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Article

Dynamic Modeling and Passivity Based Control of the RV-3SB Robot

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Abstract: In this paper is shown the dynamic modeling and design of a passivity based controller for the RV-3SB robot. Firstly, the dynamic modeling of the of the Mitsubishi Rv-3SB robot is done by the Euler-Lagrange formulation in order to obtain a decoupled dynamic model considering the actuators orientation besides the position of this analyzed robot. It is important to remark that the dynamic model of the RV-3SB robot is done based in the kinematic model obtention in which is developed by the implementation of screw theory. Then the passivity based controller is obtained by separating the end effector variables and the actuator variables by making an appropriate coordinate transformation. The passivity based controller is obtained by selecting an appropriate storage function and by the Lyapunov theory the passivity based control law is obtained in order to drive the error variaable, which is the difference between the measured end effector position variable and the end effector desired position variable. The passivity based controller makes that the error variable reach the origin in finite time taking into consideration the dissipation properties of the proposed controller in order to stabilizes the desired end effector position. A numerical simulation experiement is performed in order to validate the theoretical results obtained in this research study. It is verified by numerical experimentation that the proposed control strategy is efficient and effective in order to drive the error variable to the origin in comparison with other modified techniques found in the literature. Finally, the appropriate discussion and conclusion of this research study are provided.

Keywords: dynamic output feedback control; robotics; passivity based control

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0. Introduction

Industrial robots have been extensively implemented since several decades ago considering the different kinds of applications of these kinds of mechanisms in operation like drilling, painting, screwing nd welding in different kinds of industrial environments. It is important to mentions that, as it is known, the industrial robots are classified into serial and parallel robots. The serial robots are those kinds of robots in which each link is connected to the other successively, and the parallel robots are those in which each link are connected into a parallel fashion. Among the most important serial robots implemented for industrial environments are many types of six degrees of freedom mechanisms for different kinds of tasks. Meanwhile, parallel robots which are common to be implemented in different kinds of industrial applications are the delta robot and the Stewart platform which provides the necessary degrees of freedom and flexibility in comparison with serial robots.

As it is known, serial robots are implemented and studied considering the importance that they have in the implementation of this kind of mechanisms in different tasks in order to increase the productivity and reliability on an assembly line. Despite this, it is important to remark that many experimental robots are implemented nowadays taking into consideration that new kinematic and dynamic analysis must be done appart from designing new control strategies in order to obtain the optimal performance when the trajectory tracking of the end effector is necessary for different industrial applications. For these reasons, it is important to analysis the kinematic and dynamic properties of experimental or laboratory robotic manipulators, in order to provide relevant theoretical, experimental and practical conclusions about any kind of implementation of robot manipulators.

Kinematics plays an important role in the mathematical modeling of robot manipulators. There are many kinematic models methodologies in order to define the direct and inverse kinematics of a robot manipulator. Among these strategies are found the Denavit-Hartenberg convention, Hamilton quaternions and screw theory. It is crucial to mention the following research papers in which these kinematic model methodologies are found. So for example in [1] a novel inverse kinematic model for a novel 6R manipulator by implementing quaternions. Then in [2] the kinematics of a parallel robot by using lie group theory is evinced. Other interesting results are found in papers like [3] in which the forward kinematics of a surgery assisted robot is presented. Meanwhile in [4] the kinematic reliability of industrial robots is evinced. Then in [5] a 7R six degrees of freedom robot with non-spherical wrist kinematic calibration procedure is presented. Then another interesting research study is shown in [6] in which the kinematic calibration of a 5-DOF machining robot is performed by the Kalman Filter approach. All these results are important for this present research study taking into consideration that they provide the theoretical framework for the analyzed robotic mechanism. It is important to consider that in these mentioned research study there are some strategies such as quaternions which are very important for the design of the kinematic model of the RV-3SB robot by screw theory.

One of the main issues in which this present paper is focused is the dynamic modeling of the RV-3SB robot. The approach used in this research study posses their fundamentals in the Euler-Lagrange approach, but considering the kinematic model obtained by screw theory for the analyzed robots it is important to consider that the dynamic model derivation is significantly reduced, something that is a must when the dynamic model derivation for a new robotic mechanism is obtained. The following references are important for this present research study taking into consideration the contribution for the dynamic model derivation of the RV-3SB robot. For example in [7] the bi-stable dynamics in a two-module vibration driven robot is presented. Then in [8] the dynamics equation of an Hexabot robot are obtained by the Lagrange equation of second kind. Then in [9] the neural dynamics driven control of a redundant robot is provided. Therefore in [10] the remote teaching of dynamics and control of robots is performed. Other research studies which provides significant results are found in papers like [11,12] according to the dynamic model mathematical derivation for different types of robots. The implementation in these research studies of different dynamic model techniques are an important contribution to this present paper considering that the dynamic models based on the Euler-Lagrange formulation are significant for the dynamic model derivation of the RV-3SB robot analyzed in this research study.

