

Original Research Article

Hardware Efficient Scheme for Indoor Environment Using Grid Mapping

ABSTRACT: Robotic Navigation is a key aspect in mobile robotics. This paper presents about the grid mapping algorithm for navigation of a robot which is controlled by an FPGA. The environment is divided into the grids where Landmarks are considered as grid points in the environment. The proposed path planning is also developed with obstacle avoidance mechanism to overcome the obstacles in robust environment. The robot navigation efficacy improves with the landmarks and hardware scheme. The hardware scheme is developed with an NI lab view and implemented on Spartan 3e FPGA. The FPGA's are best in parallel processing comparatively with other control devices.

Aim: Navigation of FPGA based Autonomous robot efficiently towards the target using grid mapping technique.

Study design: The study of path planning methods. Among that efficient path planning is proposed with landmark by using grid mapping. Developed the hardware scheme for proposed algorithm.

Place and Duration of Study: Padamasri Dr B V Raju Institute of Technology, Narasapur, Medak (Dist), Telangana, 502313. Duration of study in 2014-15.

Methodology: Hardware scheme for autonomous robot navigation.

Results: Simulation results of proposed algorithm and experimental results with snapshots

Conclusion: Navigation of Autonomous fpga based robot with a hardware scheme by parallel processing and using grid mapping methods.

Keywords— Path Planning, Hardware, Landmark, Obstacle avoidance, FPGA.

1. INTRODUCTION

Robotics is one of the most important fields in automation sciences, where assistance is improved in different areas of mankind like health, agriculture, transportation, service industries and so on. The mobile robots play vital role in automation and also in providing services. The researchers have proposed different navigation methods or algorithms for the mobile robots in both indoor and outdoor environments for last three decades. The importance of navigation with minimal sensing has increased in present scenarios. The mostly known path planning algorithms are as like D*, A* algorithms are used for navigation of robots.

Many algorithms have come into existence for computing the shortest path which has some merits and demerits. Palatino's graph growth algorithm implemented with two queues (TWO-

22 Q) algorithm which is useful for path routing on road networks. This algorithm spends a lot of
23 time on useless work when the shortest path is relatively short. An improved version of
24 TWO-Q is Mild-TWO-Q algorithm which reduces the time to reach the shortest path [1].

25 Though conventional quad tree-based path planning approach is simple, robust and efficient
26 has some limitations. Dijkstra's shortest path searching algorithm, a fast path planning
27 overcomes the limitations of the quad tree by optimization of a path graph for both efficiency
28 and accuracy is proposed in [2].

29 In real time applications, path planning in known or unknown environments is a difficult job.
30 The D * algorithm is implemented for path planning in partially known environments with the
31 help of sensor information. For effective path planning, improved version of D* algorithm
32 based grids is studied in [3].

33 RFID-assisted indoor localization and the impact of interference on its performance [4].
34 Performance-based evaluation of RFID-based indoor location sensing solutions for the built
35 environment is studied in [5]. Improving location awareness in indoor spaces using RFID
36 technology [6].

37 To find out the appropriate shortest paths in a convex polygonal environment, by reducing
38 the visibility graph a new parallel algorithm is developed and its FPGA implementation is
39 studied in [7]. Several practical applications that require high-speed shortest-path
40 computations are developed by field programmable gate array (FPGA) -based accelerator to
41 achieve high performance at low cost. Bellman-Ford algorithm adapted to solving the single-
42 source shortest-path problem in a fast and efficient manner [8]. The proposed algorithm is
43 carried out on FPGA (Spartan 3E) due to its high features like less power consumption and
44 parallel processing nature [9]

45 Presently, services for humans are provided by the robots, but all these robots prefers the
46 path planning based on the particular identity like track. Track type of path planning has its
47 own limitations like less self intelligence which fails to extend their services in all directions
48 of the indoor environment. The Landmark determination method overcomes the track issues
49 by proposing algorithm in service robots, by estimating its current position and improves self
50 intelligence. When the robot is assigned to a desired task, it establishes a relevant path from
51 the source to the destination with landmarks in the mapping environment. Path planning
52 without track can increase the abilities of robot with minimum resources and fulfils the task in
53 short span of time. The proposed path planning is also developed with obstacle avoidance
54 mechanism to overcome the obstacles in robust environment.

