M7-021 The Development of Fire Fighting Robot Algorithm for Navigation using Proximity Sensor and Digital Compass

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Abstract

Fire Fighting Robot (FFR) is a type of robot that competes in the Smart Robot Contest in Indonesia (KRCI). This competition places importance on a robot's abilities to recognize its environment and navigate in the arena in order to complete its mission to put out the flame of a candle. To navigate itself, FFR is very dependent on its inbuilt sensors, as well as the algorithms used. This paper explains FFR's algorithm model with the help of the State Flow toolbox from MATLAB. This study used three proximity sensors and a digital compass as navigation tools so that FFR can finish the mission faster and saver.

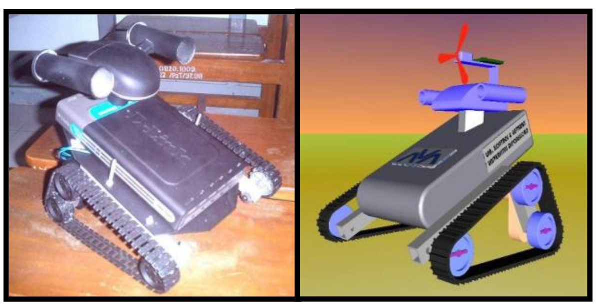
Keywords: Fire Fighting Robots, FFR, Navigation, Algorithm, Digital Compass

1. Introduction

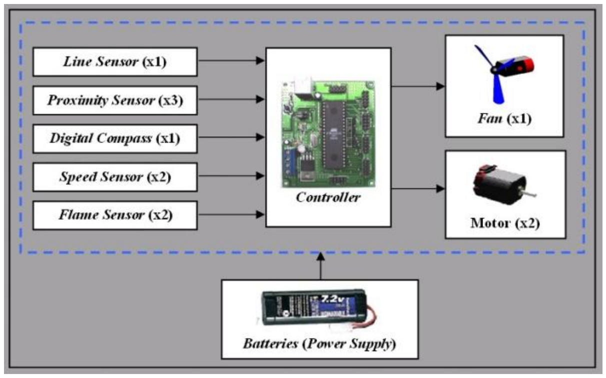
Fire Fighting Robot (FFR) is an autonomous robot in which the robot does not require operator assistance (human) directly to complete its missions or duties. Instead, the robot has an embedded program in it or an artificial intelligence algorithms that have been made by the operator.

FFR contested every year by many countries including Indonesia, which is known as the KRCI. Where the rules are adopted from Trinity college, in the USA. Basically the main task of the FFR is to turn off the fire in the form of a candle placed in a room in a labyrinth that has been determined with the regulations[5] and return to home as soon as possible.
This paper describes how the development of algorithms that may be performed using three distance sensors and a digital Compass as the robot's navigation, and represents it on an animated movement of a robot based on the algorithm used earlier so that it easier to analyze any improvement in the new design.

The FFR has been developed to meet contest rules in [6]. As shown in Fig. 1, it is designed as a tracked vehicle with differential drive controlled by a unique algorithm embedded in its microcontroller. The control system the FFR shown in Fig. 2 will be mathematically modeled including its environment, which is the arena used in the competition shown in Fig 3.
After designing the FFR and the algorithm, this study tries to remodel it on virtual reality environment, which is nowadays the trends of simulation has become more
popular and widely used. Since with simulation an engineer can easily plan and decide and of course, it is safer and also cheaper. For example like in driving simulator[3], pilot ROV learning[4] and and even when engineers want to build something big such as a ship[2] or an industry.



