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Model Design and Hardware Implementation of an Intelligent Laser Warning System

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Abstract :*The laser weapons were put into use more widely in the modern battlefield. The first important mission of the laser countermeasure is to give an alarm of the enemy laser weapons rapidly and rightly[1]. During identifying the laser menaces, realizing the detection of the orientation, the direction of the laser signal and the angle of incidence of laser to determine the source of laser. Then the detect data were fused in virtue of the expert decision making system, and distinguishing of the laser from the background noise of the sun is very serious, to get the aim of correct countermeasure. In this paper a simple intelligent algorithm for laser angle detection is proposed using fuzzy logic data fusion to detect laser incidence angle for early warning. The proposed system is simulated and tested using MATLAB software using four laser sensors to detect the incident laser angle from 0 to 360 and an additional sensor to distinguish the incidence laser from background sun light. A Hardware implementation of the system using TI-430 microcontroller has been introduced. The system has been tested and a GUI interface is developed to make the system easy to use.*
Keywords :*Embedded system, Laser Detection, Fuzzy systems,Fuzzy data fusion*

I. Introduction

Lasers technology got an increasing importance in military weapon systems as a means of designating targets for guided missiles and as weapons themselves. Current laser warning systems provide laser detection, angle of arrival, wavelength discrimination and temporal characterization of the laser source. However, there is a need to improve their threshold detection level and false alarm rate for detection of low-intensity pulsed lasers associated with beam-riding type guided missiles[1]. Laser warning systems must be improved to cope up with the new threat of low power laser beam-riding missiles.

This is not the only part to look after in order to enhance laser warning sensor (LWS) detection capability. Most of the conflict areas in the modern world have hot climates. Areas such as the middle-east have severe weather conditions which are now known to affect the performance of laser warning systems in a negative way. Then the detect data were fused in virtue of the expert decision making system, and distinguishing of the laser from the background noise of the sun is very serious, to get the aim of correct countermeasure. However, the use of intelligent methods may help solving this problem.

Fuzzy logic methods are capable of fusing uncertain data from multiple sensors to improve the quality of information. They require less computational power than conventional mathematical computational methods such as addition, subtraction, multiplication and division. In addition, only few data samples are required in order to extract final accurate result. Finally, they can be effectively manipulated since they use human language to describe problems[2, 3].

Aim of this paper is to design and develop a simulation model with improved detection performance. This model will be designed to simulate the direction of incidence of laser with the presence of sun light and examine if the system can detect it. Then implement the system using embedded circuits.

In this study, we give the configuration and operating principle of the laser warning system, which is composed of a laser sensors , microcontroller and fuzzy algorithm downloaded on the microcontroller to calculate instantly the output of this sensors and estimate the direction of incidence of laser. Using these as an embedded system can improve the performance of the laser warning system, reduce the cost, array of laser sensors can distinguish laser from background noise and other non-coherent radiation such as flares, sunlight, and lighting. Based on fuzzy logic principle, we can timely get laser source spectrum information from interference pattern.

A long term objective of our research is to design and establish a robust, low cost, reconfigurable sensing hardware and software framework that can be adapted to various military equipments in order to give them the ability to face laser menaces. We believe that there is a strong need for such a framework because of the high cost and hard to replicate nature and complexity of existing designs. Advances in open source software, electrical sensors and microcontroller frameworks such as Arduino open the possibility of creating reusable, adaptable designs that can easily be applied to existing equipment without requiring extensive technical expertise and leveraging traditional technique. It is our hope that as electronics on stage are becoming more ubiquitous in many military fields, approaches like ours will reach larger communities of users. The proposed system is a good case study of how such a framework can be used for increasing the efficiency of equipment.

II. Fuzzy Logic and Embedded Systems

An objective of fuzzy logic has been to make computers think like people. Fuzzy logic can deal with the vagueness intrinsic to human thinking and natural language and recognizes that its nature is different from randomness. Using fuzzy logic algorithms could enable machines to understand and respond to vague human concepts such as hot, cold, large, small, etc. It also could provide a relatively simple approach to reach definite conclusions from imprecise information. Almost every application, including embedded control applications, could reap some benefits from fuzzy logic. Its incorporation in embedded systems could lead to enhanced performance, increased simplicity and productivity, reduced cost and time to- market, along with other benefits. Fuzzy logic has the advantage of modeling complex, nonlinear problems linguistically rather than mathematically and using natural language processing (computing with words). The use of fuzzy logic requires, however, the knowledge of a human expert to create an algorithm that mimics his/her expertise and thinking. Also, studying the stability of a fuzzy system is a demanding task[4-8].

Numerous applications, including embedded ones, combine the use of fuzzy logic and neural networks. Neuro fuzzy techniques take advantage of both fuzzy logic and neural networks, leading to systems that can:

- Mimic the human decision-making process
- Handle imprecise or vague information
- Learn by example and hence do not require the knowledge of a human expert
- Self-learn and self-organize.
- Process numeric, linguistic, or logical information.[9]

Increased market demands require embedded systems to be developed even further at a rapid pace. Fuzzy logic and neural approaches can provide a mechanism for getting the most out of embedded system capabilities and making them more intelligent. They can also accelerate the development cycle and reduce the time-to market of new products to meet ever-increasing demands. It is important for engineers to know about the capabilities of fuzzy logic and neural networks as possible design approaches from which one may select the most suitable for the problem at hand.[9]

1.1 Sensors FuzzyData Fusion

Data fusion is the process of integration of multiple data and knowledge representing the same real-world object into a consistent, accurate, and useful representation[2].

Fusion of the data from two sources (dimension #1 & #2) can yield a classifier superior to any classifiers based on dimension #1 or dimension #2 alone as shown in Fig.3

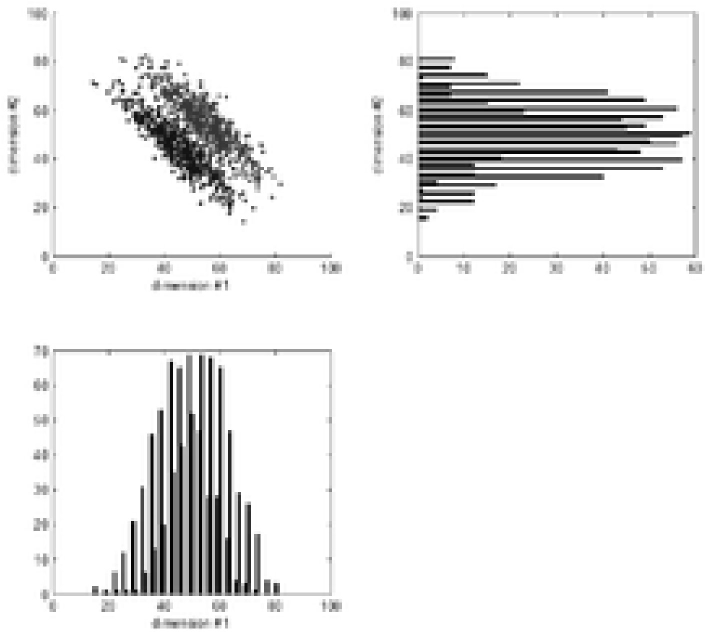


Fig 1 Data fusion from two sources

Data fusion processes are often categorized as low, intermediate or high, depending on the processing stage at which fusion takes place. Low level data fusion combines several sources of raw data to produce new raw data. The expectation is that fused data is more informative and synthetic than the original inputs.[2, 3]
For example, sensor fusion is also known as (multi-sensor) data fusion and is a subset of information fusion.

In the framework of fuzzy set and possibility theory the modeling step consists in defining a membership function to each class or hypothesis in each source, or a possibility distribution over the set of hypotheses in each source. Such models explicitly represent imprecision in the information, as well as possible ambiguity between classes or decisions.

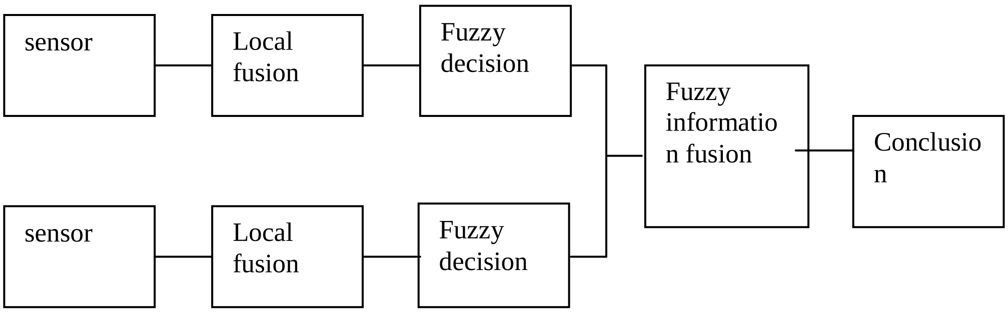


Fig 2 Structure of the information fusion.