55 This research work summarizes in different sections like Section 1 introduces the
56 introduction of robotics path planning and also the importance of landmark determination.
57 Section 2 presents the proposed algorithm with necessary environments and environments.
58 Section 3 gives VLSI architectures for proposed algorithm with the explanation of individual
59 blocks. Section 4 deals with experimental setup and results . Section 5 concludes with
60 conclusions and future scope.

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63 2. PROPOSED PATH PLANNING ALGORITHM

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65 The interest of authors is to develop assistive methods to reduce the human efforts by using
66 robots in service oriented indoor environments. The main theme of this chapter is to develop
67 an autonomous FPGA based robot of self intelligence which can assist in the service
68 environment to perform various tasks by sensing its location with the help of Landmark

(RFID) tags. The environment is mapped initially with defined parameters like distances between one location to another location. When a robot receives a task by the external world, it assesses all the possible probabilities for different paths to reach indeed destination. Among all probabilities it looks attentively at the low weight, distance path as the shortest route by comparing the distances from present location to the desired task destination using FPGA hardware.

The obstacle detection and obstacle avoidance is one of the major issues to reach the destination successfully. It can easily detect all the obstacles through ultrasonic sensors and avoids by obstacle mechanism which is developed in FPGA control unit. The mobile robot equipped with eight ultrasonic sensors and RFID reader is configured to the robot such that it can be capable of estimating particular location and move towards the destination. With the help of these devices (ultrasonic sensor and RFID) which are of being low cost, the robot can easily accomplish any kind of navigation task.

An RFID system is a pair of RFID Reader and RFID Tag. A radio frequency identification reader (RFID reader) is a device used to collect information from an RFID tag. All RFID tags are unlike to each other and contains the unique ID about a particular location

RFID system works under the phenomenon of electromagnetic. RFID reader has an antenna and creates a electromagnetic field in its surrounding areas. When the robot moves close to the RFID tag, the tag gets activated by the emission of electromagnetic field emitted by an RFID reader. The RFID reader reads the tag's unique value which is under the electromagnetic field and stores in stack memory. It gathers all the tag data sequentially in the given environment and stores in a stack memory. After receiving all the available tags it evaluates its current position and take appropriate action to reach the next step. In this manner, it moves step by step based on the collected data.

Ultrasonic sensors are used to detect the obstacles and avoid the obstacles by easy method of distance measurement (PWM). The sensor continually transmits an ultrasonic wave. When the ultrasonic wave hits the obstacle, it gets reflected to the sensor as echo signal. By measuring the echo pulse width, the distance of the obstacle can be easily calculated. By knowing the distance value the robot changes its direction with the help of stepper motors into the path where there are no obstacles. Finally, it traverses the path towards the destination.

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2.1 INDOOR ENVIRONMENT

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The indoor environment represents in Fig1, it consists of six different Halls like Hall A, Hall B and so on Hall F. Respective RFID tags are placed at each hall. The current position of the robot is identified by using RFID tags. One of the experimental exemplar is followed by considering the desired task as Hall 'F', when the robot is localized at Hall 'A'.

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The weights of the path distance of different path probabilities between starting Hall 'A' to destination Hall 'F' are evaluated. The comparison circuit between path distances concludes the shortest path. The same path is defined as the trajectory of the robot, in this example shortest path is A-D-E-F. All these computations are done in control unit of the FPGA.

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Robot continually checks for RFID tag values, then moves towards the destination with respect to the path planning algorithm. The each Hall is having subset Landmarks for example Hall A by A1, A2, A3 in the localization of the robot. This subset values is used for accurate path planning by the correction and prediction module.

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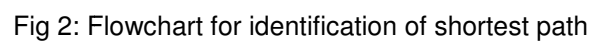
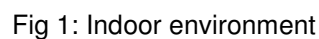


