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Soft Computing Techniques on Tele-Operated Robot

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Abstract—*Tele-operated robotic system plays an important role in defense, biomedical, image processing, toxicology, machine control, software engineering, etc.The development of tele-operated robotic systems has remarkably attracted interest as a cost-effective solution for performing complex tasks. The dynamics of tele- operated robotic system is highly coupled, non linear and unstable. Control of these tele-robotic vehicles becomes a challenging task.*

Few control techniques like PI, PID have already been applied on tele-robotic systems. In this paper Fuzzy Logic Control technique has been attempted on tele- robotic system to minimize the time delay. Simulations have been carried out in MATLAB. Simulation results have been confirmed satisfactory performance.

1. INTRODUCTION

Usage of soft computing techniques with fuzzy logic on tele-operated robot has been applied from last decades it has been seen that tele-control system is used in various field such as biomedical, machine industry where as telesurgery is very interesting field [1] where soft computing techniques has been applied. Other various field i-e mining, construction and forestry.

Additionally environment causes make system unstable and gives reduction in system transparency [2,3]. Jee-Hwaven et al. [4] has identify the period by implementing a time domain passivity and the main motive to control the remote system and sense the exerted force on remote in the remote environment so transparency and stability should satisfy with time-delay. By measuring the impedance tele-operated system transparency has been investigated. which is transmitted to operate through environment. Tele-operation system controller with master and slave robot uses velocity and position signal[5-7].When slave robot is getting contact with environment then position error is indispensible between master and slave robot[5-7] such error break the transparency of close-loop tele-operation system. Transparency can be improved when force signal is transmitted to position and velocity signal [8-9]. Most of the robotic system task are non-linear but stability is achieved in linear tele-operation systems. Due to high cost factor in robotic system, measuring of external force is not possible. There are other many factors is associated with tele-operation system i-e force sensor installation and noise.

In our previous work [10], we have used [PI,PID] and waved variable formalism to stabilize the system in spite of communication delay between transmitter and receiver (operator and electric vehicle). For other applications there are so many approaches are proposed by soft computing to deal with bilateral tele-operation with varying time delays[11]. The main problem which is considered in this paper i-e designing of telerobotic system based on fuzzy logic approach.

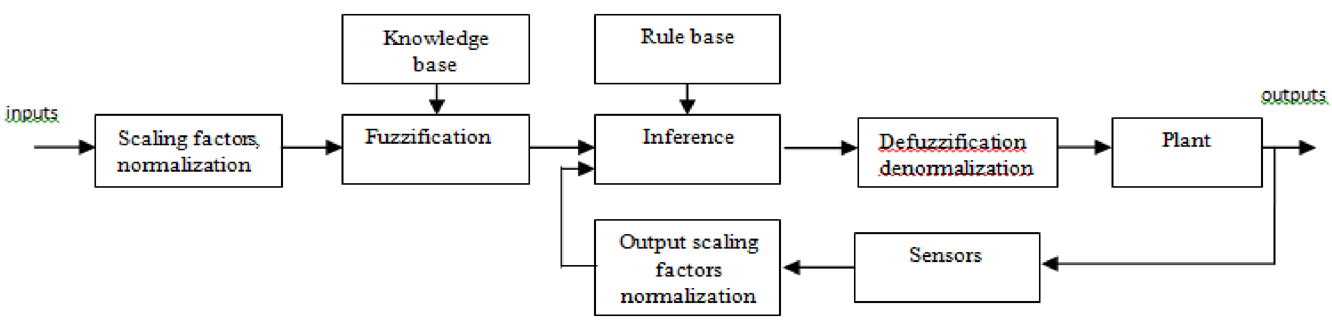


Fig. 1: A Fuzzy logic control system block diagram

The fuzzy logic controller used a approximate mode of reasoning which makes the system decision based. i-e similar to human beings [12]. Fuzzy logic works on two concepts, linguistic variables and fuzzy "IF-THEN" rule. Where linguistic variable is render as a label of fuzzy set which is shown by membership function[21]. From various soft computing techniques fuzzy control is one of the most useful method to implement tele-robot control strategies. Fuzzy-Logic also has many advantages i-e noise level, low sensitivity to variation of parameter and wide range in application[13]. With the no. of input variable in fuzzy reasoning the total no. of fuzzy rules system parameter increases exponentially. This enforce burden on the system needs a special fuzzy reasoning with many input variables for low no. of rules and robust control.