Screw theory is fundamental for the derivation of feasable kinematic models for the forward kinematics and inverse kinematics, for this reason it is important to mention the following research studies. For example in [13] a complete review of screw theory for the kinematic modeling of serial and parallel robots is presented. In this chapter is stressed how the reciprocal screw theory facilitates to obtain compact and elegant kinematic model representations for the previous mentioned kinds of robots. Meanwhile in [14] it is shown how the screw theory is implemented for a force model of a crane. Then in [15] it is proposed the configuration synthesis of deployable anthenas based on screw theory. Another interesting paper that is worthy to cite is found in [16] in which a higher order representation of metamorphic mechanism based on screws is presented. In [17] the screw theory is used for the vibration analysis of a space parallel robot. Then in [18] a mobility analysis of scissors like elements is presented by the implementation os reciprocal screw theory. As it is known, the screws consists in defining the velocities and moment or force vectors which represents the rotation about an specified axis. Screws provide a compact and simplified model that is used for the forward and inverse kinematics derivations of the studied and analyzed robot, that in this case, is the RV-3SB robot. The previous cited research results provides the mathematical fundamentals for this research study.

Nowaday are a vast amount of control strategies for different kinds of robots, independently if they are serial chain or parallel chain. So for this reason it is important to mention several research studies regarding this topic in order to be used as a introductory theoretical framework for the passivity based control strategy of the RV-3SB robot. Among these papers found in the scientific literature are [19] the visual control of a robot is performed as evinced in this paper. Then in [20] the control of a laparoscopic robot is performed by a leap motion sensor. In [21] the coordinated control of a space robot manipulator is evinced. Other interesting result is shown in [22] the robust variable admittance control of a humar-robot manipulator is shown. In [23] a non-singular terminal sliding mode controller for a prosthetic leg robot is shown. Ultimately in [24] the robust control of a planar snake robot by Takagi-Sugeno fuzzy control is presented.

Passivity based control is the main control strategy implemented in this research study so it is worthy to mention the following control stragies based on passivity based like [25] the control of a piezoelectric actuator is performed by a Krasovskii pasivity based approach. Then in [26]. Other important results for this research paper are found in papers like [27] in which a self-balancing robot is controlled by a PID passivity based control strategy. In [28] an underactuated three dimensional crane is controlled by a passivity based controller. Then in [29] a three degrees of freedom crane is controlled by a passivity based adaptive trajectory tracking controller. Finally in [30] a spacecraft attitude simulator is controlled by a passivity based sliding mode controller. Passivity based control, as it is known, consist in a control strategy based on the energy consideration of the nonlinear dynamic system to be controlled. It is important to mention that this is the main control strategy for this research paper, taking into consideration that this strategy is novel taking into account the energy properties of the nonlinear dynamics of the RV-3SB robot mechanism.

In this paper it is proposed the passivity based control of a Mitsubishi RV-3SB robot. First in this paper is shown the kinematic model of the robot that is obtained by the implementation of screw theory. Then the dynamic model of the robot manipulator is obtained by the implementation of the Euler-Lagrange formulation yielding a decoupled non-linear dynamic model for the position and orientation of the Mitsubishi RV-3SB robot. Then the passivity based controller of the robot is obtained by selecting an appropriate storage function in order that the passivity based condition by implementing the selected control law must met the closed loop stability conditions. It is important to remark, that the passivity controller consist in the passivity based control law along with a output feedback controller in order to meet the desired trajectory tracking system performance. A numerical experiment is provided in order to validate the theoretical results provided in this research study. A discussion and conclusion section is provided to discuss the results of this research study.

1. Related Work

In this section a detailed reference to closely related work is presented in order to demonstrate the importance of the present research study. This present section is focused on the following issues which are important in order to evinced a detailed overview of the most relevant research studies found in the scientific literature:

- Kinematics.
- Industrial robotics.
- dissipative dynamic systems.
- Passivity based control
- Diverse control strategies for robotics.

GTo begin this literature review we start with some kinematics techniques for industrial robots taking into consideration that in this present research study is considered screw theory for the kinematic and dynamic modeling of the RS-3SB robot. So for example, in papers like [31] a differential kinematic modeling of a mobile robot is presented. Meanwhile in [32] the kinemaatic workspace model of 3R, 4R, 5R, or 6R robots are presented. Then in [33] the meaning of four co-reciprocal screws are presented in terms of its kinematic significance. In [34] the identification of kinematics parameters of a multilink manipulator is presented. Then other research studies in which the kinematics of different times of robotics manipulators are shown, so for example in [35] a new formulation of the inverse dynamic of a parallel delta robot is provided. Meanwhile in [36] is presented a closed form inverse dynamic model of the delta parallel robot is presented.