Fire Fighting Robot, Real and Animation

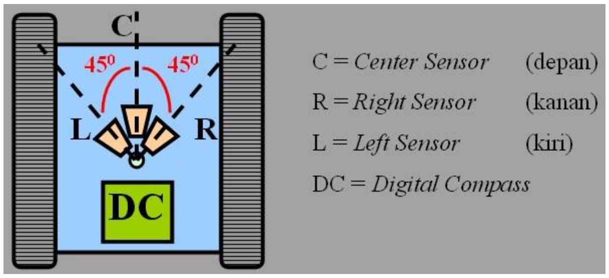


Control System of Fire Fighting Robot

Contest Arena of Fire Fighting Robot

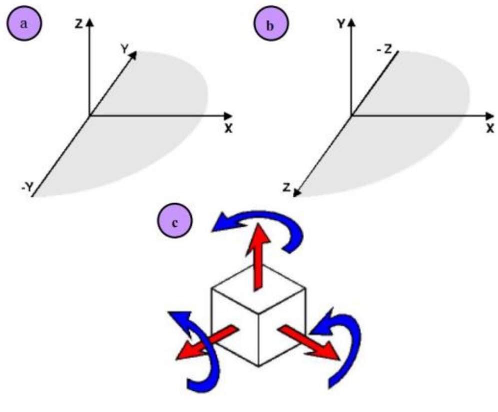
2. Sensors

All sensors installed on the FFR as shown in Fig. 2 are assumed to have relatively very high bandwidth such that there is no need to model their dynamics. However, for the proximity sensors, the characteristic of GP2D12 infrared sensor is used[10]. Its calibration curve that relates the distance and the resulting voltage is incorporated to the simulation in order to reveal the effect of its nonlinear characteristic. The location of three proximities sensors from the top view of the FFR are shown in Fig 4. One proximity sensor is facing forward of the FFR noted as CF while two others are 45^o from CF to left and right. Using simple geometric distance equations, the effect of the location and orientation of these sensors are included besides the effect of FFR location and orientation in order to navigate in the arena without hitting walls.



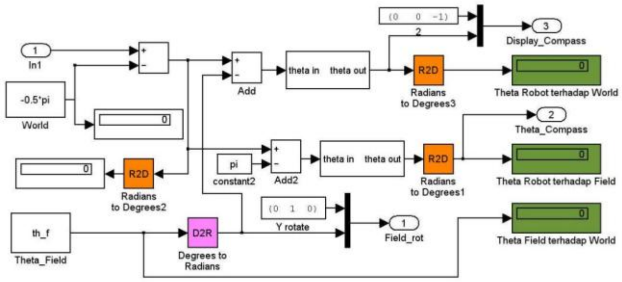
Location of Three Proximity Sensors And Digital Compass

A Digital Compass used as a navigation sensor is DEVANTECH CMPS03. Inside of the Digital Compass there is Magnetometer that can detects the condition of earth magnetism and Digital Compass itself has its own north, so when the Digital Compass is turned on, the Digital Compass will directly read the deviation between the north of the Digital Compass and the results of the Compass detection that it assumes to be the north of the earth.



(a) MATLAB coordinate, (b) VRML coordinate, (c) VRML turning rules

Since there are major different rules about coordinate system between MATLAB and VRML shown on Fig. 5, a comparable conversion on turn angle and the reset of angle value after its turn 360 degrees to 0 degree as shown in Fig.6 is needed



Digital Compass modeling

3. Navigation Algorithm

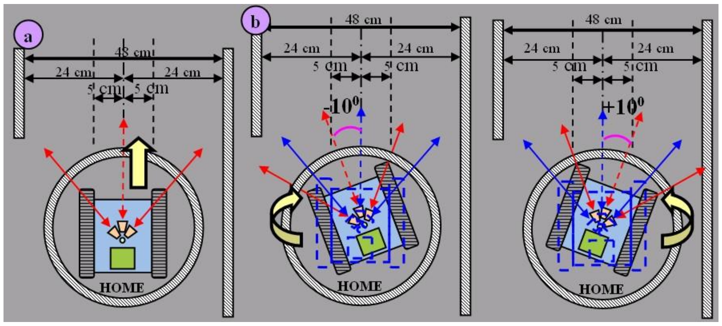
A navigation algorithm used for the *FFR* to move efficiently in the arena has been uniquely developed. The algorithm can be separated into three main tasks:

