autonomous robot industry and indeed the need for more efficient food production techniques in an ever expanding populace. The paper describes the need to stringently monitor parameters of the environment specific to user defined requirements by employing the flexibility of the AMBOA sensor arrays in the achievement of their goals.

Fig. 1. AMBOA fully autonomous robot.

The AMBOA robot as depicted in Fig.1 can operate an obstacle avoidance system which is a Neuro-Guided learning controller using a Delta Rule Single Layer Propagation method to achieve clear path mobility. However this is not the specific topic of the paper and the methodology may be found within [1]. The robot is also equipped with a myriad of additional "safety" sensors, ensuring collision free movement within selected environments.

II. Design parameters

AMBOA was purpose designed by the author yet may not be an appropriate choice of form factor for a user and therefore it should be noted that the paper refers only to the sensory and MCU module of the AMBOA system which may be fitted to any chassis system of choice and has the capability to control a range of motor drives and other systems. An example of chassis design would be a mobile platform designed to control a watering system within a hydroponics

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production plant. The robot would need to be at least as high as the planters being monitored and possibly include an extendable or telescopic arm for various monitoring requirements. As stated the Module of the AMBOA system with its 16bit processor is sufficient “at present” for most applications. An ideal chassis solution for a well organized server room may be the EAI system in Fig.2, which is well suited to the design of the AMBOA Module, with the added advantage of being an extremely robust and energy efficient system.

Fig.2. EAI system is the author’s preference for indoor closed environments

III. MODULE PARAMETERS

The proposed environmental monitoring system is more an adaption which aims to utilize the already existing sensor array module with a view to performing those necessary changes to achieve the required result which includes the collection of relevant data within closed environments.

The module of the AMBOA system was developed with a wafer form factor and consists of three component parts being:

- The power wafer described in A.
- The MCU, MOB and SPI wafer described in B.
- And the Sensor array wafer described in C.

A. The Power Wafer consists of a fully inductance balanced system capable of delivering the requirement of the processor wafer, motor drivers, sensor wafer array and other peripherals. The wafer is divided into three DC/DC Converters: 7~40Vdc to 3.3Vdc, 7~40Vdc to 5Vdc and 7~40Vdc with fully adjustable VDC, all with mechanical pin connection for adaptability. AMBOA currently operates on a 24V 14Ah battery stack. The power wafer supplies sufficient voltage and current ratings for most available sensor types. See Fig.3.

B. The CPU Wafer comprises a DsPIC33 100 pin 16bit processor. The features of this chip rendered it ideal for its original purpose and the most important in short-form here are, CPU Speed of 40 MIPS, 256 Kbyte Programmable flash, 85 pin I/O, 30720 Bytes RAM, Analogue x 2-A/D 32x12-bit @ 500 (ksps), Internal Oscillators 7.37 MHz and 32.768 kHz and of great importance to the system, Digital Communication Peripherals (2 x UART, 2 x SPI and 2 x I2C). The board was also fitted with 2Mb MOB pursuant to the requirements of the Guided Learning requirements outlined in [1]. See Fig.4.

C. The Sensor Wafer consists of 3 sensors each within 8 banks or sectors, forming 1 array of 24 sensors, each having a dual function of both analogue and digital ambient light data collection. The system, originally designed with an ambient light obstacle avoidance function and equipped with a range of high quality photodiodes, can however utilize a variety of peripherals allowing the sensor array to be utilized for many other purposes at the discretion of the user. Alternatively a second Sensor Wafer may be daisy chained retaining the original system while expanding the original purpose, the purpose of this paper. It must be remembered that the array as it stands is capable of a large number of permutations within the sensor array which exponentially increase when account is taken to duplicate or repeated signal.

$$24^{24} = 1.3337358e + 33 \tag{1}$$

We can raise 24 sensors to the 24th power to calculate the number of combinations obtainable with repetition (1) of any received signal, or receiving the same signal more than once, the permutations are large. See Fig.5.

