Design of PID Controller for Teleopration System With Genetic Algorithm

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Abstract

This paper presents a novel teleoperation controller for a nonlinear master–slave robotic system with constant time delay in communication channel. The proposed controller enables the teleoperation system to compensate human and environmental disturbances, while achieving master and slave position coordination in both free motion and contact situation. The current work basically extends the passivity based architecture upon the earlier work of Lee and Spong (2006) to improve position tracking and consequently transparency in the face of disturbances and environmental contacts. The proposed controller employs a PID controller in each side to overcome some limitations of a PD controller and guarantee an improved with genetic algorithm is investigated. We wanted to build on the controller can be designed as desired, and the optimal coefficients are obtained.

Keywords: Teleopration systems, master slave robot, time delay, Genetic algorithm, PID controller

1. Introduction

Over the past 3 decades, teleoperation technologies have been gradually growing through the world. Teleoperation is used in many applications such as space operation [1], handling of toxic and harmful materials [2], robotic surgery [3,19] and underwater exploration [4,20]. Teleoperation can be divided into two main categories, namely, unilateral and bilateral. In unilateral teleoperation, the contact force feedback is not transmitted to the master. In bilateral teleoperation, the remote environment provides some necessary information by many different forms, including audio, visual displays, or tactile through the feedback loop to the master side. However, the contact force feedback (haptic feedback) can provide a better sense of telepresence and as a consequence improve task performances [5].There are many structures for the bilateral teleoperation system. Two main structures are two-channel (2CH) architecture [6] and four-channel (4CH) architecture [7,8]. In two-channel structure usually the master position is sent to the slave controller, and the contact force of the slave robot with the environment is directly transmitted to the master .In bilateral teleoperation, there are two main objectives that ensure a close coupling between the human operator/master robot and slave robot. The first goal is that the slave robot tracks the position of the master robot and the other is that the force, that occurs when the slave contacts with the remote environment, accurately transferred to the master. When these conditions are met, the bilateral teleoperation system is called a transparent system. Lawrence [8] has shown that there is a tradeoff between the stability and transparency, the improvement of one will deteriorate the other.

The delay existing in the network teleoperation system can destabilize the closed-loop system and degrade transparency. Most previous studies on stability were based on the passivity formalism, such as scattering theory [9] and wave variables [10]. The key point for these approaches is to pacify the non-passive communication medium with time delay. Although transparency of these two approaches is poor, the stability is robust against the communication delay and called the delay-dependent stability.

A comprehensive survey on the delay compensation methods can be found in [11]. Chopra and Spong [12] proposed a new architecture which builds upon the scattering theory by using additional position control on both the master and slave sides. This new architecture has an improved position tracking and comparable force tracking abilities than the traditional teleoperator model of [9,10].In [13], Lee and Spong, introduced a PD-based controller scheme for the teleoperation system that keeps position coordination and ensures the passivity of the closed-loop system. The main drawback of this structure is that the backward and forward communication delays must be exactly known and symmetric. Therefore, they removed these aforementioned restrictions in their recent works. They used the controller passivity concept, the Lyapunov–Krasovskii technique, and Parseval's identity, to passify the combination of the delayed communication and control blocks altogether since, the delays are finite constants and an upper bound for the round-trip delay is known [14,15]. Nuno et al. [16] showed that it is possible to control a bilateral teleoperation with a simple PD-like controller and achieve stable behaviour under specific condition on control parameters. According to the complexity of the communication network, the backward and forward delays are not only time-varying but also asymmetric. In [17,18], two different methods based on the PD controller have been presented to address these problems. The method in [18] uses a Lyapunov–Krasovskii functional to derive the delay-dependent stability criteria, which is given in the linearmatrix-inequality (LMI) form. This controller guarantees the passivity of bilateral teleoperation under some condition, independent of the amount and variation of time-delay in communication channel. The key feature of the proposed PID controller [15] is that it preserves the control passivity of the teleoperation system. In this study we sought to evaluate the performance of the controller PID ,with a genetic algorithm is investigated. We wanted to build on the controller can be designed as desired., And the optimal coefficients are obtained.