Other interesting strategies for kinematic modeling of serial and parallel robots are found in papers like [37] in which Clifford algebra is implemented for kinematic control of a serial robot. Then in [38] an automatic approach to identify the parameters of a serial link chains using reciprocal screws is presented. Meanwhile in [39] screw theory and dual quaternions are used for motion controllers. In [40] conformal geometric algebra is implemented in order to obtain the inverse kinematic of serial robots. Then in [6] an extended Kalman filter is implemented in order to obtain the kinematic calibration of a 5-DOF hybrid machining robot. To finalize in [1] the inverse kinematic formula for a new class of 6R robot is presented.

Industrial and many kinds of novel robot manipulators are crucial to be mentioned in this research paper taking into consideration the important results for this present research study. For example, in papers like [41] a bipedal walking robot is shown. Other interesting results are found in papers like [42] in which model control for industrial robots is presented. In [43] the adaptive output feedback tracking control of a non holonomic mobile robot is presented. Meanwhile in [44] a control strategy for two link underactuated planar robots is presented. In [45] a stable controller for a robot manipulator is evinced.

Dissipation properties of nonlinear dynamics systems is important considering the characteristics of passivity based controllers. So for example in papers like [46] the dissipative characteristics of a negative imaginary system are exploided in order to design a control strategy. Then in papers like [47] it is study the dissipative properties for an infinite dimensional continuous control as shown in this paper. Menwhile in [48] the dissipative output feedback dissipative control of Markovian jump systems is presented. In [49] is studied the dissipative optimal infinite dimensional control. Another interesting results are found in papers like [29] in which dissipative discrete time stochastic delayed system. Finally, in [50] a discrete time neural network and its dissipative control is designed and performed in this research paper.

Passivity based control is one of the control strategies developed for many kinds of physical systems such as electrical and mechanical. As explained before, this strategy consists in the selection of a storage function in order that the election of the control law meets the passivity requirements. In papers like [51] is presented the passivity and power based control of a robot. Then in other papers like [52] the adaptive passivity based force controller is presented for an uncertain system. Then in [53] the passivity based control of hydraulic robots is evinced. Then in [54] a distributed passivity based controller for constrained robotics networks is shown. Then in [55] some new results in passivity based control for robots are shown. Finally other control strategies like backstepping control, sliding mode control, output feedback robust control, among others are found in papers like [22,56–60].

2. Dynamic Modeling of the RV-3SB Robot Manipulator

The dynamic modeling of the RV-3SB (Figure 1) robot is evinced in this section. The dynamic modelling consists into implementing the Euler-Lagrange formulation, in order to obtain a simple dynamic model and tractable for As corroborated in this section, the dynamic model of the RV-4SB robot is decoupled, taking into consideration the position and orientation of the robot. This dynamic model formulation is suitable for trajectory tracking controller design, as verified in the control design section. Consider the following kinetic and potential energy functions:

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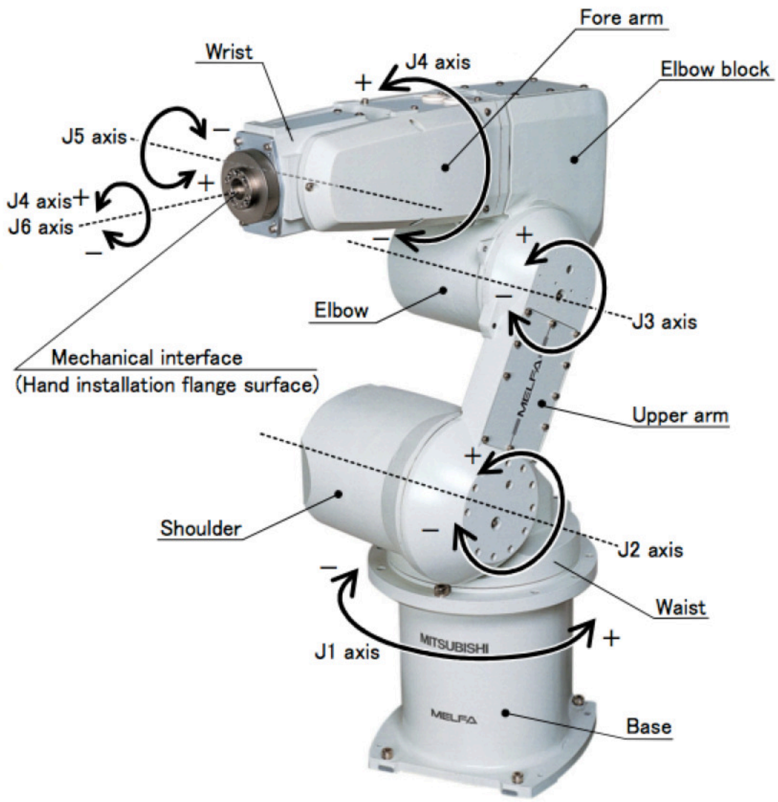