Therefore, as shown in Fig 2 Fuzzy Data fusion techniques combine data from multiple sensors, and related information from associated databases, to achieve improved accuracies and more specific inferences than could be achieved by the use of a single sensor alone[10][11, 12]

2. The Proposed Laser Angle Detection Fuzzy Model

The proposed algorithm is based on the fuzzy logic inference methods described in previous section. The fuzzy model for the laser angle detection diagnostic was implemented in MATLAB using the fuzzy logic toolbox. The proposed Simulink model has five different inputs: the Right, Left, Upper, Down and Dummy inputs which come from the sensors organized in the basic directions as shown in Fig 5. These five inputs are processed by a fuzzy logic algorithm that gives the angle of incidence of laser as an output.

This resulting angle is decoded into one of nine possible outputs: UU (upper), UR (between upper and right angles with fuzzy values), RR (right), RD (between right and down), DD (down), LD (between left and down), LL (left), UL (between left and down) and NONE (no dangerous).
Using fuzzy rules and output membership functions the exact output angle is produced by fuzzy data fusion.

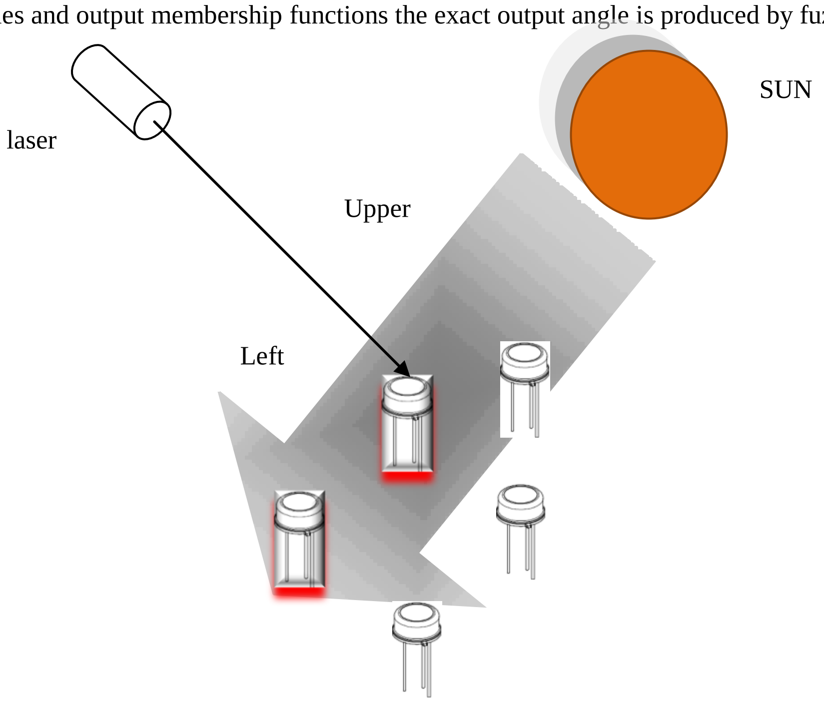


Fig 3The proposed system sensors configuration.

2.1 The proposed system block diagram

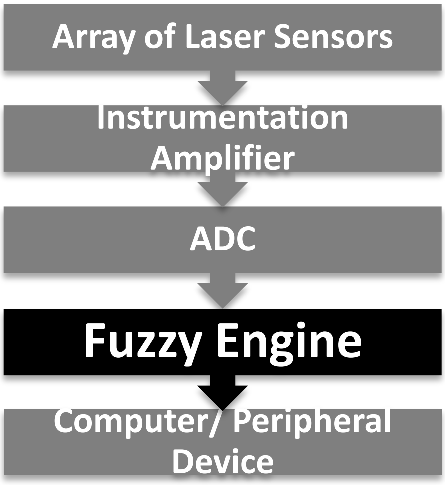


Fig 4The proposed system block diagram

This diagnostic system uses Signal builder inputs (which allow to create and generate interchangeable groups of signals whose waveforms are piecewise linear) for the five inputs (upper, right, down, left and dummy). Each input has a certain signal in the range from 0 to 255 represents the strength of the incident laser. The signal from the sensors then go the interface circuit that condition the signal to be processed by the microcontroller which as the fuzzy algorithm. Finally the output is displayed. (Refer to block diagram shown in Fig 4)

2.2 Sensor orientation model for laser angle detection

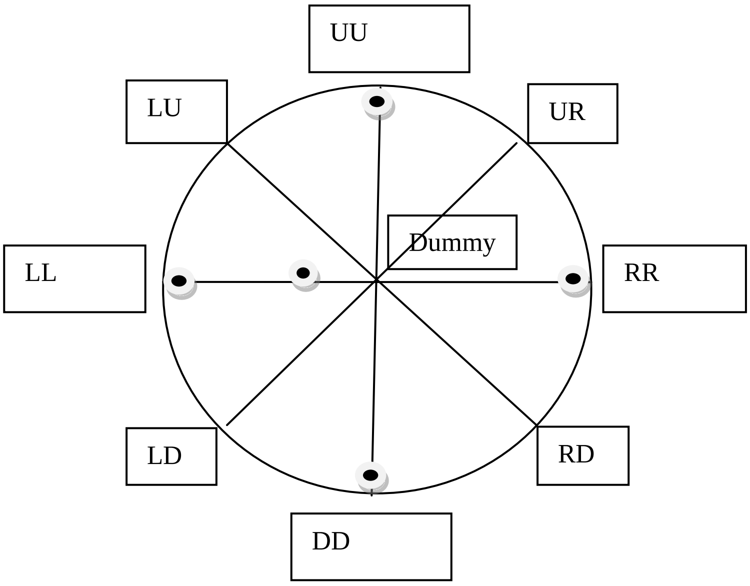


Fig 5 Sensors configuration and orientations

Fig 5 shows sensors configuration used to cover all domain angles from 0 to 360 degree. Each sensor indicates a direction as follow:

Upper Sensor (UU) is at 0 or 360 degree, Right sensor (RR) is set at 90 degree, Down sensor (DD) is set at 180 degree and Left senor (LL) is at 270 degree. In order to increase the resolution and make fuzzy data fusion the following directions have been defined:

UR is the angle between upper and right sensors; UL is the angle between upper and left sensors; RD is the angle between right and down sensors and LD is the angle between left and down sensors.

For the fuzzy data fusion algorithm, and in order to get the right angle depending on the sensors readings, some comparisons between the sensors readings have been set as follow:

- Error between Upper and right readings
- Error between Upper and left readings
- Error between Down and right readings
- Error between Down and left readings

The dummy sensor illuminates the sun effect by exposing it directly to the sun …so we can indicate the incidence of the laser by comparing all the sensors with the dummy sensor.