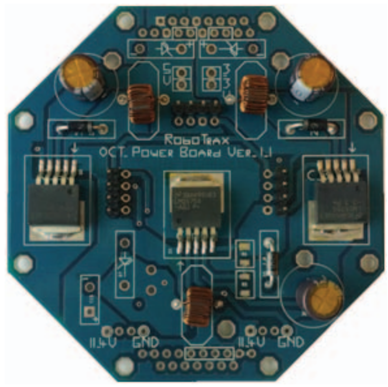

Fig.3. Power Wafer. 3 x DC/DC Converters

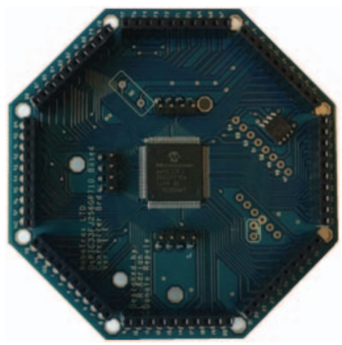

Fig.4. MCU Wafer with additional MOB

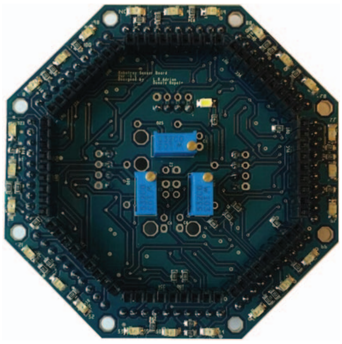

Fig.5. Sensor Array Wafer. 24 sensor input. In 8 sectors

IV. Sensor array configuration

In order to understand the array, it must be understood that it was divided into 8 quadrants consisting of 3 sensors in each. This was done in order to accomplish three tasks:

1. Reduce the total permutations to reasonable levels on each sector.
2. Due to the wide variation of received wavelength of the photo sensors it greatly reduced the opportunity for repetitive signals.
3. The segmentation has reduced significantly the number of variable tuning resistors from 24 to 3.

The original circuit consisted of trans-impedance amplification which was necessary when the system was purely analogue and where higher or more amplified voltages were required to obtain suitable reactive response. That system also provided disadvantages in the instability of the amplifier gain. It was confirmed that across the board some 24 VAR's would be required to stabilize the system for a photodiode array which was unacceptable. The simpler solution can be seen in Fig.6 and requires two quad comparators for each eight sensors; reducing the U_{ref} control to only three LDR/VAR's for the whole system.

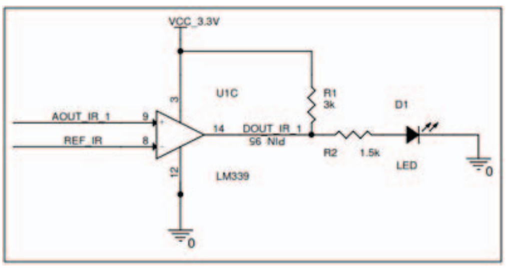

Fig.6.Differential Comparator circuit. As ¼ of each LM339A

V. Adapting sensor inputs

As may be seen in Fig.7 the connection for the photo diode Q1 as is the standard configuration for each of the 24 sensors on the sensor wafer. Ergo the sensor array has been designed in order to attach many sensor types falling to the definition of having a two or three pin configuration of GND, Signal and Vcc, which is quite a common configuration.

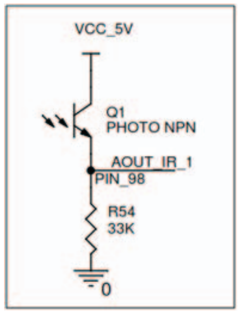

Fig.7. Sensor part. Four to each LM339A.

In some instances a secondary GND will be required when the Signal line is connected to A_{Out}, using then R_{gnd} as a buffer.

VI. Adapting potential divider

Adjustment when the sensor array is in its original configuration relies on the three LDR/VAR potential dividers which are in effect Ambient Light Sensors, which when tuned give constant linear adjustment to the robots' sensors as it crosses from a well lighted area to a darker area, maintaining constant and understandable readings from the photo sensors. If however it is selected to use for example, Infrared Proximity Sensors, there is no need for variable ambience to be considered. Therefore the LDR, Fig.8 for that particular sector of sensors must be replaced with a standard resistor calculated to achieve the correct voltage output to keep the sensor just below trigger point. In this way the integrity of the system may be maintained with U_{ref} of the comparator remaining the control influence across the sensors. Sensor adjustment is achieved in this manner through the VAR in Fig. 8 and tuning is achieved when the LED in Fig.9 illuminates, then backing off until the LED goes out. In this manner the LED will illuminate yet will not change in intensity due to the current limiting resistor but at this trigger point, the signal from the Infrared Proximity Sensor at A_{out} will trigger the override the inverting input of the comparator causing logic 1 output at D_{out}. Both A_{out} and D_{out} are connected to the MCU.

The author has found that a distinct advantage of this configuration is the illumination of the LEDs and the subsequent visual representation of the system during operation and program development.