Figure 1. The RV-3SB Mitsubishi Serial Robot with 6 Degrees of Freedom.

$$\begin{aligned} K &= \frac{1}{2}\dot{q}^T I \dot{q} + \frac{1}{2}\dot{X}^T M \dot{X} \\ P &= mg\epsilon^T X \end{aligned} \tag{1}$$

In which I is the inertia matrix, M is the mass matrix and g is the gravity constant, with the following vectors:

$$\begin{aligned} q &= [\theta_1, \theta_2, \theta_3, \theta_4, \theta_5, \theta_6]^T \\ \epsilon &= [0, 0, 1]^T \\ X &= [x, y, z]^T \end{aligned} \tag{2}$$

In which θ_i for $i = 1...6$ are the actuator angles, x, y and z are the end effector coordinates. Basically the vector q is related with the orientation and X is related with the position of the designed robot. Consider the following Lagrangian:

$$\mathcal{L} = K - P = \frac{1}{2}\dot{q}^T I \dot{q} + \frac{1}{2}\dot{x}^T M \dot{X} - mg\epsilon^T X \tag{3}$$

Now consider the Euler-Lagrange Formulation:

$$\frac{d}{dt}\left[\frac{\partial \mathcal{L}}{\partial \dot{q}}\right] - \frac{\partial \mathcal{L}}{\partial q} = \tau \tag{4}$$

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obtaining the following dynamic system:

$$\begin{aligned} I\ddot{q} &= \tau \\ M\ddot{X} + mg\epsilon^T &= 0_n \end{aligned} \tag{5}$$

Or in other way:

$$\begin{bmatrix} I & 0_n \\ 0_n & M \end{bmatrix} \ddot{Q} + mg \begin{bmatrix} 0 \\ \epsilon^T \end{bmatrix} = \begin{bmatrix} \tau \\ 0 \end{bmatrix} \tag{6}$$

In which $Q = [q^T, X^T]^T$. So the previous equation can be transformed into state space formulation in the following way:

$$\begin{aligned} \dot{Q}_1 &= Q_2 \\ \dot{Q}_2 &= D^{-1}\tau - D^{-1}C \end{aligned} \tag{7}$$

For $Q_1 = Q$ and $Q_2 = \dot{Q}$ with the following vector and matrix:

$$\begin{aligned} C &= \begin{bmatrix} 0 \\ \epsilon^T \end{bmatrix} \\ D &= \begin{bmatrix} I & 0_n \\ 0_n & M \end{bmatrix} \end{aligned} \tag{8}$$

3. Passivity Based Control of the RV-3SB Robot Manipulator

For the passivity based control strategy of the RV-3SB robot manipulator, the required energy considerations are took into account in order to ensure the closed loop stability. It is important to recall that passivity based control is an important technique for robotic systems that has been implemented during decades for different kinds of mechanisms. It is important to remark than in this case a passivity based control strategy is implemented for this kind of robot, something that is considered as an important contribution for the field. To obtain the obtained passivity based control law consider the following theorem:

Theorem 1. *The dynamic model which represents the robot RV-3SB (6) represented in state-space model as appears in (7) is passive iff the following control law is implemented:*

$$\begin{aligned} \tau &= C - DR_2^{-1}R_1Q_1 - DR_2^{-1}\frac{Q_2}{\|Q_2\|^2}e^T\dot{Y}_{ref} \\ &+ DR_2^{-1}\frac{Q_2}{\|Q_2\|^2}e^TY + DR_2^{-1}\frac{Q_2}{\|Q_2\|^2}\tau_p^TY \end{aligned} \tag{9}$$

In which the error variable is given by:

$$e = Y_{ref} - Y \tag{10}$$

Y_{ref} is the reference variable for trajectory tracking purpose, and $Y = [x, y, z]^T$. The matrices gains are defined as $R_1 \in \mathbb{R}^{9\times9}$ and $R_2 \in \mathbb{R}^{9\times9}$.