2.3 Membership functions for the fuzzy model of laser angle detection

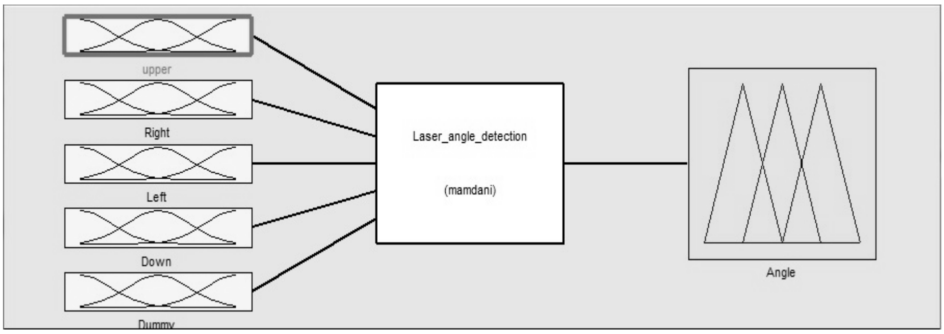
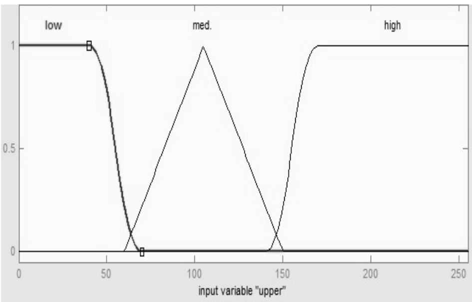
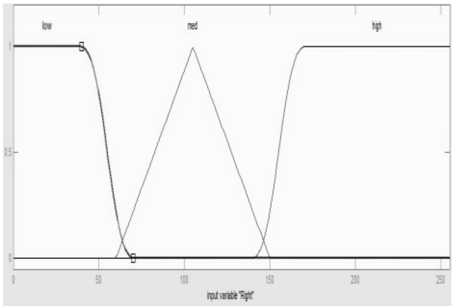


Fig 6 The proposed system Inputs and outputs functions

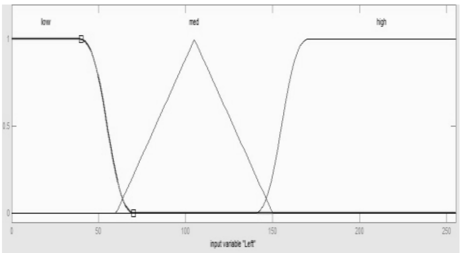
These inputs function ranges (sensors readings ranges) can be used in determining the fuzzy membership sets. The fuzzy system will have five inputs and one indicating output (Fig 8). The fuzzy system uses Mamdani type fuzzy system [4][13, 14], and the centroid method for defuzzification. The input membership functions for the four sensors (upper, down,left,right)are shown in Fig.9.Each sensor input has three different membership functions: low, medium and high. They ranges from 0 to 255, which are the possible input values, came from the real laser detector. The low and high membership functions continue to infinity to include any voltage value out of range and avoid the system saturation.



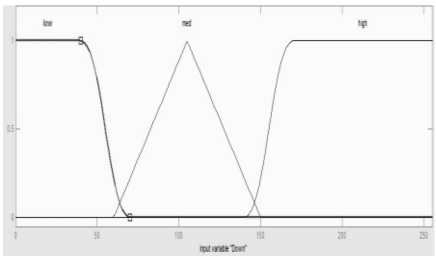
Fuzzy subset and membership degree of upper



Fuzzy subset and membership degree of upper



Fuzzy subset and membership degree of left



Fuzzy subset and membership degree of down

Fig 7 The Membership function for the input sensors

The membership degree x of three fuzzy subsets (low, med., High) for the four sensor inputs can be expressed as follow (an example for the upper sensor):
Low:**µ***uu*(x:40,70)
Med.:**µ***uu*(x: 60,105,150)
High:**µ***uu*(x:140,170)

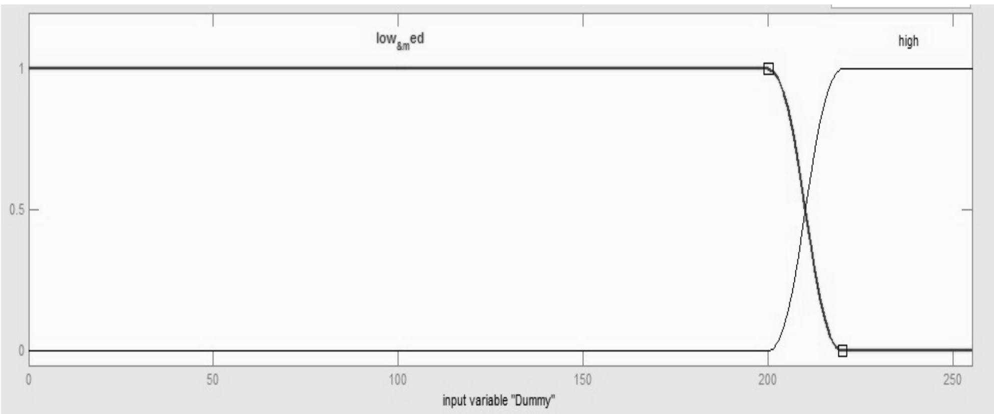


Fig 8 Fuzzy subset and membership degree of dummy sensor

The dummy sensor input readings can be divided into two fuzzy sets as shown in Fig. 8. They are defined as low_medium function (using Z-shaped membership degree) ranges from 0 to 220 and high function (using S-shaped membership degree)ranges from 200 to 255 as high. The membership degree of two fuzzy sets can be expressed as followed:
Low_med.:**µ***dummy*(x:000,220)
High:**µ***dummy*(x:220,255)

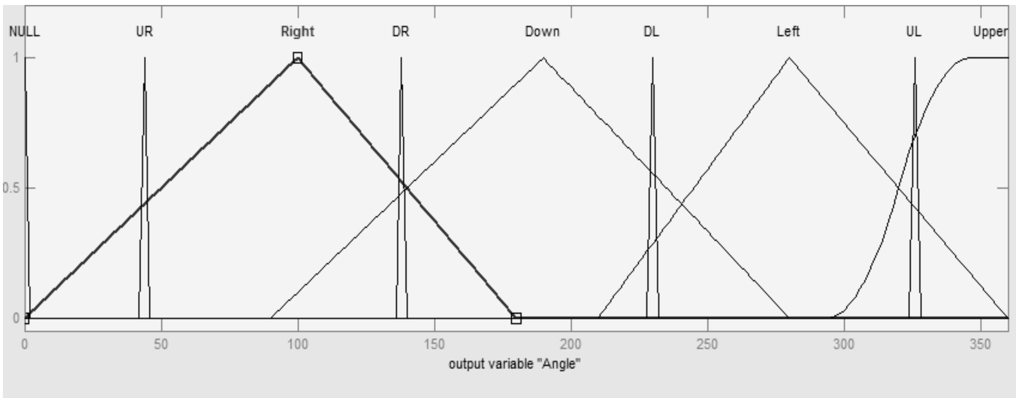


Fig 9 Fuzzy subset and membership degree of the output angle

The output has nine membership functions: UU (upper), UR (angle between upper and right), RR (right), RD (angle between right and down), DD (down), LD (between left and down), LL (left), UL (between left and upper again) and NONE (no dangerous).The output membership functions are triangular shape andcover the range from 0 to 360 as shown in Fig 9.

Once all of the input and output membership functions have been defined the heart of the control can now be defined; the rules. The fuzzy rules are in the form of if-then statements.

These statements look at both inputs and determine the desired output. In this system when laser beam incidence occur on one of the sensors so the output reading of this sensor will be compared with the output of the dummy sensor (exposed directly to the sun) to distinguishing the laser from The background noise of the sun, to get the aim of correct countermeasure and in the same time compared also with the other neighbor sensor. As one of the advantages of the fuzzy system is the parallel processing of the data at the same time.
Examples of the rules defined for this system are in Table 1 below:

Table 1 the proposed system fuzzy rule examples

If Upper	And Right	And Dummy	Then The Output Angle
Low	Low	Low	None
Medium	Low	Low	Upper
Medium	Medium	Low	UR
High	Low	Low	upper

The fuzzy rules have been set such that it makes use of all the data and ensure data fusion of all the sensor readings. The rules were formulated one-by-one, and then the whole rules-set was analyzed to make it:-

• Complete: any combination of the inputs fired at least one rule.
• Consistent: contains no contradictions.
• Continuous: Have no neighboring rules with output fuzzy sets that have an empty intersection.