1. Navigation going through corridors
2. Navigation in rooms
3. Navigation to return home

3.1.Navigation through Corridor

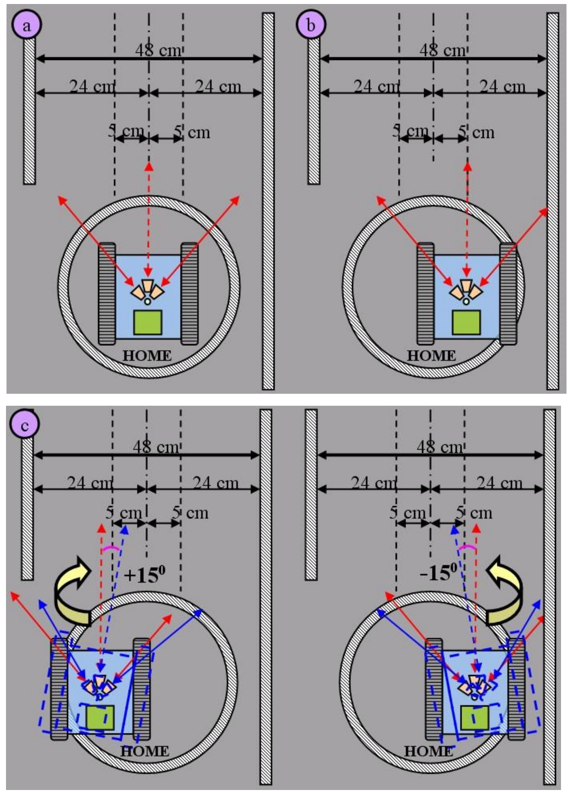
There are five basic motions that the FFR can perform in this task:

1. Angle correction and position correction. They are useful for the initial motion of the robot from home so that the robot will not touch the wall when it walks through the corridor. Angle correction algorithm is made to come near the real conditions where at the time a contestant usually put the robot in the home to run to start the mission. The angle of the robot is not headed front but there will be a small gap through the misplacement. With this algorithm, a robot is expected to head front when it departs from home so that the robot will safely move forward in the corridor without fearing there will be a collision with the wall. The principle of movement angle correction can be seen in Fig.7.

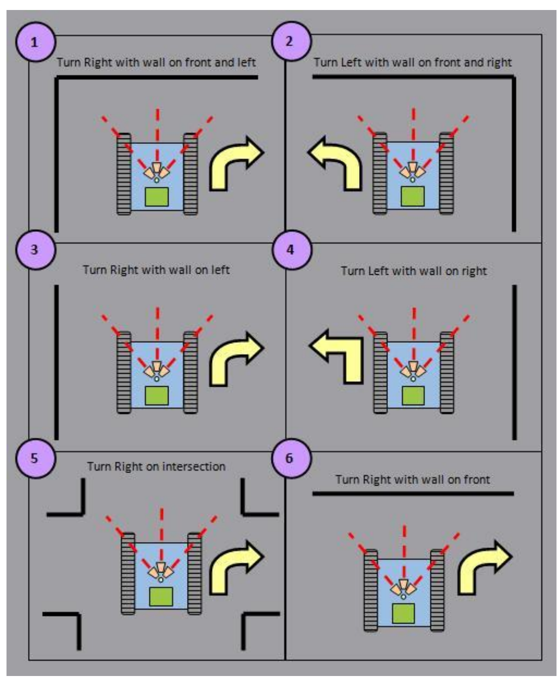


Angle Correction Algorithm

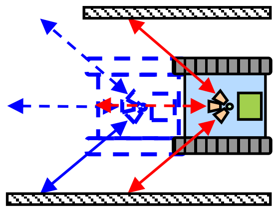
2. Similar to the angle correction algorithm, position correction algorithm is also made to come near the real conditions. At the time a contestant put the robot in the home before starting the mission, the distance between the left and right sensors are not exactly in the middle of the home so that the robot can touch the walls continuously or become disoriented. In principle, this study gives the value of tolerance -5 cm or + 5 cm from diameter of the home, when the right and left proximity sensors are still in tolerance then the robot can walk directly to accomplish the mission. If it exceeds the initial placement of the tolerance limit, the algorithm provides commands to a robot to head to -15^o when too close to the wall while the right +15^o when the robot was too far to the right wall. The principle movement of position correction can be seen in fig.8.
3. Moving forward that depends on the readings from the proximity sensors.
4. Turning that is determined by the odometry of encoders connected to the right and left drive wheels. The odometry reading is used to estimate how many degrees the FFR has rotated during turning. When to turn to the left or to the right depends on the six cases shown in Fig. 9.
5. Wall Following. This motion is needed to make sure the FFR is always moving in parallel with detected side walls as shown in Fig. 10.



