Haptic system with fuzzy controller for extended control of Teleoperation mine detector wheeled robots

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Abstract

In the tele-operation robots one of the big challenges is operator's error in urgent situations that can make big problem for robot and other systems which working beside the robot. This paper proposes an approach of haptic system and fuzzy logic system with implementation on tele-operation deminer robot, in order to reduce operator's error through fusion of haptic system and fuzzy logic controller, The haptic system convey vibration to user's hand and fuzzy controller, controlled rate of the vibration in different situation to user hand and controlled the speed of the robot.

Keywords: Haptic system, fuzzy logic, deminer robot, vibrotactile, magnetic field.

1. Introduction

Tasks of deminer robot is detecting mine in landmine and marks it with tools mounted on the robot (fig. 1) and rescue robots [1].Currently robots controlled by human operators [2] with visual display (fig. 2) and operators are limited in their interact with the robot and because of difficult situation and the low threshold for dealing on demine tasks. Minimizing operator's error while care for high level of accuracy and speed is difficult also if operator can't clearly hear or see data from mine detector sensor (MDS) in operator GUI (fig.2) or for some other problem as communication delay between operator and robot so the robot will enter to hazardous region. For these reasons we used vibrotactile feedback according to the level of MDS's output to inform user when robot is near dangerous touch with environment.

Accordingly, we investigated the use of a force three-dimensional joystick for applying forces and vibrations on user hand. This joystick connected to operator computer in (fig. 5) the joystick haptic device also used to control the robot speed and robot navigation [3].

This approach presents a fuzzy logic system (FLS) based force feedback generation method for deminer robots in teleoperation manipulators deminer robot. The approach utilizes the MDS's output and position of arm to generate desire vibrotactile using FLS.

In this paper, we investigated problems of previous work on deminer robot such as safety controlling, communication time delays, communication fail, and operator's error. The structure of this paper is in the following: in section 2 we described completely previous work on demine robot, in section 3 we explained new approach in detail. In section4 where we implemented FLS and haptic system in MATLAB fuzzy tools, while in section 5 we concluded result of implementation in section 4.

2. Background

2.1. *Deminer robot*

Basically mobile deminer teleoperation robot uses for detection mine in landmine with MDS mounted on the robot and user controls this robot by joystick, but user just send command to robot by joystick and monitoring robot is through visual display (fig. 2) and sound without any repulsive feedback from MDS in urgent situations.

Fig. 1: photographs of the deminer robot.

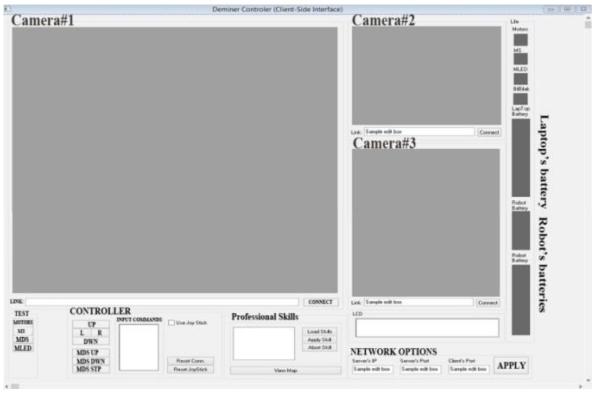


Fig. 2: operator GUI which contained: camera monitoring, robot controller, mine illustrates, network monitoring, robot's batteries status illustrates, laptop's battery status illustrates, motors statues indicators.

This console developed in windows and this is a graphical consol between operator and robot, this console installed in operator computer (fig. 5)

2.2. *Mine Detector sensor (MDS)*

MDS work on the principle of transmitting a magnetic field and analyzing a return signal from the target and environment. These systems may use a single coil as both transmitter and receiver, or they may have two or even three coils working together. In this project we used two coils first coil is transmitter and second one is receiver signal fig. 3.

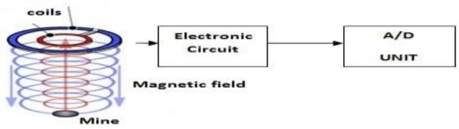


Fig 3: Overall hardware of mine detector sensor

2.3. *Electromagnetic induction*

As we mentioned before, in this section there are two parts first one is transmitter and second one is receiver we simulated this two coils with FEMM (fig. 4) [4][5].FEMM is one of power full software that uses for designing and analyzing magnetic problems[6][7].