2.4 Matlab Model for the system using fuzzy logic controller

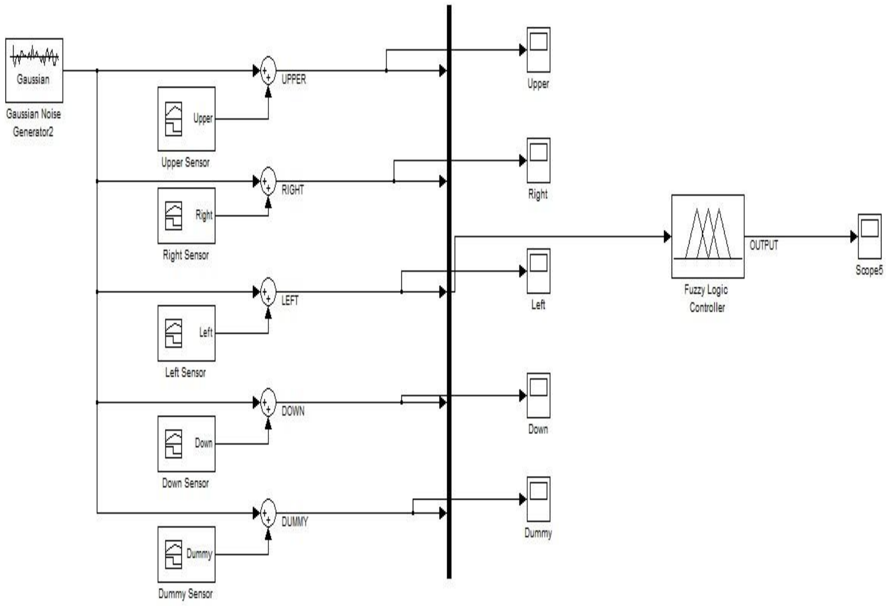


Fig 10 Matlab Model for the system using fuzzy logic controller

3. System Simulation and Testing

The proposed system has been designed and simulated on Simulink software using different combinations of input readings of the sensors to ensure the prober working of the system. The next table (table 2) shows examples of the simulation results; input and output combinations for the basic direction sensors. Table 3 shows another combinations of sensors readings to test the in between directions data fusion of the proposed system.

Table 2 Example results of simulation for the basic direction sensors

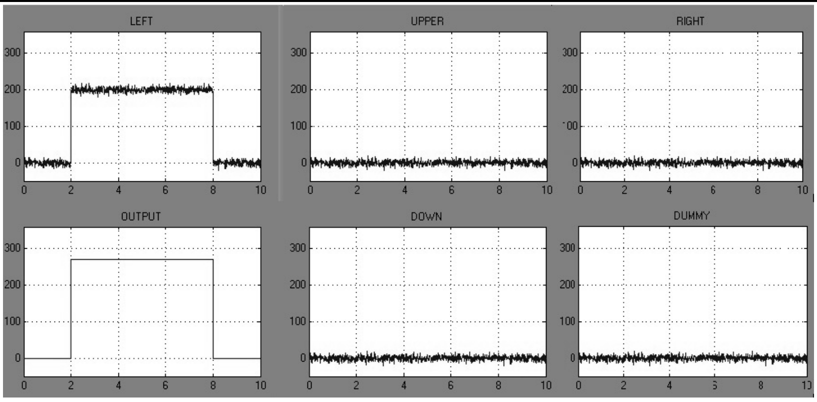
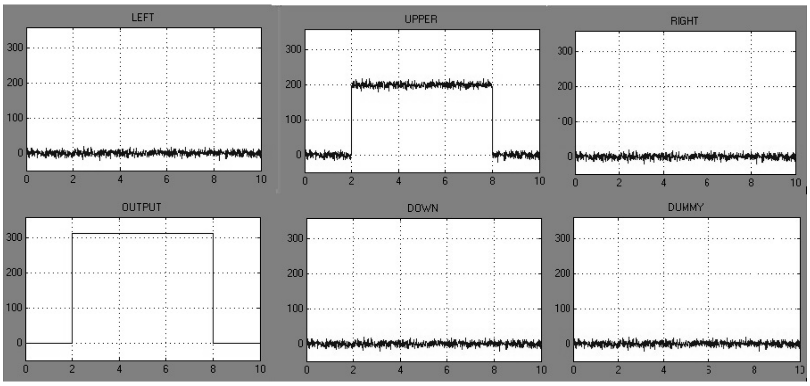
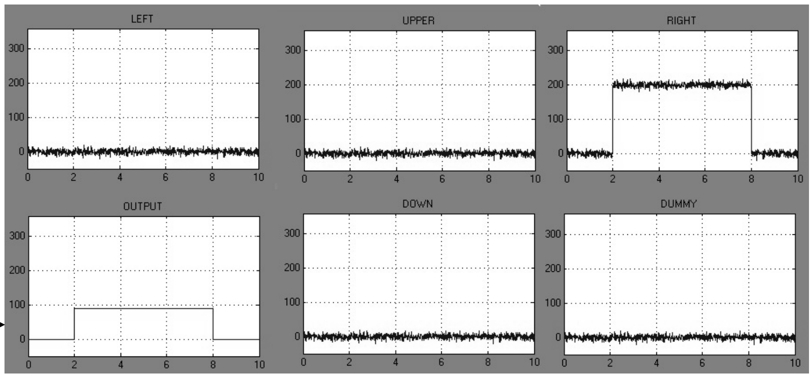
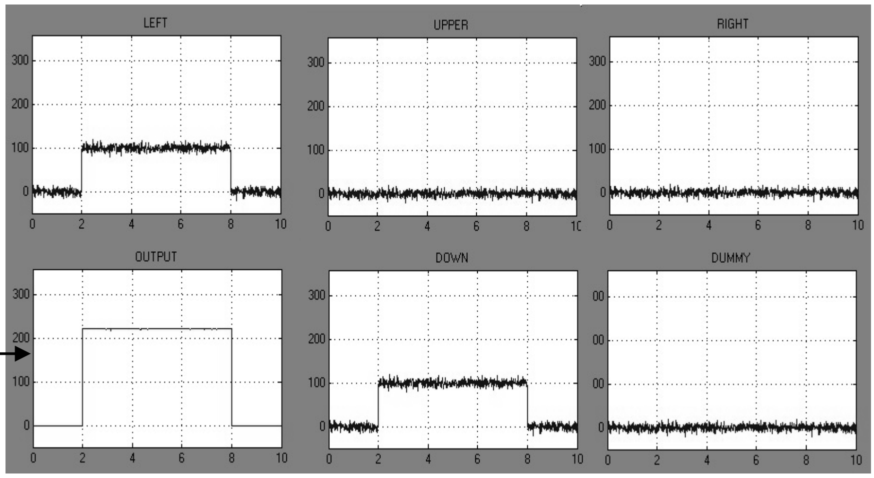
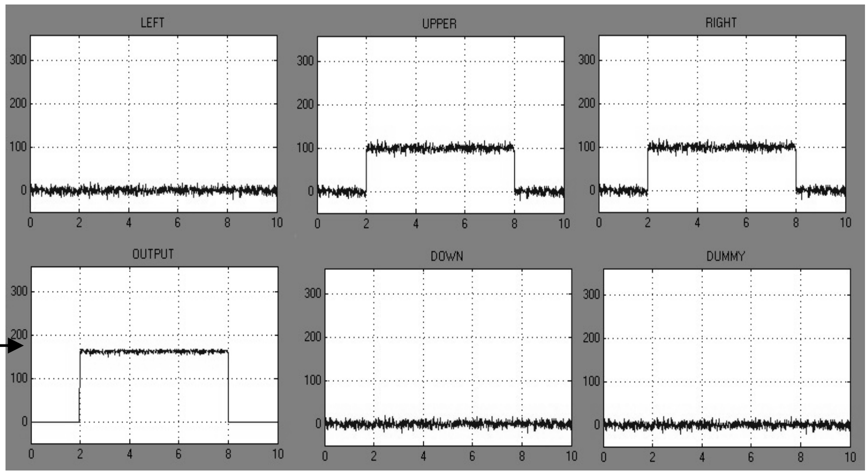
Parameters Control signal (input signal)	Angle detection (output)
a)Upper=low b)Right = low c)Down = low d)Left= high e)Dummy = low Signal is applied to the left sensor Result is 270 degree	
a) Upper =high b) Right = low c) Down = low d)Left = low e)Dummy = low Signal is applied to the upper sensor Result is 350 degree	
a) Upper =low b) Right = high c) Down = low d)Left = low e) Dummy = low Signal is applied to the right sensor Result is 90 degree	

Table 3 Example results of simulation of in between direction of the basic directions

Parameters Control signal (input signal)	Angle detection (output)
a)Upper =low b)Right = low c)Down = medium d)Left = medium e)Dummy = low Signals is applied to both down and left sensors The result is LD 222.75 degree	
a)Upper = medium b)Right= medium c)Down = low d)Left = high e)Dummy = low Signals is applied to both upper and right sensors The result is UR 166.85 degree	