2. Problem Formulation

The teleopration system is examined in a system for remote tracking of speed and power as a degree of freedom of the robot and the slave robot command is used. Robot dynamics equations below [16].

$$J_m u_m = F_n + \tau_m \quad (1)$$

$$J_s u_s = F_e + \tau_s \quad (2)$$

$$\tau_m = -b_m u_m - F_{md} \quad (3)$$

$$\tau_s = -b_s u_s - F_s \quad (4)$$

And the u_m and u_s speed at which the master and the slave robots, and Inertia J_s , J_m , and Damping b_s , b_m force applied to the robot operator command F_n , and torque motors τ_s , the return of the slave site F_{md} ., the coordinator torque and torque setting F_s , F_e . environment torque Usually the matching speed torque command signal is applied and the slave by the controller. According to the above equations become the chief and the slave robot are calculated.

$$H_m(s) = \frac{u_m}{F_n - F_{md}} = \frac{1}{J_m s + b_m} \quad (5)$$

$$H_s(s) = \frac{u_s}{F_s - F_e} = \frac{1}{J_s s + b_s} \quad (6)$$

Channel can be modeled with a pure delay. So there

$$U_{sd}(t) = U_m(t - T_1) \quad (7)$$

$$F_{md}(t) = F_s(t - T_2) \quad (8)$$

T_1, T_2 ,The channel delay and quickly went back to the site of the slave and F_{md} the slave is returned from the site. So we have

$$U_{sd}(t) = e^{-T_1 s}.U_m(s) \quad (9)$$

$$F_{md}(t) = e^{-T_2 s}.F_s(s) \quad (10)$$

$H_{rd}(s)$ The model reference adaptive controller designed in the above site for the slave that has been converted into Tier 2 below.

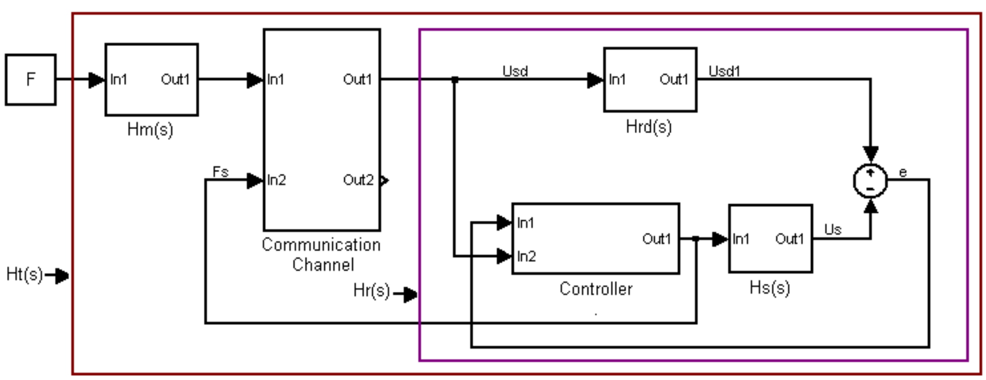

Fig.1. The model reference adaptive controller

$$H_{rd}(s) = \frac{\omega_s}{s^2 + 2\omega_s s + \omega_s{}^2} \quad (11)$$

Making the right track if we are obedient to the site: $U_{sd} = U_s$

And thus become visible on the site of the commander is calculated as follows.

$$H_3(s) = \frac{F_s(s)}{u_{sd}(s)} = \frac{F_s(s)}{u_{sd}(s)}.\frac{U_{sd}}{U_{sd}} = H_s^{-1}(s).H_{rd}(s) \tag{12}$$

$$H_t(s) = \frac{F_{md}(s)}{F_h - F_{md}(s)} = H_m(s).e^{-t_1 s}.H_r(s).e^{t_2 s}$$

$$H_t(s) = \frac{H_m(s).H_{rd}(s)}{H_s(s)} \tag{13}$$

$d = t + T_2$ and $H_r(s)$ The slave function and the site converted into a commanding view of the site. By substituting equations (5) and (6) and (11) in equation (13) we have.