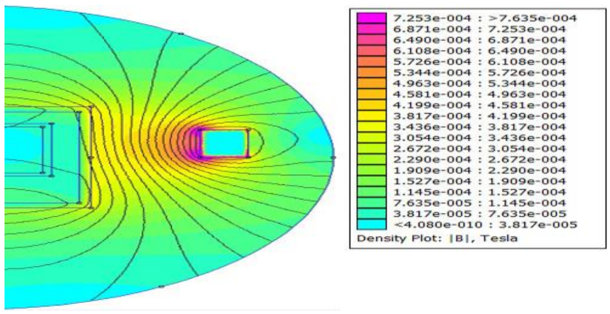


Fig.4: color flux density plot of two coils with mine.

we added a mine in analyzed region, most of flux passed through mine because reluctance of mine is smaller than air therefore most flux passed through low reluctance and least flux passed through receiver coil and caused least EMF induced in receiver coil.

3. Haptic system and fuzzy logic controller

3.1 *New approach*

Our solutions for those problems we mentioned in previous section (2.1) are haptic system and fuzzy logic controller. Haptic system solved feedback problem we suggest two ways for using haptic system in this project the first one is vibrating electric motors in joystick and second suggestion is haptic force three-dimensional joystick (fig.5) actually this joystick is a haptic system contains the vibration electric motors and joystick (fig.5) .Haptic increases human sensitivity from environment and user's hand can feel environment through vibrotactile feedback.

The level of vibrotactile with respect to different situations as MDS sense, robot speed and robot's arm status is variable, for controlling level of vibrations and velocity of robot we used fuzzy logic controller.

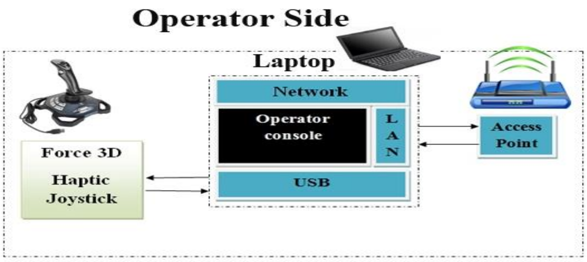


Fig. 5: overall framework of operator side controller.

In new approach we added force three dimensional haptic joystick in this part.

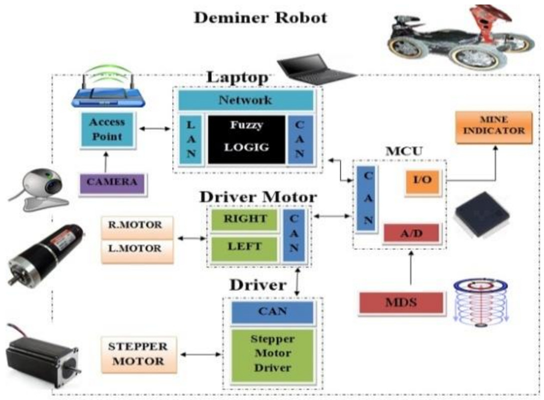


Fig. 6: overall framework of deminer robot.

4. Implementation

Trap membership function used for MDS inputs and outputs in two FLSs, (fig. 8) and (fig. 10).the rule based in this work is shown in Table 1 and Table 2The commonly used Madman's min-max implication function was utilized. Finally for defuzzification we used centroid technique because it's very accurate .The control surface generated by the rule base and the given fuzzy sets is depicted in (fig. 9) and (fig.11). Detail of fuzzy logic system could find in literature [8] [9].

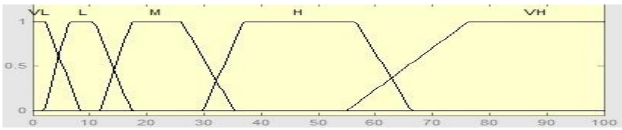
4.1. *Fuzzy logic system for dealing with haptic system*

MDS OUTPUT / ARM STATUS	DP	OAP	RTP
VL	VH	M	VL
L	H	M	VL
M	M	M	VL
H	S	M	VL
VH	VS	L	VL

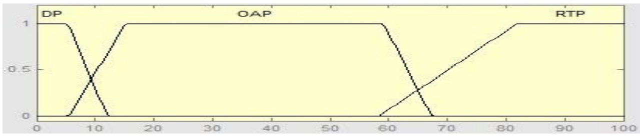
Table1: Rule table of the vibrotactile controller with respect to MDS output and arm status.