Proof. Consider the following Lyapunov functional:

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$$V = \frac{1}{2}Q_1^T R_1 Q_1 + \frac{1}{2}Q_2^T R_2 Q_2 + \frac{1}{2}e^T e \tag{11}$$

By obtaining the first derivative of the previous Lyapunov functional yields and making the appropriate substitutions:

$$\begin{aligned} \dot{V} &= Q_1^T R_1 Q_2 + Q_2^T R_2 \left[D^{-1}\tau - D^{-1}C \right] \\ &+ e^T \dot{Y}_{ref} - e^T Y \end{aligned} \tag{12}$$

Now by substituting (9) into (12) it is obtained:

$$\dot{V} \leq \tau_p^T Y \tag{13}$$

So the system is passive and stable and the proof is completed.
□

4. Numerical Experiment

In this section two numerical experiments are evinced taking into consideration the simulation parameters and conditions given in Section 2. The two numerical examples consists in the trajectory tracking of the robot Mitsubishi RV-3SB with different trajectory profiles as explained below:

- A sigmoidal reference profile.
- A sinusoidal reference profile.

The results obtained with the proposed control strategy are compared with two strategies found in the literature as evinced in the content of this section. In Table 1 the controller parameters of the proposed control strategy are presented:

Table 1. Mitsubishi RV-3SB robot parameters for experiment 1 and experiment 2.

Parameter	Parameter value
R_1	$I_9 \times 8 \times 10^{-1}$
R_2	$I_9 \times 10 \times 10^{-1}$
K_p	$I_9 \times 1 \times 10^{-1}$

4.1. Experiment 1

This experiment is performed by implementing a sigmoidal function as the reference for the trajectory tracking of the robot Mitsubishi RV-3SB. The main purpose of this experiment is to validate that the tracking error yielded by the proposed control strategy are driven to zero in finite time. The gain matrices are selected in order that the variables in order to obtain the optimal performance, clarifying that closed loop stability is assured independently of the initial conditions of the robot's dynamic system. The results are compared with two control strategies [61,62] in order to obtain conclusions about the results.

In Figures 2 and 3 the evolution in time of the variables x, y and z along with their respective errors are presented. It is important to notice that the results obtained by the proposed controller are improved by the proposed control strategy. Maybe the difference between the trajectory tracking error is smaller, but as verified later the integral square error ISE obtained with the proposed method is significantly smaller than the obtained by the other methods [61,62].

In Figures 4 and 5 the actuator torques of the robot Mitsubishi RV-3SB are presented. It can be noticed that the actuator torques reach the origin in finite time faster, taking into consideration the

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passivity based control law designed in order to dissipate energy from the robot dynamic system in order to drive the actuator torques to the origin.

Then in Figures 6 and 7 the angular velocities of the actuators are presented evincing first that these variables reach the origin in finite time with a considerable small velocity.

Finally in Figure 8 the trajectory of the end effector in three dimensions is presented observing how the reference trajectory is tracked accurately by the passivity based controller for the robot Mitsubishi RV-3SB. This plot corroborates in three-dimensions how the end effector is guided in a 3-D workspace. In Table 2 is presented the integral square error of the proposed control strategy in comparison with the proposed control strategies [61,62]. It is observed that the ISE obtained with the proposed control strategy for the variables x, y and z is smaller in comparison with the control strategies which appears in [61,62]. It is important to remark that the proposed control strategy provides similar results as the other two control strategies, but it is important to mention that apart from the smaller ISE obtained with the proposed control strategy the control effor is more adequate in comparison with the comparative approaches used in this benchmark.

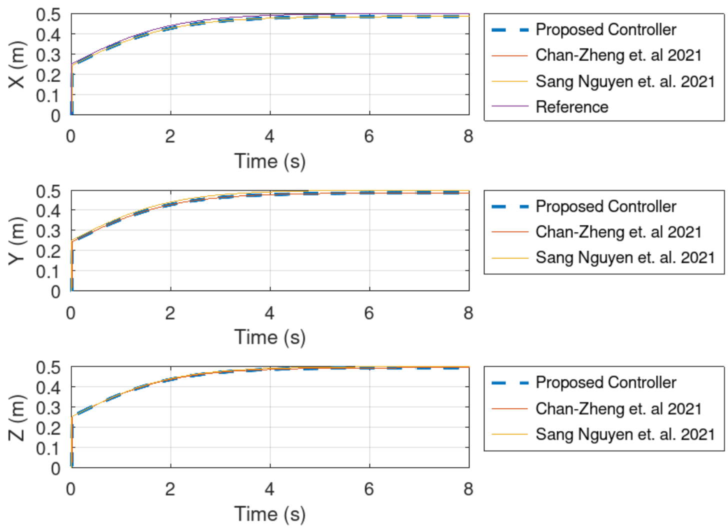

Figure 2. Position of the mobile robot in the x, y, z frames.