Fig 2: Flowchart for identification of shortest path

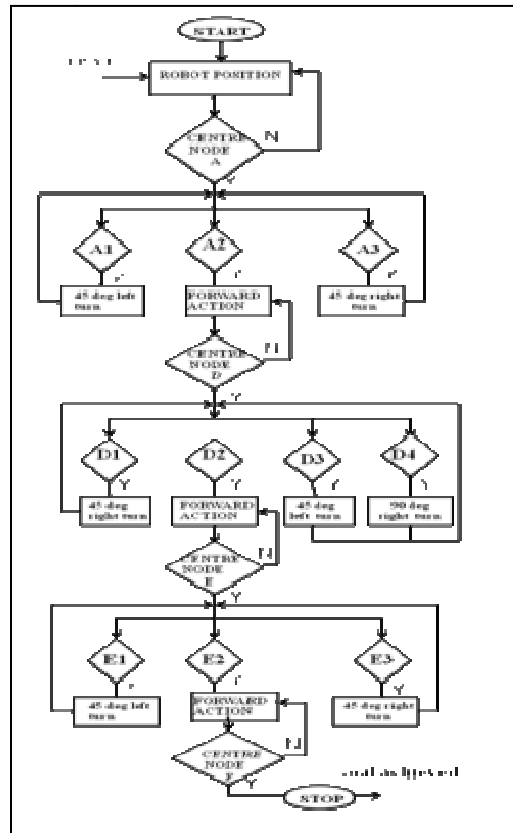


Fig 3: ASM Chart for Path Navigation

2.3 PSEUDO CODE FOR THE PROPOSED ALGORITHM

Algorithm Steps:

STEP 1: The Localization of the robot is performed by capturing the landmark by RFID system.

STEP 2: The next level of algorithm is assigned by desired task. The Probability Path Analyzer module gives the shortest path between source to destination node as shown in Fig 2.

STEP 3: The robot starts at source point and traverse towards the destination point by using the RFID landmark. Each Hall has few subset landmarks, it provides perfect direction to traverse towards indeed destination.

STEP 4: In trajectory of the robot, it also visits the other Halls to reach the final destination node. In this process the correct module internally having computation method which always checks the visited Hall and gives the next Hall of the trajectory to achieve proper path planning. The path traversing has shown with flow chart in Fig 3.

STEP 5: when the robot reaches for final Hall, it compares with destination Hall and concludes as a goal.

Remark 1: After evaluation of different path probabilities at step 2, one of the examples Hall 'A' considered as start and Hall 'F' as the destination. The shortest trajectory of the robot between A to F presents as A- D -E – F path as shown in Fig 2.

Remark 2: According to the example the robot start from 'A' and feed forward up to 'D' landmark. If any subset of 'D' landmark is achieved, it considered as D and corrects the next direction of the path as shown in Fig 3. This action performed by correction and verification module. It repeats similar method for all Halls.

3. VLSI ARCHITECTURE OF PROPOSED ALGORITHM

The Proposed algorithm architecture is deployed on FPGA and navigated successfully. The sensor modules are used to estimate the distance with pulse width modulation technique. Minimum distance finder exhibits output for each sensor. The angles are known in path planning by digital compass module with UART protocol. The CORDIC IP CORE module has been used for trigonometric computations. The soft core odometer module is a special technique developed for computing odometer distance without external devices. The CU also bridges the communication between the FPGA and external devices like sensor and compass. It performs parallel processing in sensing the information, odometer and angle computations and, other than these, the motors are driven by motor logic control, the actions required are synchronized with device clock frequency.

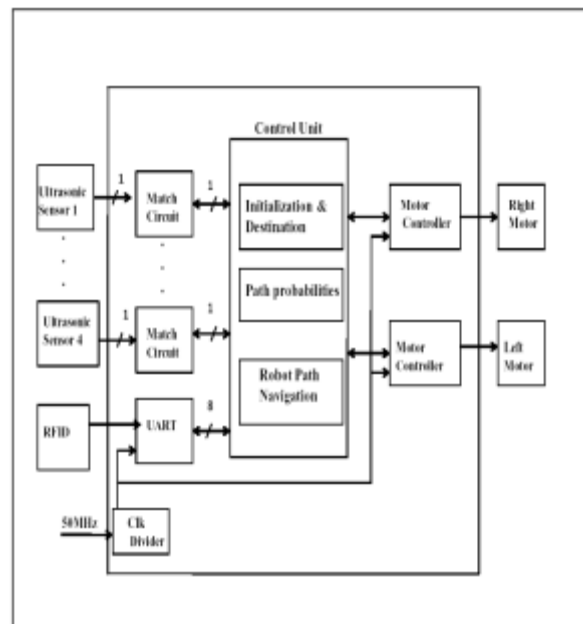


Fig 4: Overall VLSI Architecture of Proposed algorithm in indoor environments.