Respectively, they are decomposed into five fuzzy partitions for output ,such as very low (VL),low(L), medium(M), high(H),very high(VH), and three partition for arm status as : Down position(DP),obstacle avoidance position(OAP),rest time position(RTP) in last portions related to vibrotactile signal as: very slow(VS),slow(S),medium(M),fast(F), very fast (VF) and nothing (NOP).

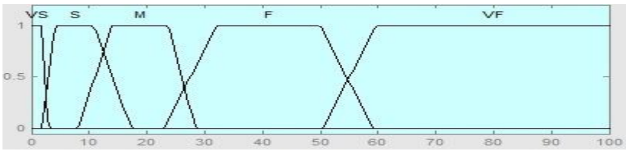
Since one input divided to five fuzzy sets and another one divided to three fuzzy sets, thus fifteen fuzzy rules for vibrotactile controller must determined. Following the output signal of MDS directly related to distance between coil and mine in the ground therefore when the robot is far from the mine sensed a mine with very low level and fuzzy logic gets the level of the MDS and give very slow vibrotactile to haptic system and haptic system transfer vibration to user hand and user feels mine through vibration.



(a)



(b)



(c)

Fig. 7: (a) membership functions of MDS. (b) Membership functions of arm status. (c) Membership functions of vibrotactile.

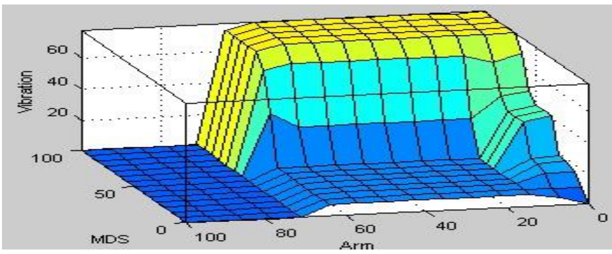


Fig. 8: The output surface of the implemented fuzzy vibrotactile, generator.

Three-dimensional curve that represents mapping from MDS and arm to level of the vibration, because this curve represents a two-input and one output case. As this curve is obvious when the arm is in down position and MDS level is increased therefore vibrotactile corresponding with MDS's level increases.

4.2. *Fuzzy logic system for velocity controller*

This section is similar to section (4.1) inputs of FLS are same as last one just output is different.

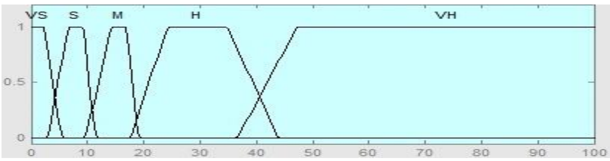


Fig9: Membership function of velocity.

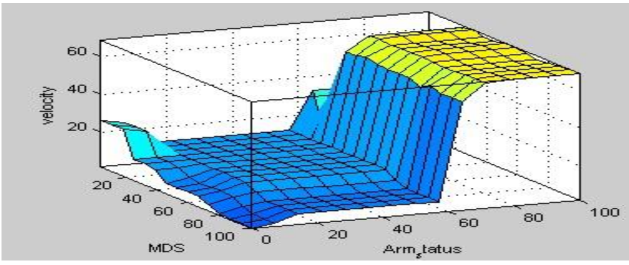


Fig 10: The output surface of the implemented fuzzy velocity controller.

Three-dimensional curve that represents mapping from MDS and arm to robot velocity, because this curve represents, a two-input and one output case. As this curve is obvious when the arm is in down position and MDS level is increasing in other side velocity with respect to MDS's level reduces.

5. CONCLUSION

This paper presented a dynamic, real-time fuzzy logic based force feedback control for deminer robot in remotely operated robot manipulators. The presented method utilizes distance from the mine to the robot, it needs consider two items first one is mine distance to robot and second one is arm's position with respect to these items new approach generates force feedback and control speed of the robot. The presented method was implemented on a deminer robot and for simulate and illustrates result of vibrotactile data and velocity controller we used MATLAB.

The results shows which fuzzy logic controller and haptic system, significantly reduced operator's fault and also fuzzy logic can prevent dangerous contact between the robot and mine when network connection drops, with this method operator drives robot with confidence because this system warned the operator in urgent situation.

6. ACKNOWLEDGMENT

This work supported in part by grant from the XI'AN JIOTONG UNIVERSITY and MRL laboratory of QIAU.

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