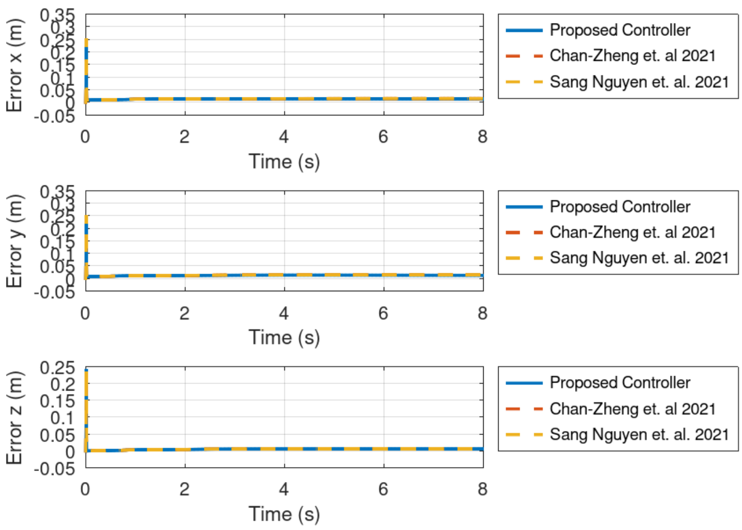

Figure 3. Position error of the mobile robot in the x, y, z frames.

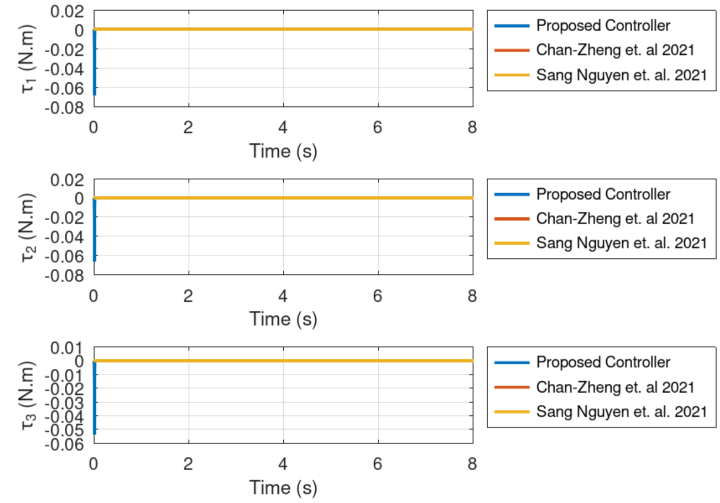

Figure 4. Actuator torque for experiment 1.

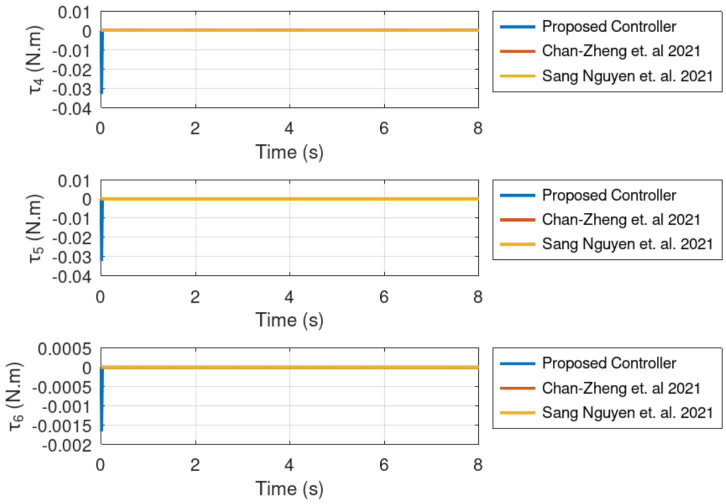

Figure 5. Actuator torque for experiment 2.

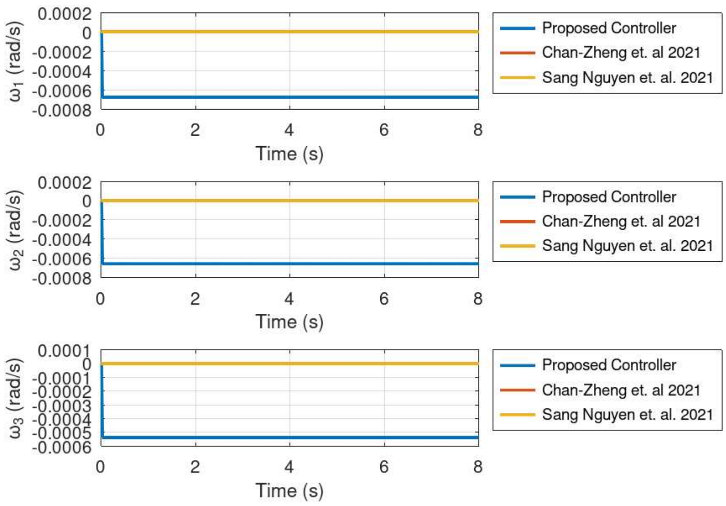

Figure 6. Actuator Angles ω_1, ω_2 and ω_3.