2. FUZZY LOGIC CONTROLLER DESIGN

This paper organizes: section 2 which consist the design of fuzzy controller with time-delay consideration and section 3 in order to prove effectiveness.

This main slave tele-operation[13] robotic robotic system is shown in in fig. 2. It consist two parts one is master part and second one is slave part. This master part is directly operated by by human operator and it's movement effect observed on slave through the communication channel and controller. So that the human operator can directly interact with remote environment. The stability of closed-loop system is the requirement which is satisfied by the controller[14].

3. ARCHITECTURE OF TELE-OPERATION SYSTEM

As in fig. shown this is the block diagram of tele-operated remote vehicle system. Master and slave defined the position and force relationship at

$$X_m(t) = X_s(t-T) \; f_h = fs(t-T)$$

Where f_h and f_s are the operator force reflected force i-e force from slave to master, respectively; x_m and x_s are position of master and slave i-e

$$Pm(s) = 1/ {}_{Mm}S^2+K_mS+B_m$$

$$Ps\,(s) = 1/{}_{Mm}S^2+K_{\,m}S+Bs$$

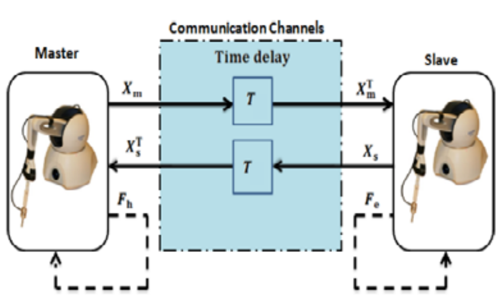


Fig. 2: Teleoperation system [2]

Here Mm is the mass of master Ms is the mass of slave, the compliance coefficients are km and k_s for master and slave respectively; B_m and B_s velocity coefficients, f_h and f_s are operator and reflected force from the remote vehicle, X_m and X_s are position of master and slave where e-*sT1* is the delay variation from master to slave and e-*sT2* is the dealy variation from slave to master.

4. MASTER FUZZY LOGIC CONTROLLER DESIGN

In the fig. of master controller, the reference input function is followed by master position Km.

The master fuzzy controller design is done using MATLAB [20].

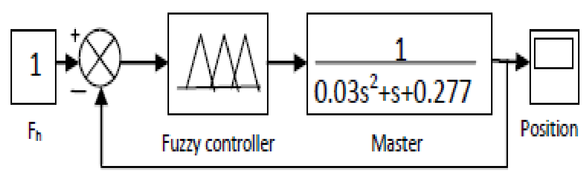


Fig. 3: Master fuzzy controller (Km) design

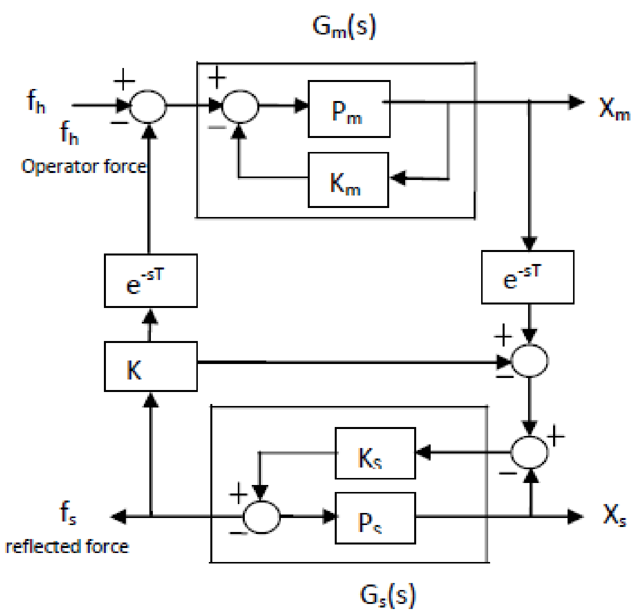
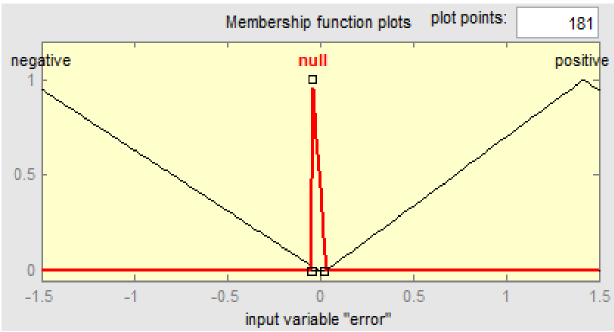