3.1 Comparison of system without using fuzzy logic

Matlab Model for the system without using fuzzy logic controller

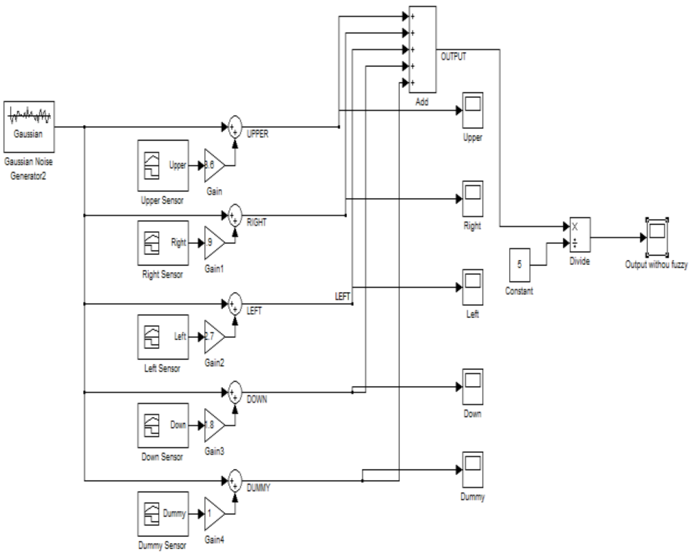
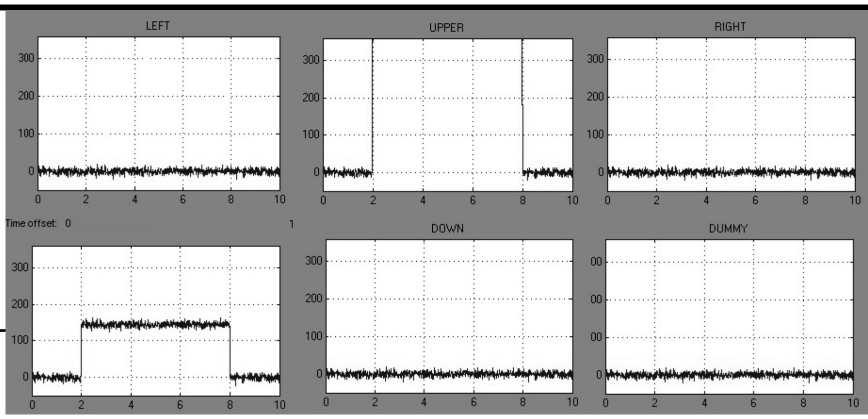
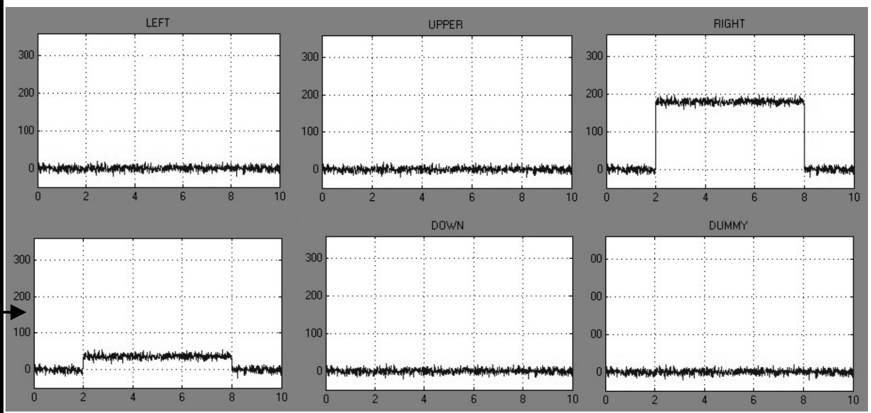
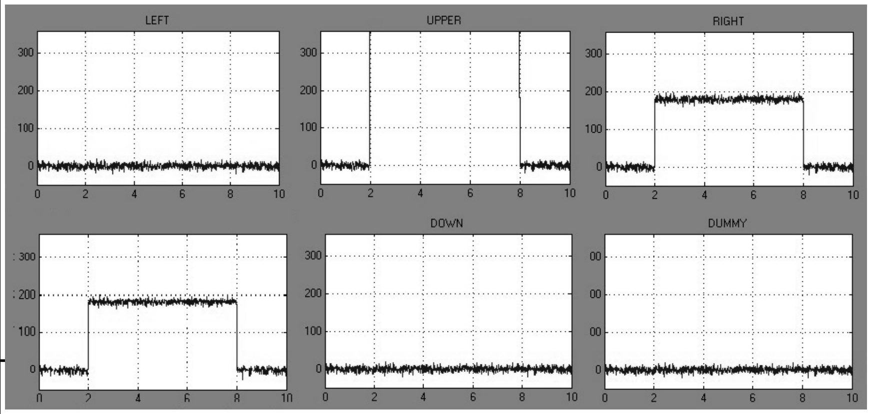


Fig 11 Matlab Model for the system without using fuzzy logic controller

Table 4 Example results of simulation of system without using Fuzzy

Parameters Control signal (input signal)	Output after Calculations (taking the mean of 5 sensors)
a)Upper =value *3.6 b)Right = 0 c)Down = 0 d)Left = 0 e)Dummy = 0 Signals is applied to upper sensor The result is 150 degree After taking the mean value .	
a)Upper =0 b)Right = value*0.9 c)Down = 0 d)Left = 0 e)Dummy = 0 Signals is applied to upper sensor The result is 60 degree After taking the mean value .	
a)Upper =value *3.6 b)Right = value*0.9 c)Down = 0 d)Left = 0 e)Dummy = 0 Signals is applied to upper sensor The result is 180 degree After taking the mean value of the 2 sensors	

4. Hardware Implementation and Verification Using TI MSP430

4.1 Introduction

This project aims is to detect the direction and estimate the angle of incidence of laser in military battlefield by using MSP430f2274 experimenter boards and the eZ430/RF2500 wireless development tools. Laser sensors attached to MSP430f2274 can be applied in many military types of equipment, for example. By placing it in certain directions in the vehicle and aircrafts, the information and direction of incidence of laser can be obtained from a PC collecting the information from all the sensors using fuzzy algorithm.

It is important in this stage to find a way to verify the functionality of the laser sensor model on MSP430f2274 experimental board, The basic way to do that is to build it and test it by incidence a laser beam toward the sensors attached to the microcontroller and then compare the results coming from the sensors to detect the direction and the angle of incidence of laser. In this chapter, the model circuit has been built and tested. The results for the sensor have been compared to the calculation, simulation and field trials results and show a good correspondence.

There may be similar projects before. However, with the ultralow-power MSP430 family microcontrollers [15]and the CC2500 RF transceivers, the system cost could be reduced, which prolongs the lifetime of the model without the need for changing the batteries, and the performance could be better. Furthermore, the nodes can be easily equipped with other types of sensors (e.g., chemical, biological, etc.) to allow collecting other information from the environment.

4.1.1 Basic Methodology

The working steps for the experimental research setup are:

1. Reading the output of laser sensors from MSP430f2274 ,starting with one sensor then increase the number of sensors on the microcontroller till reaching to four sensors each in a certain direction indicating a certain angle .
2. Implementing a fuzzy algorithm and download it to MSP430f2274 microcontroller to calculate or estimate the direction of incidence of laser according to the output of each laser sensor.
3. Incidence a laser beams to the sensors and take the results directly from the microcontroller which is the direction (angle) of incidence of laser as a result of the fuzzy algorithm.
4. Comparison between the output results of the experiment and the simulation results taken before.

```
$HUB0,1:0120,N#
$HUB0,1:0118,N#
$HUB0,1:0105,N#
$HUB0,1:0116,N#
$HUB0,1:0112,N#
$HUB0,1:0163,N#
$HUB0,1:0231,******Light
$HUB0,1:0230,******
$HUB0,1:0120,N#
$HUB0,1:0116,N#
$HUB0,1:0107,N#
$HUB0,1:0109,N#
$HUB0,1:0117,N#


$0001,1:0069,N#
$0001,1:0069,N#
$0001,1:0075,N#
$0001,1:0077,N#
$0001,1:0080,N#
$0001,1:0082,N#
$0001,1:0085,N#
$0001,1:0078,N#
$0001,1:0150,******Light
$0001,1:0186,******
$0001,1:0083,N#
```