It should also be noted that the informative signal received from an infrared proximity sensor has far differing data meaning than a photodiode, therefore with all changes must also come a change in the algorithm or program operating within the system.

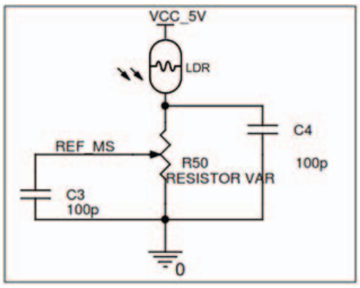

Fig.8. LDR/VAR controlled potential divider

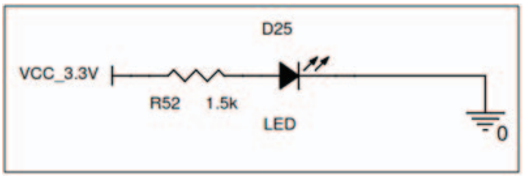

Fig.9. On-off indicator and trigger adjustment for Sensor Board

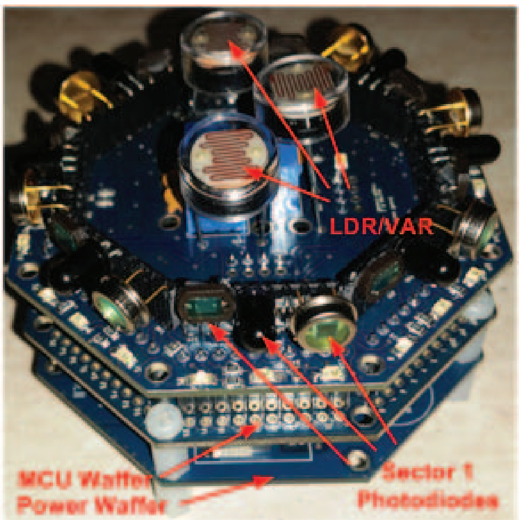

Fig.10. Complete Wafer Board

VII. Thermal Environmental Monitoring

The proposal of the paper is to adapt an existing system to another purpose, in this instance from that of primarily Obstacle Avoidance to that of Environmental Monitoring. With the ease of sensor exchange offered in the AMBOA system, this is very achievable. It is not possible here to evaluate all possible sensor types, however, interesting is the temperature control of environments such as controlled greenhouses where temperature is a critical factor. Let us create a logical scenario for the AMBOA system in its current form. Modelling has been performed to estimate response for temperature sensors of the type TMP36 Analogue Low Voltage Temperature Sensor and the Vishay NTC Low Thermal Gradient Lug Sensor. The modelled data was in accordance with their respective data specifications with simulations from minus 5°C to 105°C as in Figs. 11 and 12. The model displays exaggerated temperatures purposefully established to provide clarity of result and for the purpose of evaluation two sensors have been affixed to a mast connected to our EAI system as in Fig.2. The sensor heights were adjusted to low level (attached to the sensor board) and the second, raised to central room height. This was in following a similar method as described in [6] [7] except that we did not have the requirement to utilize so many sensors to enable modelling requiring only the two for a useful analysis.

Only one sensor input of the Sensor Wafer was utilized for the NTC with the second sensor attached to the built in TMB36 slot, so as not to interfere with the Obstacle Avoidance parameters of AMBOA as they currently stand.

Forward motion of AMBOA was set to approximately 1000cm per minute, somewhat slower than normal due to allowances made to time/temperature variations in the sensors. There was some guesswork involved as a more complete analysis is yet to be done.

The additions to the onboard programming were slight with the inclusion of few lines of code, primarily for the analogue inputs:

- Voltage at pin mV = (ADC reading * (3.33/1024))
- Temp C = ((analogue voltage mV) – 500) / 10

Of course specific coding requirement remain pursuant to the chosen language of the user and are irrelevant here. As we are attaching the sensor directly the ADC pin, we use these to convert the 10-bit analogue readings to temperature.