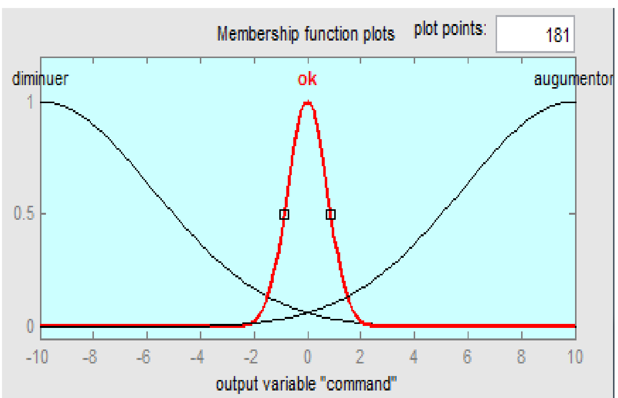
Fig.4: Teleoperation system architecture with time delay

Fuzzy controller consist three stages: fuzzification, Fuzzy reasoning[21] and defuzzification. This overall model consist input stage, processing stage and output stage.

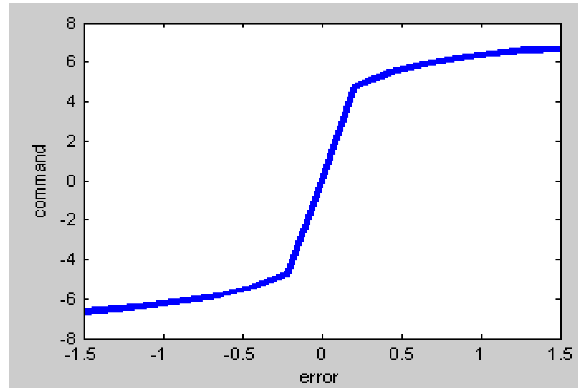
For checking the error the appropriate membership function are applied as the input. In the processing stage checks each and every possible rule and verify, then create the final result and combine the all results and according to the requirement the output stage changes this combined result in a proper control output value by using defuzzification which is suitable and then master position is compared with constant reference F_h and if the difference occur then select a controller based on fuzzy rule. Selection of membership function is important so that it can maintain the stability of the system. There are various sort of fuzzy memibership function exist. The membership function is for master fuzzy controller are in shape of Gaussian (input) and triangular (output) which is shown in the fig.



Input variable "error"
(a)



Output variable "command"
(b)
Fig. 5: Fuzzy membership function (a) input variable (f_h-x_m) (b) output variable (u_m)



error
Fig. 6: Fuzzy rule surfaces

5. DESIGN OF SLAVE FUZZY LOGIC CONTROLLER

Fig. 8 shows the design of slave controller K_s

The slave position X_s should track by the master position X_m (t-T) for the slave controller design. Here time delay which w used is 1.0 second. And for the slave part who having two inputs and one output type membership function.