Position Correction Algorithm



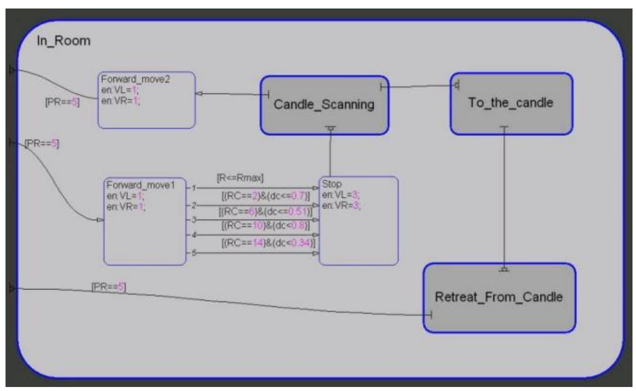
FFR Turns due to Encountered Wall Cases



Wall Following using Information from at Least Two Proximity Sensors

3.2.Navigation in Rooms

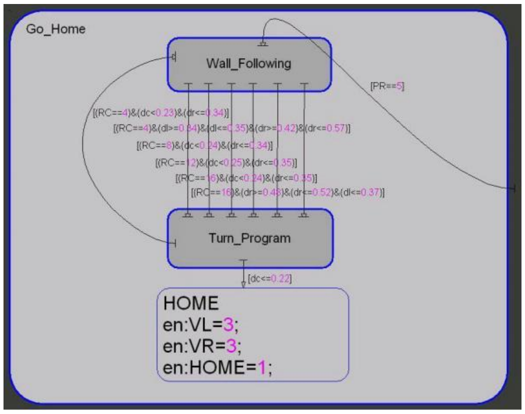
Once the FFR identifies that it has been in a room and has few distance passing a white line on a doorway, the controller will switch to the task noted as the Navigation in Rooms as shown in Fig 11.



Task of Navigation in Rooms

3.3.Navigation to Return Home

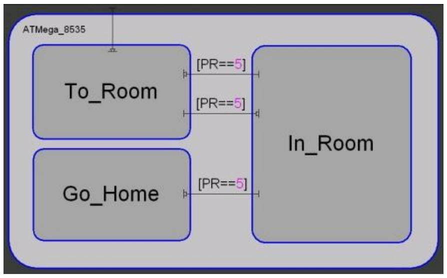
The controller will switch to the task Navigation to Return Home after the flame has been extinguished. This task is basically use Wall Following motion explained in section 3.1. At the end the FFR is set to stop after few distance passing the white circle of the Home. The State Flow diagram of algorithm can be seen in fig.12.



Task of Navigation Go HOME.

4. Simulation Result

Algorithm of FFR navigation is implemented on State Flow of MATLAB/Simulink™ from Mathworks as shown in Fig. 13.



State Flow of Main Algorithm.

Fire Fighting Robot virtual reality is created using Virtual Reality Toolbox in MATLAB/Simulink. The result of the virtual reality environment can be seen in Fig. 14.

View of Virtual Reality Environment

The results of this study are compared to the results of simulation time in previous studies by Arief [1] and Subchan[9]. The simulation time is the estimated time needed for the robot's to run its mission in the real world. In a competition the time that the robot needs to turn off the candle is very critical because this elapsed time is a major assessment in KRCI. In addition the elapsed time from turning off the candle until arriving back to the circle of home is also important because it is limited by KRCI for two minutes only. The comparison between the simulation time of the present study to the previous ones can be seen in Fig.15.

It is found that the incorporation of the digital compass as navigation sensor is very useful. We can conclude it from the simulation time in Fig 15. In every cases, the newly design navigation system, whether the candle is in the first room or second or third or maybe at fourth room the combination of navigation and algorithm proven to be the most fastest mission traveller.
From the complexity of programs and the simplicity of algorithm the author research is proven the smallest program size, and efficient as shown in Fig. 16.