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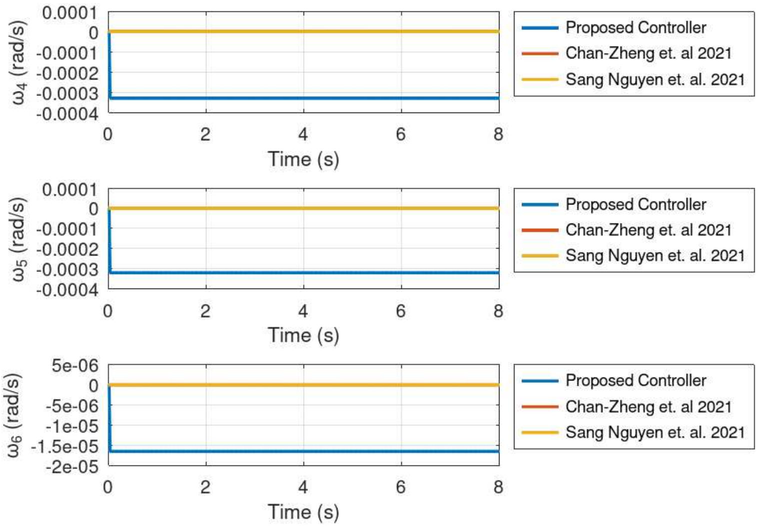

Figure 7. Actuator Angles ω_1, ω_2 and ω_3.

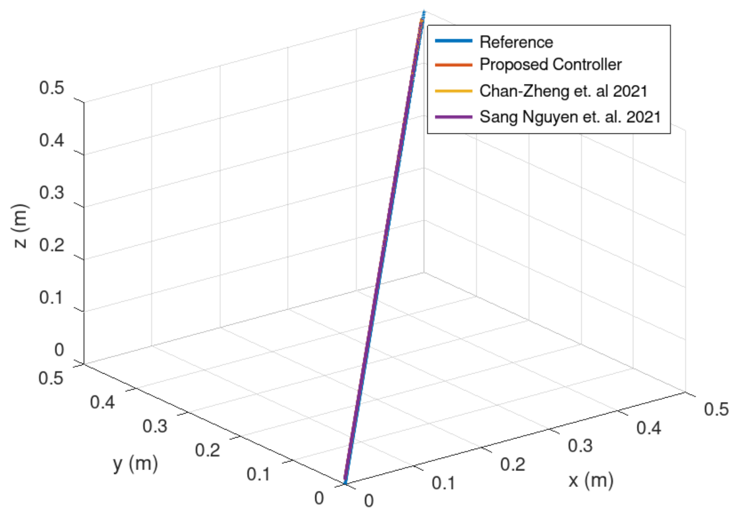

Figure 8. 3D trajectory of the robot RV-3SB.

Table 2. Integral square error of experiment 1.

Controller approach	ISE x	ISE y	ISE z
Proposed Controller	1.5957×10^{-2}	$1.5457\ \times10^{-2}$	$9.6052\ \times10^{-3}$
Chan Zheng et. al. 2021	1.6341×10^{-2}	1.5863×10^{-2}	9.6887×10^{-3}
Nguyen 2021	1.6341×10^{-3}	$1.5863e\times10^{-2}$	9.6887×10^{-3}

4.2. Experiment 2

This numerical experiment is done similar to experiment 1 considering other conditions and trajectory generation to validate and corroborate the theoretical results obtained in this research study.

In Figure 9 the position of the end effector of the robot Mitsubishi RV-3SB with obtained with the proposed control strategy in comparison with the other two strategies used in this comparative benchmark are presented [61,62]. It is corroborated how the results obtained with the proposed controller are the optimal in comparison with the results obtained in [61,62]. As it corroborated later it

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is verified that the proposed strategy provides better results in comparison with the results obtained in [61,62].