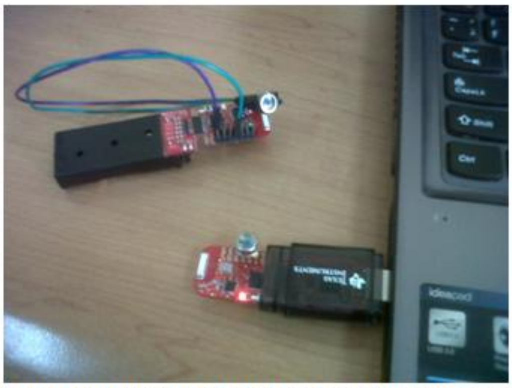
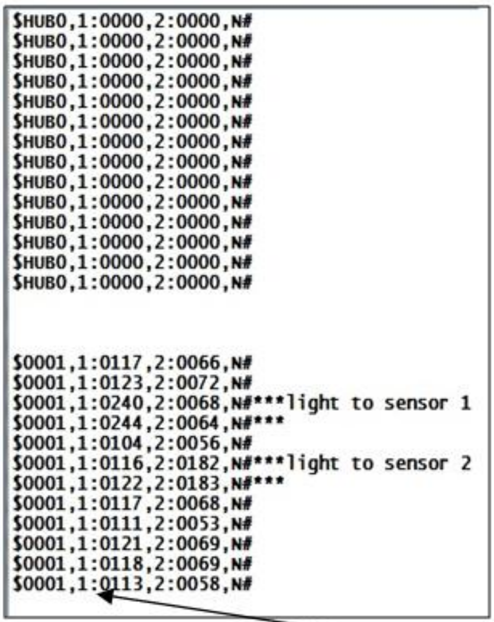


Fig 12 Reading the Output of each sensor on msp430 in each module

Laser Light



```
$HUB0,1:0000,2:0000,N#
$HUB0,1:0000,2:0000,N#
$HUB0,1:0000,2:0000,N#
$HUB0,1:0000,2:0000,N#
$HUB0,1:0000,2:0000,N#
$HUB0,1:0000,2:0000,N#
$HUB0,1:0000,2:0000,N#
$HUB0,1:0000,2:0000,N#
$HUB0,1:0000,2:0000,N#
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$HUB0,1:0000,2:0000,N#
$HUB0,1:0000,2:0000,N#
$HUB0,1:0000,2:0000,N#


$0001,1:0117,2:0066,N#
$0001,1:0123,2:0072,N#
$0001,1:0240,2:0068,N#***light to sensor 1
$0001,1:0244,2:0064,N#***
$0001,1:0104,2:0056,N#
$0001,1:0116,2:0182,N#***light to sensor 2
$0001,1:0122,2:0183,N#***
$0001,1:0117,2:0068,N#
$0001,1:0111,2:0053,N#
$0001,1:0121,2:0069,N#
$0001,1:0118,2:0069,N#
$0001,1:0113,2:0058,N#
```

Fig 13 Reading the Output of two sensors on msp430 wireless module only

Attaching the sensors to the battery board only

Fig 12,13 shows that the console session. View a real time output of all data. Node: Hub0 is access point. Node: 0001 is End Device.

4.1.2 Experimental Results

Results for different values of signal voltage output acquired from the microcontroller after attaching the laser sensors to the access point and end device given in Table 5. They are experimentally measured for the signal voltage output before and after incidence laser light.

The higher laser light, the bigger in the output signal voltage. These experimental results confirm that the sensor values changed after incidence a laser light on it.

Table 5 Experimental results, signal voltage output from msp430f2274

Access point (mV) (HUB0)	Presence of Laser light	End device (mV) (0001)	Presence of Laser light
120	No	69	No
118	No	69	No
105	No	75	No
116	No	77	No
112	No	80	No
163	Yes	82	No
231	Yes	78	No
230	Yes	85	No
120	No	150	Yes
116	No	186	Yes
107	No	83	No
109	No	80	No
117	No	81	No

Attaching the laser sensors to the end device only given in Table 5, These experimental results confirm that there is no confliction between the output of the sensors after attaching it to a single module .

Table 6 Experimental results, signal voltage output from battery board only

End device (mV) First laser sensor	Presence of Laser light	End device (mV) Second laser sensor	Presence of Laser light
117	No	66	No
123	No	72	No
240	Yes	75	No
244	Yes	68	No
104	No	64	No
116	No	56	No
122	No	182	Yes
117	No	183	Yes
111	No	68	No
121	No	53	No
118	No	69	No
113	No	69	No
117	No	58	No

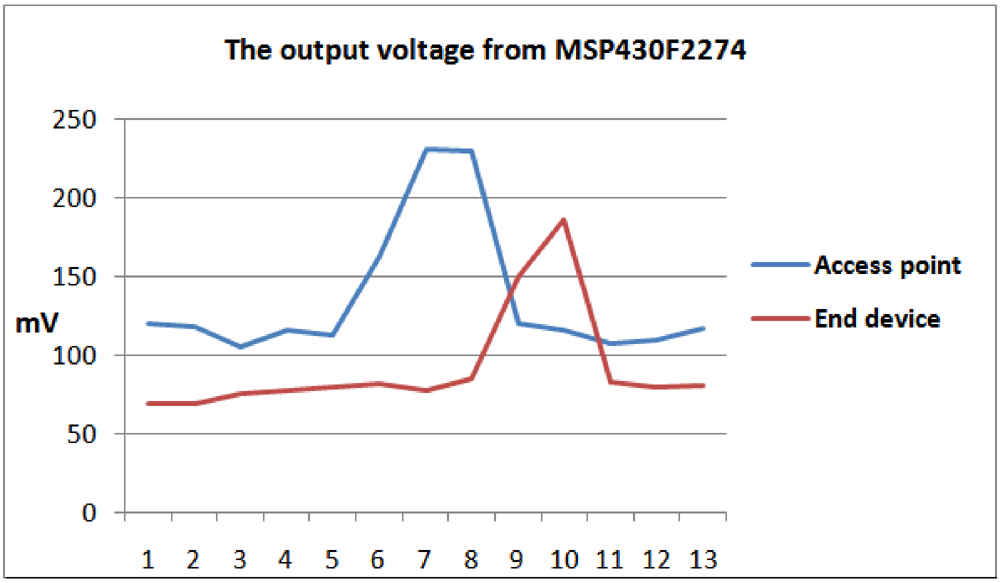


Fig 12 The output voltage from MSP430F2274 after incidence a laser light

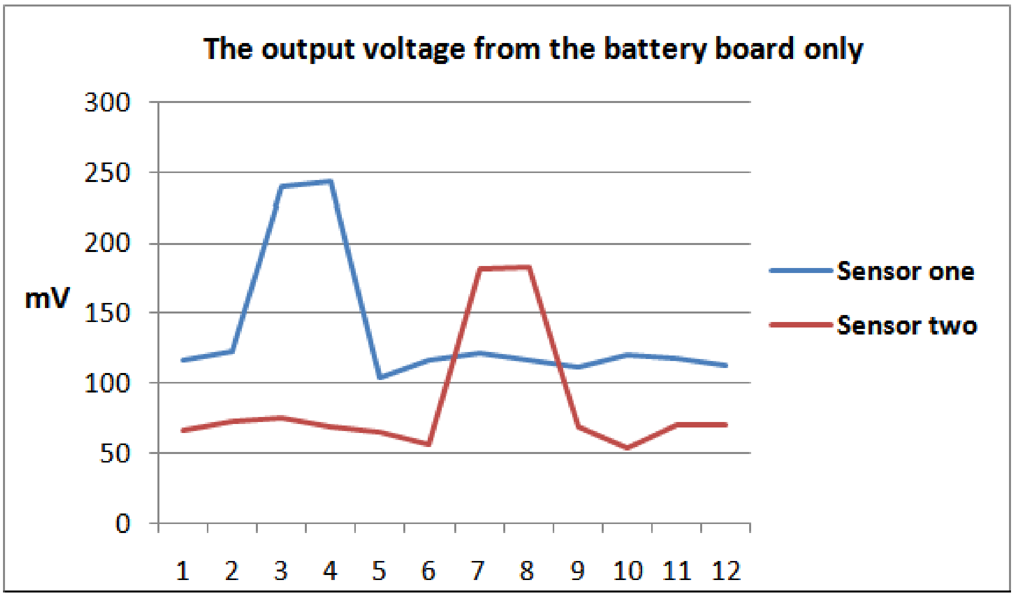


Fig 13 The output voltage from the battery board only of MSP430F2274 after incidence a laser light

4.2 Hardware implementation for laser angle detection

To evaluate our proposed approach, a complete test bed has been set up in our laboratory. We used two sensors to observe the output angle resulted from them. the sensors nodes are deployed in such a way that they connected to the end point of the MSP430f2274 and communicate with the access point (AP)node which, based on predefined rules (like table1) and the reading appears on the pc using GUI, so a laser is directed to one of the two sensors each of them represent a certain direction with a certain angle of incidence of laser ,then the laser is directed to both sensors and the reading is to be taken in both situations according to the rules of fuzzification and output angle will be resulted due to the fuzzy algorithm downloaded to the msp430 microcontroller and displayed on the screen of the pc due to the connection with AP module of the MSP430f2274 .