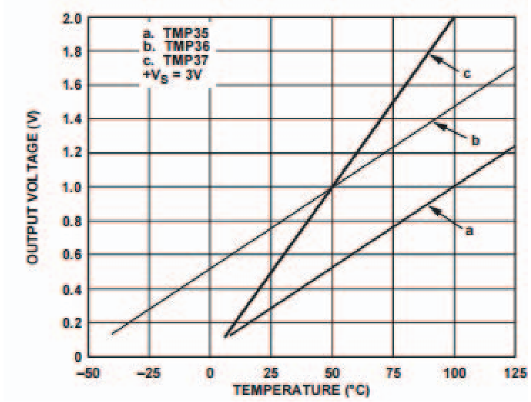

Fig.11. Graph of expected linear increases with TMP36

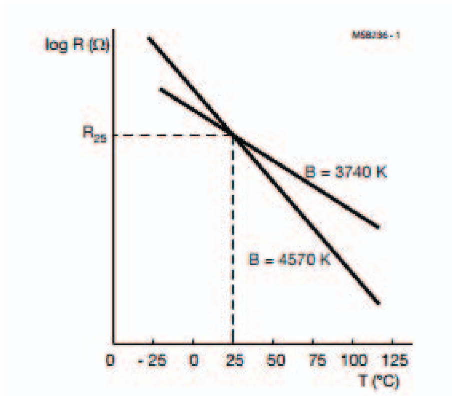

Fig.12.Typical resistance as a function of temperature for an NTC temperature sensor

For conclusive results we have used the 3.3 reference voltage as A_{ref} instead of the 5V rail as it is more precise and less noisy.

The neuro-learning [1] method was used, although only as a catch all method to review at a later point and to ascertain whether a 3D map could be extrapolated from collected data stored after the run within the MOB. It must be remembered that the neuro-guided learning algorithm is utilized as a pseudo memory method for obstacle avoidance and temperature measurement is useful for instantaneous control of heating, cooling or even fire hazard control but does not require the recollection aspects of the algorithm. However the algorithm will allow instantaneous collection of useful sensory data.

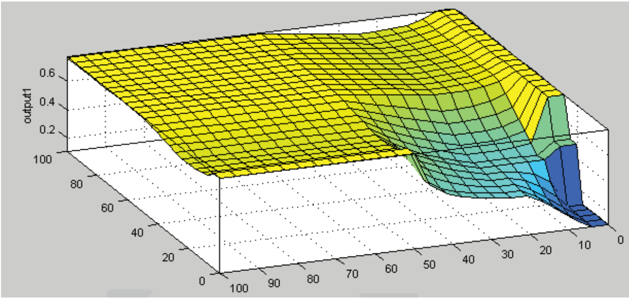

Fig.13. Successful 3D temperature map of monitoring system

- Yellow = high temperature source
- Green = medium temperatue source
- Blue = low temperature source

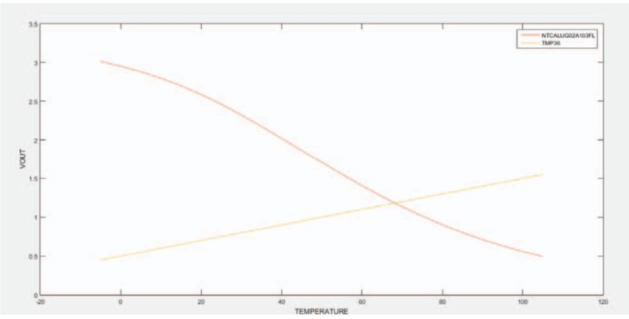

Fig.13. 2D temperature map of monitoring system

VIII. Hazardous Environmental Monitoring

Investigation into specific sensor types is being undertaken with respect to the monitoring of hazardous environments and other environmental elements. The list is exhaustive however include Toxic Gas detection, Infrared (flame) detection/location, Seismic detectors, metal detectors, Radiation detectors, Electromagnetic field detectors. The only prerequisite of the sensor which may be utilized is its ability to produce either a logic or voltaic response, essentially bringing all sensors to the table. The variable becomes the choice of data collection and utilization, the programming language used and the method of transmission.

IX. Conclusion

Many sensor types have been tested as replacements to the existing photo sensors on the wafer and to date all expectations have been met in relation to the adaptability of the sensor array utilizing other sensor varieties. This main experimentation performed with the temperature sensors provides more than adequate responses and with the flexibility to use any number of sensor types within the robots' sensory wafer. Of great interest will be in the establishment of a swarm robotic network with each robot able to share information of a completely different nature and therefore increasing computational capacity exponentially.

The core point to the exercise is the very low cost factor and ease of adaption to other system types leading to a conclusion that the exercise is beneficial to the industry as a whole and deserving of further inquiry.

The monitoring of closed and or indoor environments has numerous drawbacks; not least being the tedious tasks hitherto accomplished through extensive hours spent wandering from monitor to monitor recording data for processing. Using the AMBOA Sensor Array with our mobile robotics platform we believe we will develop a comprehensive supervisory system for many industry requirements. The system is shown to be cost effective and efficient. Further research is in order.

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LATENERGI

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ROBOTRAX LESLA technologies

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