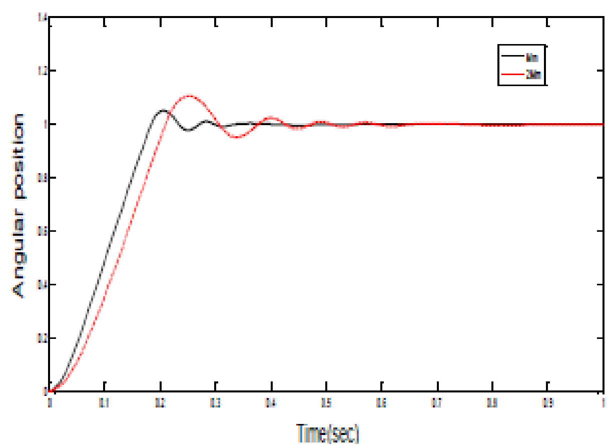


Fig. 7: Step response of master: x_m with normal m_m

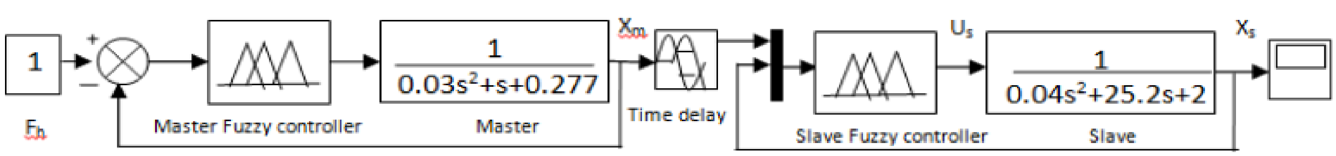
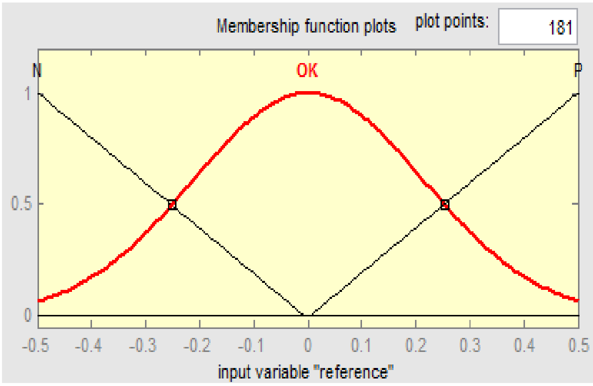
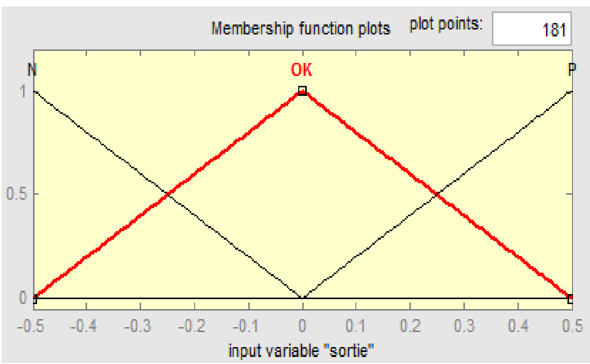


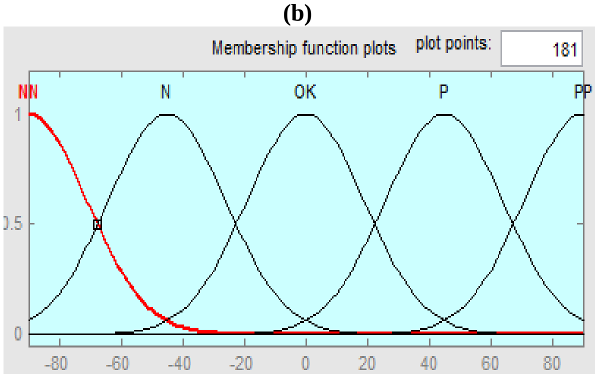
Fig. 8: Fuzzy slave controller (K_s) design



Input variable “references”
(a)



Input variable “sortie”
(b)



Output variable “command”
(c)