3.1 INITIALIZATION AND DESTINATION MODULE:

This module comprises of very first job whenever a task is given to the robot. This module particularly helps to know its initial position, with the help of RFIDs. Initially the robot gets a two tag values which indicate a source and destination. Among them it considers first Tag

252 value as source point and second as destination point. All the tag values which are under
253 given environment are stored in a stack memory. When robot receives two tag values it is
254 compared to the tag values which are already in the stored in the memory and comes to the
255 conclusion with a particular Halls as a source and destination.
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257 3.2 PATH PROBABILITIES MODULE:

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259 This module is followed by initialization and the destination. By receiving the source and
260 destination, it checks for all probabilities and chooses a feasible path which is of low weight
261 age using comparator circuit.
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263 3.3 ROBOT PATH NAVIGATION:

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265 This module comprises of correction circuit. From the above module it gets the shortest path
266 to navigate towards the destination. Correction circuit helps the robot to choose appropriate
267 subsets by taking required angle and enters into next Hall.

268 3.4 MATCHING CIRCUIT:

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270 The matching circuit comprises of the comparator and FIFO. The signals from the ultrasonic
271 sensors are converted into pulses. With these pulses the distance of an object can be
272 obtained. Now, the obtained distance value is compared with matching circuit whether to
273 focus the obstacle or to discard the obstacle. Similarly, all the RFID Tag values are stored in
274 the FIFO and gives the appropriate signals to the control unit to perform the required action.

275 3.5 UART MODULE

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277 The UART is a serial communication protocol used to interface RFID to the robot. The 12
278 byte data on RFID Tags are transmitted to control unit through the UART protocol.

279 3.6 MOTOR CONTROLLER MODULE:

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281 Depending on RFID & Ultrasonic inputs, the control unit produces specified signals to motor
282 controller module. Which helps the robot to move in all required directions like left action,
283 right action etc.

284 3.7 FPGA (Control Unit):

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286 Here the control unit is Xilinx board XC3S2000 (FPGA Spartan 3E). In this research FPGAs
287 are preferred due to its parallel processing nature. The control unit controls all the devices
288 and navigates the robot to reach the destination.

289 4. EXPERIMENTAL SETUP & RESULTS

290 4.1 Experimental Setup:

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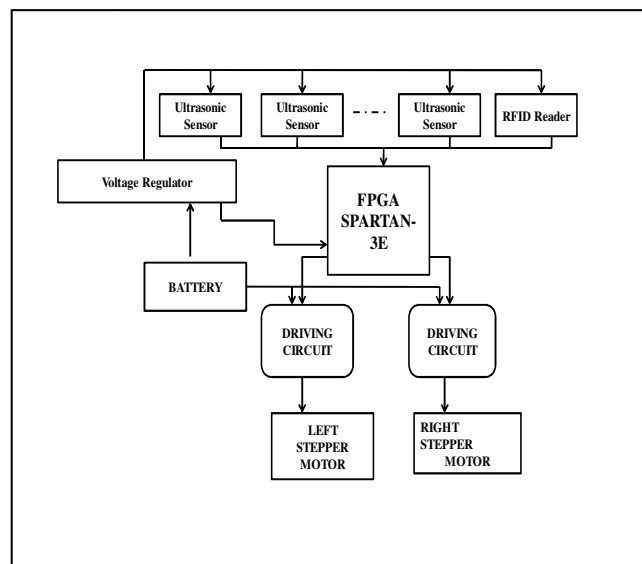


Fig 5: Block Diagram of Robot with FPGA

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296 The above fig5 shows the experimental setup to perform the given task. The heart of this
 297 setup is an FPGA (SPARTAN 3E), it receives signals from the ultrasonic sensors and
 298 RFIDs and generates appropriate signals to stepper motors through the driving circuits.

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300 4.2 SIMULATION RESULTS:

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302 4.2.1 Initialization module

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Fig 6: Simulation results of initialization module

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Source location	RFID Tag
A-001	51,52,53
B-010	54,55,56
C-011	57,58,59
D-100	60,61,62,63
E-101	64,65,66
F- 110	67,68

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310 In the above waveform, robot localizes its position by depending on the RFID data. Here Hall
311 A, Hall B..... Hall F is the different Halls in a given environment, having different number of
312 RFID tags. When an RFID reader reads the data from the RFID tags the control unit checks
313 the data is from which Hall and gives the appropriate initial location of the robot.