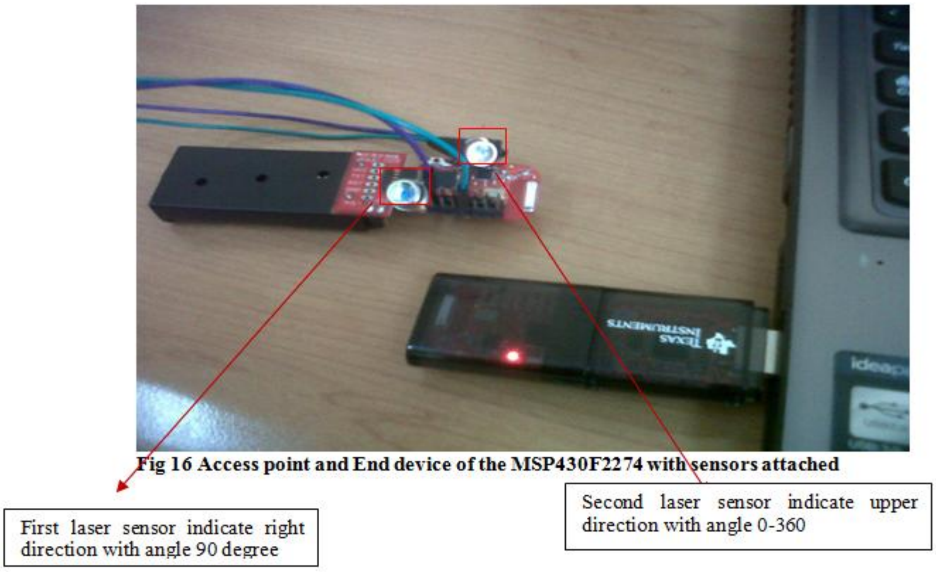


Fig 14 Access point and End device of the MSP430F2274 with sensors attached

The outputs of the system will be one of four options, when we test (right and upper sensors) 0, 45, 90, or 360 which represent the possible warning indicators. These outputs can be seen in Fig 13. In that Fig the outputs are due to taking the reading from two specific sensors, testing both the right sensor with the upper sensor.

4.2.1 Detecting the output angle using two sensors

In order to examine the results of fuzzy algorithm between the four sensors, we examined the results between each two sensors by incidence a laser beam on sensors (upper & right) (right & down) (down & left) (left & upper) separately as follows:

Table 7 shows the experimental results of proposed system using two laser sensors

Right output voltage (mV)	Upper output voltage (mV)	Resultant Angle	Description
84	44	90	Upper is low Right is medium Angle 90 degree
90	52	90	
84	47	90	
78	41	90	
42	49	0	Upper is low Right is low No dangerous
35	46	0	
40	49	0	
42	44	0	
43	52	0	
19	41	0	
19	53	0	
49	91	360	Upper is medium Right is low Angle 360 degree
48	90	360	
46	88	360	
46	88	360	
46	89	360	

47	90	360	
50	93	360	
104	72	45	Upper is medium Right is medium Angle 45 degree
93	71	45	
100	79	45	
99	80	45	
100	80	45	
100	80	45	
98	78	45	
102	75	45	
97	78	45	
102	78	45	

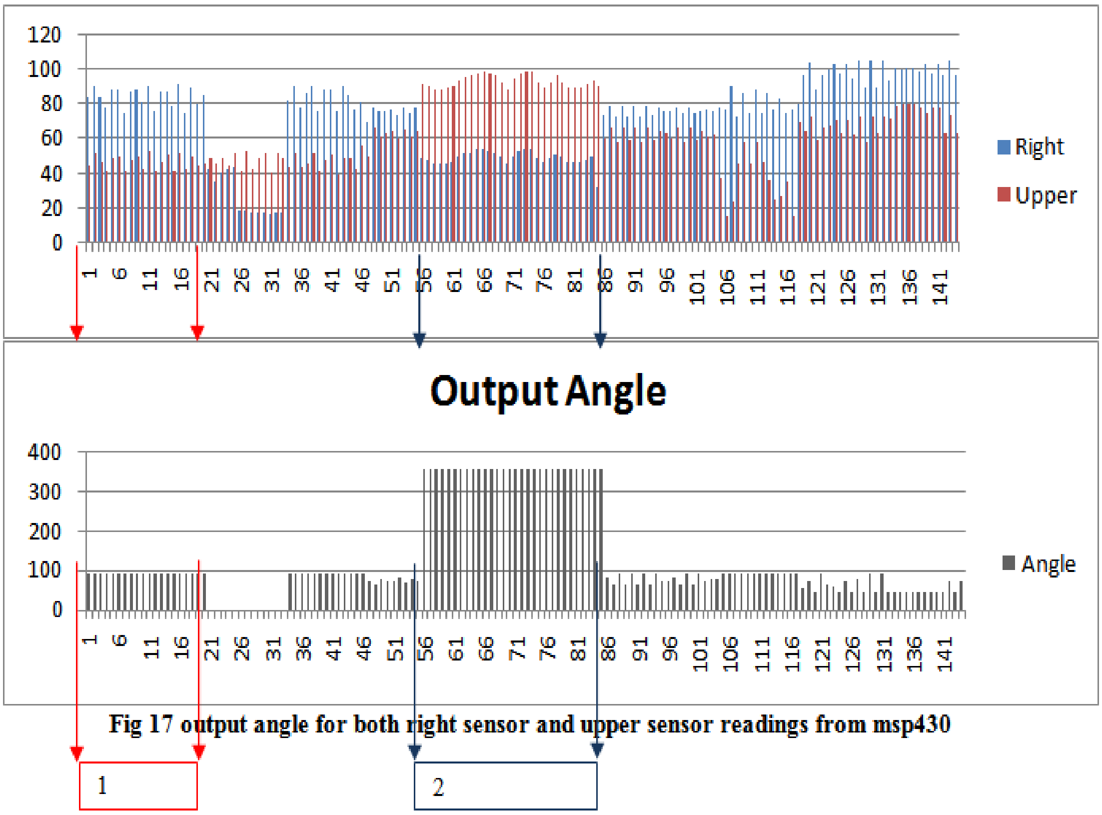


Fig 15 output angle for both right sensor and upper sensor readings from msp430

In the previous graph the rules of fuzzification between the two sensors is resulted in output angle between 90 (right), 360(upper), 0 (no dangerous) and 45 (angle in between) as follows:

1. The right sensor outputs a *medium* value voltage (60 - 140mv) while the upper sensor outputs a *low* value voltage (0 - 60mv) so the fuzzy output will be towards the right angle detection 90 degree because the right sensor give an output voltage more than the upper sensor as shown in the graph from 1 - 21 (red arrow)
2. The upper sensor outputs a *medium* value voltage (60 - 140mv)while the right sensor output *low* value voltage (0 - 60mv)so the fuzzy output will be towards the upper angle detection 360 degree because the upper sensor give an output voltage more than the right sensor as shown in the graph from 56 -86 (blue arrow) .
3. The right sensor outputs a *low* value voltage (0 – 60mv) also the upper sensor outputs a low value voltage (0 - 60mv) so the fuzzy output will be no dangerous (0) as shown in the graph from 21 to 36 in output angle graph.