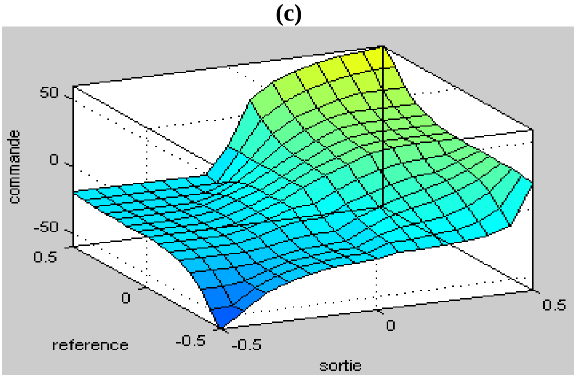


Fig. 9: Fuzzy rule surfaces

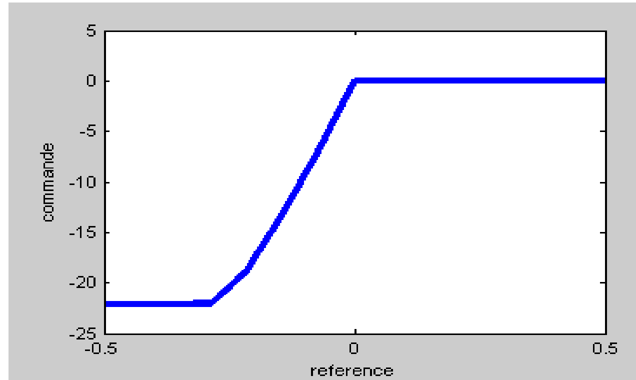


Fig. 10: Response of slave with delay: xs, xs-xm

6. PID TUNING PARAMETERS

Master $K_P = 0.497$ $K_I = 0.192$ $K_D = 0.519$

Slave $K_P = 3.168$ $K_I = 0.457$ $K_D = 5.245$

7. SIMULATION PARAMETERS

Master $m_m = 0.03$ $k_m = 1$ $b_m = 0.277$

Slave $m_s = 0.04$ $k_s = 25.2$ $b_s = 2$

8. PID CONTROLLER DESIGN

A “Three-term” controller is also known as the conventional PID controller[25]. The ideal form of “Three-term” is represented by equation (1) and (2) respectively.

$G(s) = K_p + K_I/S + K_D$ [1]

$G(s) = K_p (1 + 1/T_I S + T_D S)$ [2]

Where all these terms which have been used have their significant meaning such as K_p is the proportional gain similarly K_I, K_D, T_I, T_D are integral gain, Derivative gain, Integral time Constant and Derivative time constant. These constant values for PID controller is selected by tuning the model using MATLAB 8.1

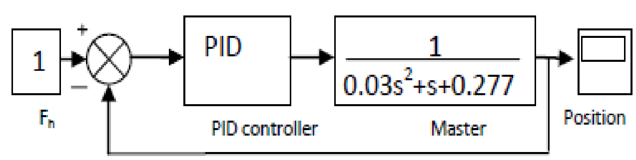


Fig. 11: Design of PID master controller

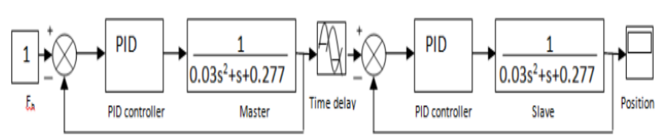


Fig. 12: Design of PID slave controller

9. CONCLUSION

This paper consist the design of tele-operation system which is proposed by using fuzzy logic controller. This controller ensure the stability of the system. In comparison to previous work using a passivity approach with (PI, PID) controller, fuzzy logic controller is designed to prove very effective where uncertainty has some unknown sources(strong non-linearities, error of environment and the limited of dynamics resolutions of sensors, noise measurement which is hard to measure). The selection of weighting function in control is very hard and bilateral control order is also very high so it's implementation is very tough. The same sort of difficulty in the implementation of adaptive gain scheduling in the designing of tele-control electrical vehicle is given in [8].

As it is observed that when we are taking fuzzy logic in to account then it track the position very efficiently as instant reference input occurs compare to PID-master and PID-slave.

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