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315 4.2.2 DESTINATION MODULE:
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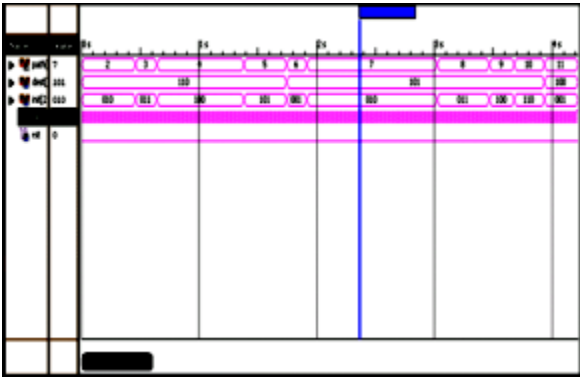


317
318 Fig 7: Simulation results of destination module
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	RFID Tag
A-001	51,52,53
B-010	54,55,56
C-011	57,58,59
D-100	60,61,62,63
E-101	64,65,66
F- 110	67,68

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321
322 In the above waveform, robot evaluates the destination from external source. Here
323 Hall A, Hall B..... Hall F is the different Halls in a given environment, having different number
324 of RFID tags. When an RFID reader reads the data from the RFID tags the control unit
325 checks the data is from which node and gives the appropriate Hall as a destination.
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330 4.2.3 PATH PROBABILITIES:
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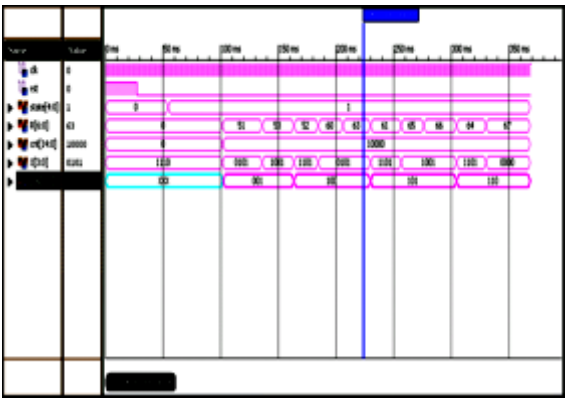
Fig 9: Simulation results of Path Probability module

Source & Destination	Path
A-001 & F- 110	A-D-E-F
B-010 & F- 110	B-D-E-F
C-011 & F- 110	C-D-E-F
D-100 & F- 110	D-E-F

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In the above waveform, the robot checks all the path probabilities for giving initial and destination locations. Among all the path probabilities, robot compares for the shortest path and navigates through that path.

342 4.2.4 ROBOT PATH NAVIGATION



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Fig 10: Simulation results of Navigation module

Location	Action ()
A-001	1001 (Right turn)
D-010	0101 (Left turn)
E-011	1001 (Right turn)
F-100	0000 (Stop)

In the above waveform, robot navigates through the shortest path to reach the destination. The robot moves through the path by depending on RFID tags. At each RFID tag it takes required action and moves forward to fulfil the desired task.

4.2.4 OBSTACLE AVOIDANCE:



Fig 11: Simulation results of obstacle module

In the above waveform, robot overcomes the obstacle and continues travelling on the desired shortest path. Here robot gets an obstacle between the subsets A&D, It avoids the obstacle and moves in through D, E & F nodes.

4.3 SYNTHESIS REPORT:

TABLE 1:Area consumption on Xilinx FPGA board Spartan XC3S2000

Block	No.of Slices	No.of 4 i/p LUTS	LUT Utilization
Matching Circuit	84	176	2%
Control Unit	838	1676	18%
US Sensor Module	67	114	1%
UART module	293	584	6%
Motor Logic Control	86	166	2%
Obstacle avoidance module	184	264	3%
Total	1551	2980	32%