$$H_t(s) = \frac{\omega_s^2 (J_s s + b_s)}{(J_m s + b_m)(s^2 + 2\omega_s s + \omega_s^2)} \tag{14}$$

3. Optimized coefficient PID Controller

In a genetic algorithm, a population of candidate solutions (called individuals, creatures, or phenotypes) to an optimization problem is evolved toward better solutions. Each candidate solution has a set of properties (its chromosomes or genotype) which can be mutated and altered; traditionally, solutions are represented in binary as strings of 0s and 1s, but other encodings are also possible.[2] The evolution usually starts from a population of randomly generated individuals and is an iterative process, with the population in each iteration called a generation. In each generation, the fitness of every individual in the population is evaluated; the fitness is usually the value of the objective function in the optimization problem being solved. The more fit individuals are stochastically selected from the current population, and each individual's genome is modified (recombined and possibly randomly mutated) to form a new generation. The new generation of candidate solutions is then used in the next iteration of the algorithm. Commonly, the algorithm terminates when either a maximum number of generations has been produced, or a satisfactory fitness level has been reached for the population

4. Results and Simulation

The structure of the controller system is a feedback control loop And the master and the slave robot system in the plant that is used. The plant controller and then with the help of the Genetic Algorithm desired estimates. And delivers optimally.

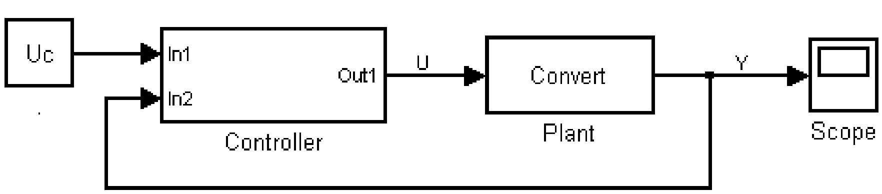

Fig.2. block diagram PID controller

The master robot is a nonlinear function using MATLAB and the linearization coefficients of the optimized controller offers. In addition to meeting the time when the system determines the polarity overshoot. Desired parameters can even get a set of given weight.

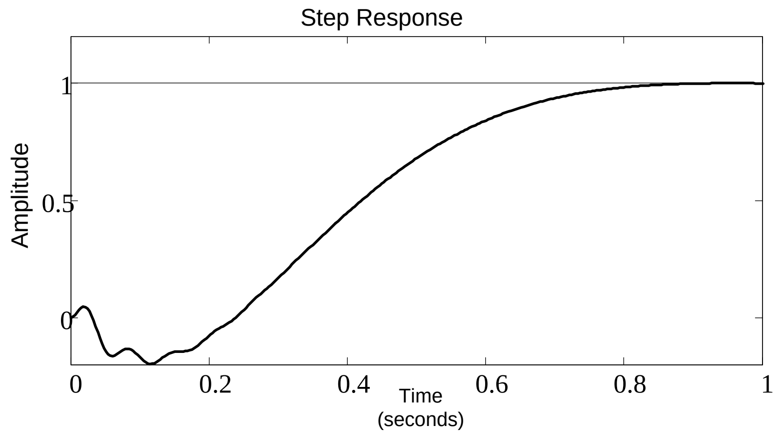

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Fig.3. step response of master robot

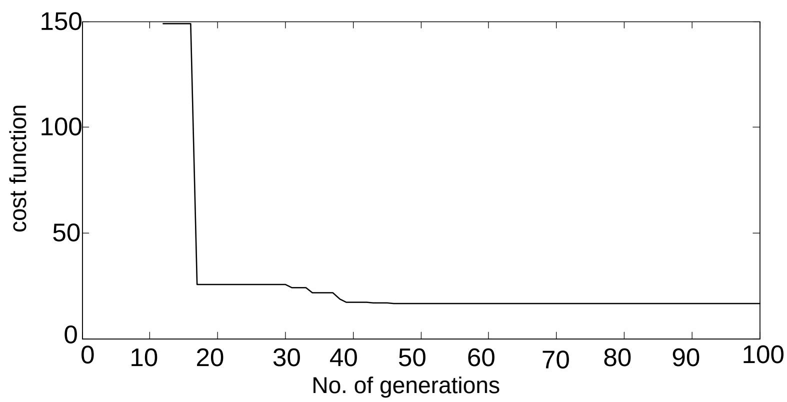

Fig.4. convergence of master robot step response

Table 1. Value of optimized PID coefficients and step response parameters of master robot