ROOM	Previous Research (s)			
	(a)[1]		(b)[9]	
	Candle Off	HOME	Candle Off	HOME
1	35,70	79,50	40,80	82,60
2	95,50	136,60	84,20	123,60
3	123,50	193,00	120,60	161,10
4	163,00	196,50	156,80	196,30

ROOM	Author Research (s)	
	(c)	
	Candle Off	HOME
1	37,34	78,21
2	77,00	117,40
3	113,30	155,60
4	150,10	187,10

Simulation Time comparison to previous studies

Program	Previous Research Program Size (kb)		Author Research Program Size (kb)
	(a)[1]	(b)[9]	(c)
Stateflow	1.094	429	269
Simulink	159	244	295
Total	1.253	673	564

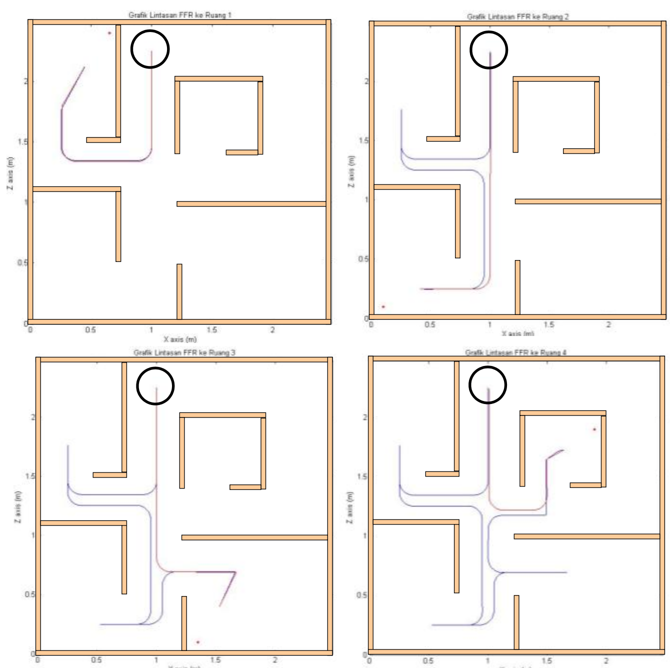
Program Size Comparison to previous studies

The FFR trajectories of four cases are provided in Fig. 17 and the elapsed times required to put out the flame and the total time until the FFR returns home are shown in Fig.15.The Simulink block diagram of the overall FFR mathematical model and algorithm is shown in Figure 18. Simulation parameters are obtained in [8].

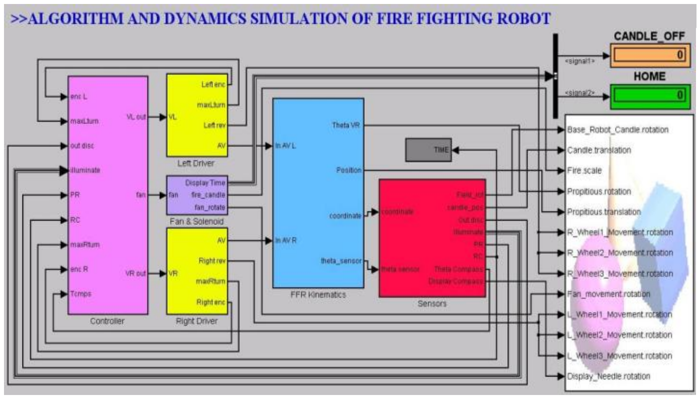
Chapter III Conclusions

This paper shows the simulation analysis of an algorithm that can be used for a Fire Fighting Robot that utilizes a digital compass as one of its navigation sensor in addition to three other proximity sensors. The simulation evaluates the performance of the robot design in meeting some of the contest rules such as navigating in a labyrinth arena without hitting walls, quickly extinguishing a flame in a room and return home.

This work shows the benefit of virtual reality tool that enables students to quickly evaluate and clearly visualize the dynamic and motion of Fire Fighting Robot and the interaction between the robot and its environment before spending too much time in building the robot and planning an algorithm. The present model gives a reasonably accurate representation of an example Fire Fighting Robot and its contest arena. In turn, students can focus designing various kind of algorithms and become more familiar with their performances and consequences.



All Track Result.



Simulink Model

Chapter IV

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