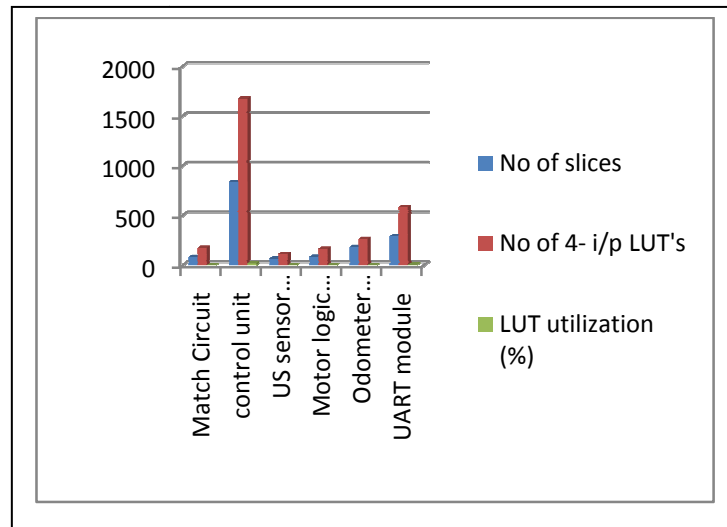
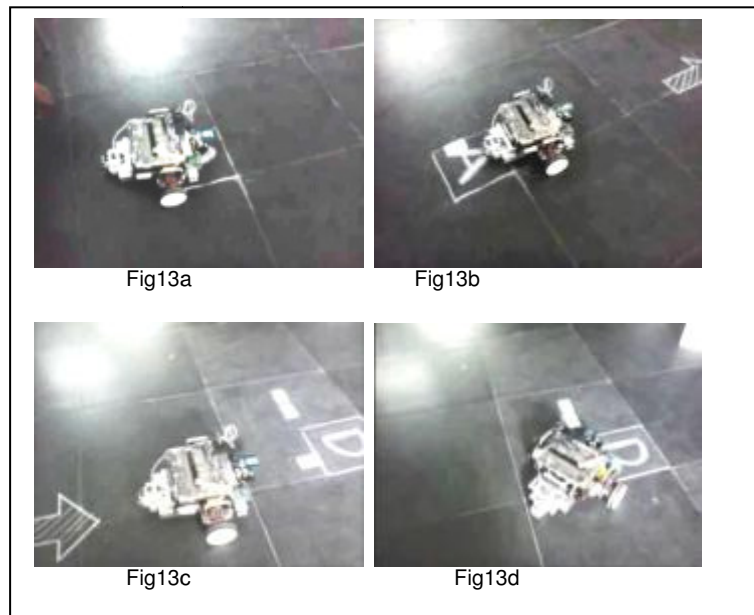


Fig 12: Analysis of Device consumption on FPGA board

4.4 EXPERIMENTAL RESULTS:



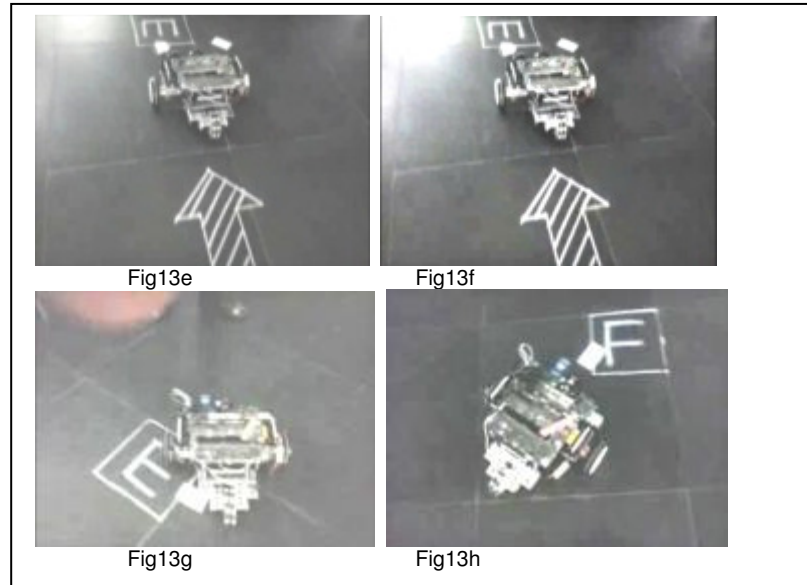


Fig13a-13h: Snapshots of Proposed algorithm's experiment results

4.5 Comparison results:

The other robot path planning algorithms like D*, A* is not perfectly fitted towards service environment. The proposed algorithm perfectly drive the robot path by landmark determination. The efficiency is improved in driving the path and hardware scheme made parallel processing with low power consumption.

5. CONCLUSIONS

This Paper presents path planning in service robot in a robust environment. In this research work, the usage of landmarks increases the abilities of a robot in knowing its current position. Its performance evaluation and conducted experiments in the defined environment have been done successfully in the laboratory. The FPGA energy consumption is only 9.64 Joules during obstacle avoidance and path planning for this experiment.

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