Coefficients and parameters	value	unit
K_p	0.0172	-
K_d	0.2098	-
K_i	-0.0125	-
Cost function value	16.5594	-
Rise Time	0.2846	s
Settling Time	0.5692	s
Settling Min	0.9038	s
Settling Max	0.9957	s
Overshoot	0	%
Undershoot	45.3666	%
Peak	0.9957	-
Peak Time	0.7078	s

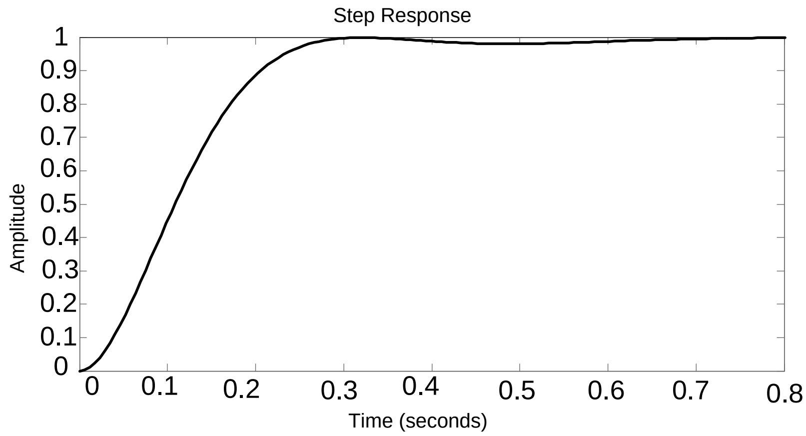

Fig.5. step response of slave robot

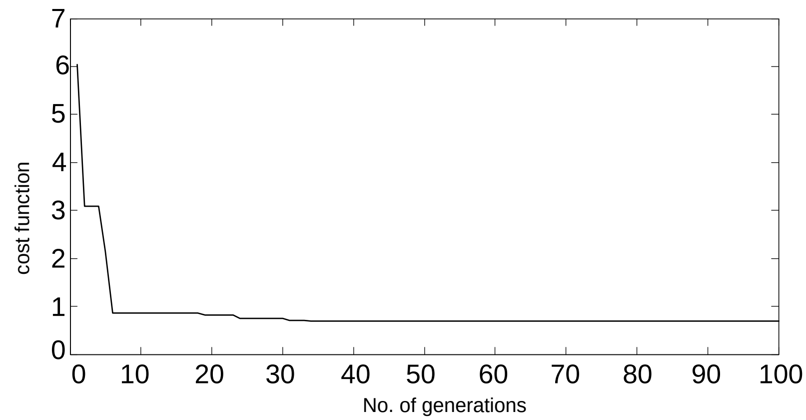

Fig.6. convergence of slave robot step response

Table 2. Value of optimized PID coefficients and step response parameters of slave robot

Coefficients and parameters	value	unit
K_p	0. 1429	-
K_d	0. 8257	-
K_i	0. 0132	-
Cost function value	0.6891	-
Rise Time	0.1674	s
Settling Time	0.2603	s
Settling Min	0.9058	-
Settling Max	0.9998	-
Overshoot	0	%
Undershoot	0	%
Peak	0.9998	-
Peak Time	0.9779	s

5. Conclusions

In this study, the two commanders and the slave controller standalone websites in order to improve the stability of the teleopration system, Simulation shows that the use of the controller in addition to ensuring the stability of the time delay of the channel is meeting our expectations. All these characteristics have been optimized by genetic algorithm.

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