4.2.2 Detecting the output angle using four sensors (each represent certain direction)

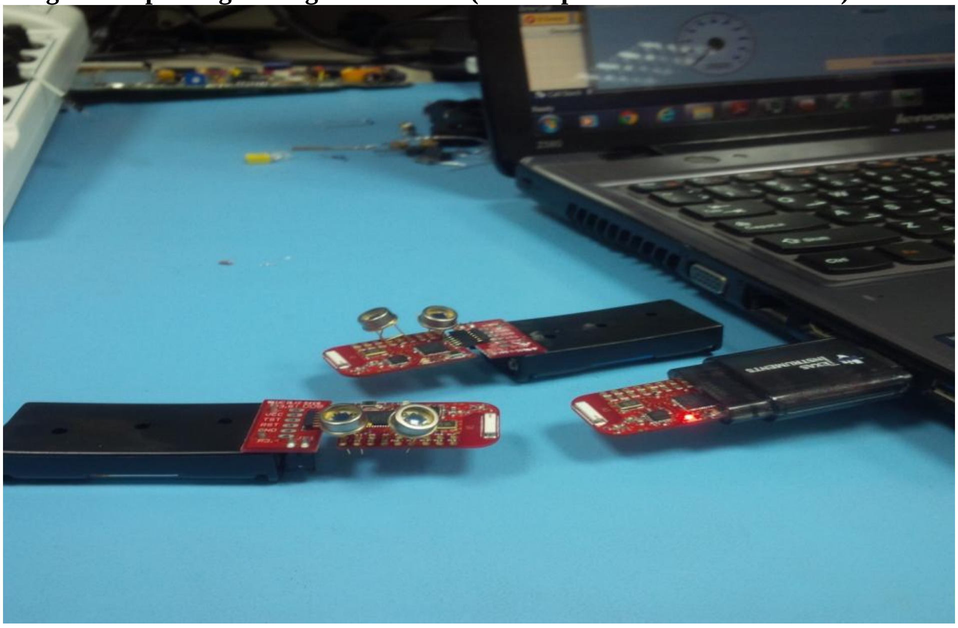


Fig 16 test bench setup using four sensors transmit the signal wirelessly

4.2.3 Graphical user interface implementation

A graphical user interface implemented in Lab View allows the detection of the angle of incident of laser using four sensors shown in Fig 17,18. The user can set the value of each sensor, while the angle is shown as numeric value colored in red and also shown on the RPM-Measure angular gauge.

4.3 System testing and Verification

The Practical System Implementation of a single Node has been tested using a GUI written using C sharp language as shown in (Fig 19). Also an experiment has been done to verify the system response, and to Fig out the false alarm and detection ratio. This experiment shows that after 500 runs, the detection ratio is 92.3% and the false alarm ratio is 7.7% as indicated in (Fig 20).

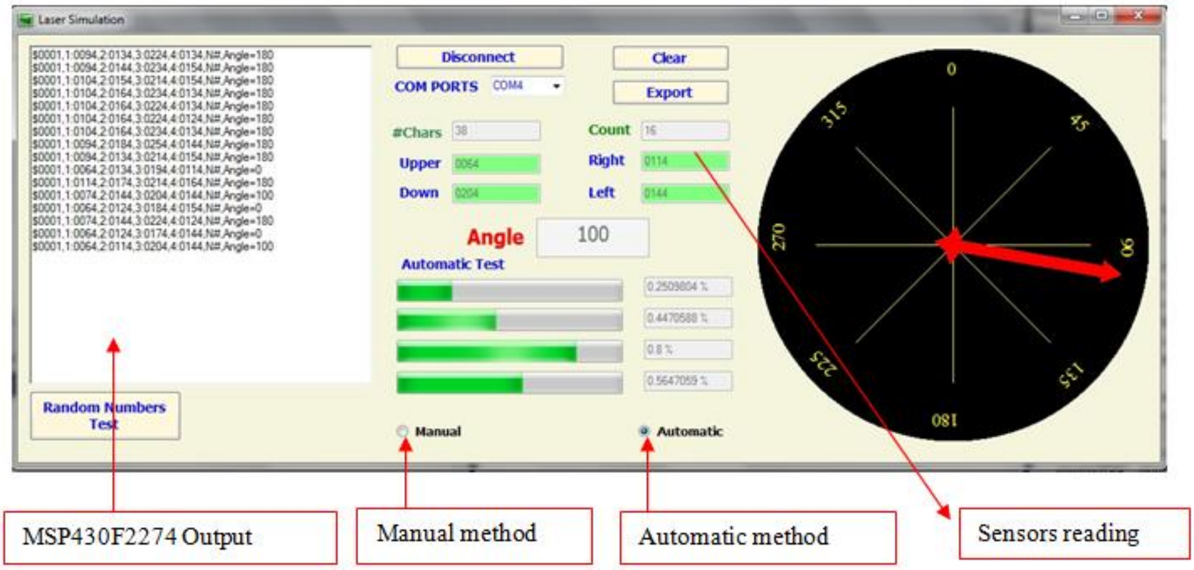
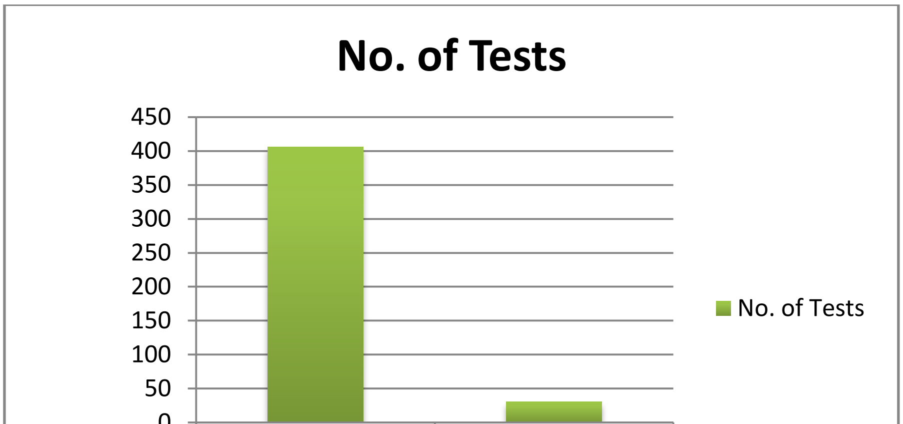


Fig 19 Graphical user interface for laser angle detection (automatic mode)



	Detection	false Alarm Ratio
No. of Tests	406	31

Fig. 20 Tests experiment

III. Conclusion

This paper has described the research work performed designing, developing, and testing a new laser sensor model, using Matlab and Simulink software. It has examined the laser warning systems to guided weapons especially low power lasers in guidance systems. The idea to do this project came as a result of the unexpected poor performance of a number of warning systems during field trials. The bad weather conditions, the high temperatures, and other factors were the reason to initiate this project. The goal was to help find a solution for these systems to do their job in protecting the tanks and armored vehicle crews and other equipments from such a threat.

The objective of this work was to study the reasons for the performance degradation of the laser warning systems in the weather conditions and to develop and recommend optimization of their structure, characteristics and hence increase the overall performance. Moreover, developments of counter-measures, which can deceive laser beam-riding anti-tank missiles from destroying the armored and personnel carriers, were investigated.

The computer model has been developed to enable the assessment of all phases of a laser warning receiver. MATLAB & SIMULINK software have been used to build the model. During this process experimentation and field trials have been carried out to verify the reliability of the model.

The fuzziness mathematical models of laser angle detection parameters and fuzzy decision rules library of identifying laser angle are built, which are set up by using fuzzy decision theory. Professional system of fuzzy decision is designed using multiple sensors orientation.The objective of this work was building model of fuzzy logic controller for laser detection using multiple sensors. The proposed model of laser angle detection system was built in Matlab – Simulink. Simulation software and the proposed fuzzy logic system were designed using the Fuzzy Logic Toolbox.

The simulation results are tested and show good results.

This research addresses a problem of how to make effective use of real-time information acquired from multiple sensors in military battle field.

- The fuzziness mathematical models of laser angle detection parameters and fuzzy decision rules library of identifying laser angle are built, which are set up by using fuzzy decision theory.
- Professional system of fuzzy decision is designed using multiple sensors orientation.
- This research addresses a problem of how to make effective use of real-time information acquired from multiple sensors in military battlefield.
- The implementation of a wireless low-cost low-power embedded application wireless MSP430 2.4-GHz wireless target boards are used for the wireless communication. A laser angle detection algorithm is implemented on the MSP430F2274 microcontroller.

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