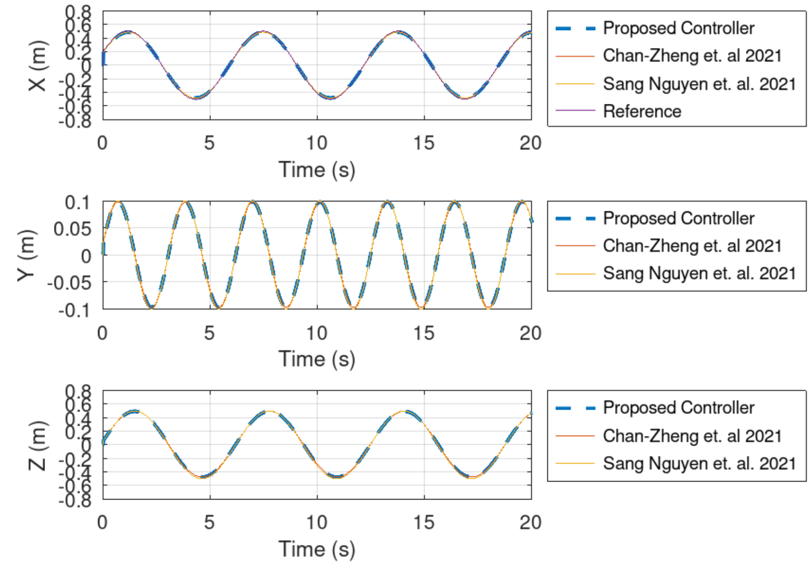

Figure 9. Position of the mobile robot in the x, y, z frames.

Meanwhile in Figure 10 the error variables of the trajectory tracking position of the end effector of the robot RV-3SB is presented for the proposed control strategy in comparison with the strategies shown in [61,62]. It is verified how these error variables reach the origin in finite time. It sould be verified later that the results obtained with the proposed control strategy are more accurate in comparison with [61,62].

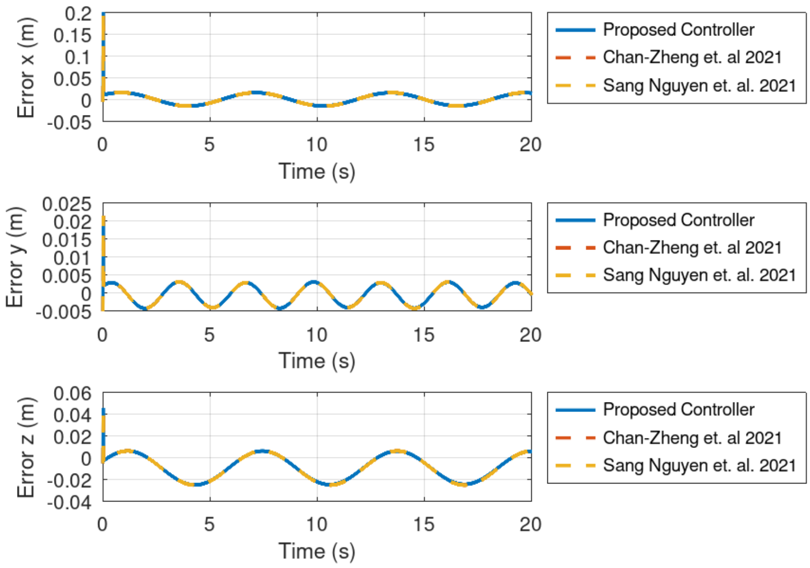

Figure 10. Position error of the mobile robot in the x, y, z frames.

Then in Figure 12 is presented the actuator torques of the robot Mitsubishi RV-3SB evincing that the actuator torque obtained by the proposed control strategy is smaller in comparison with the actuator torque generated by the approaches which appears in [61,62].

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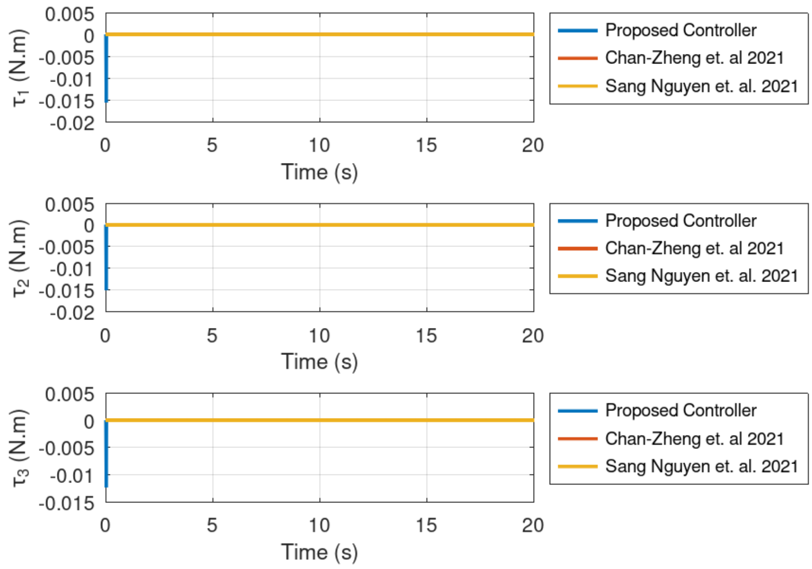

Figure 11. Actuator torque for experiment 1.

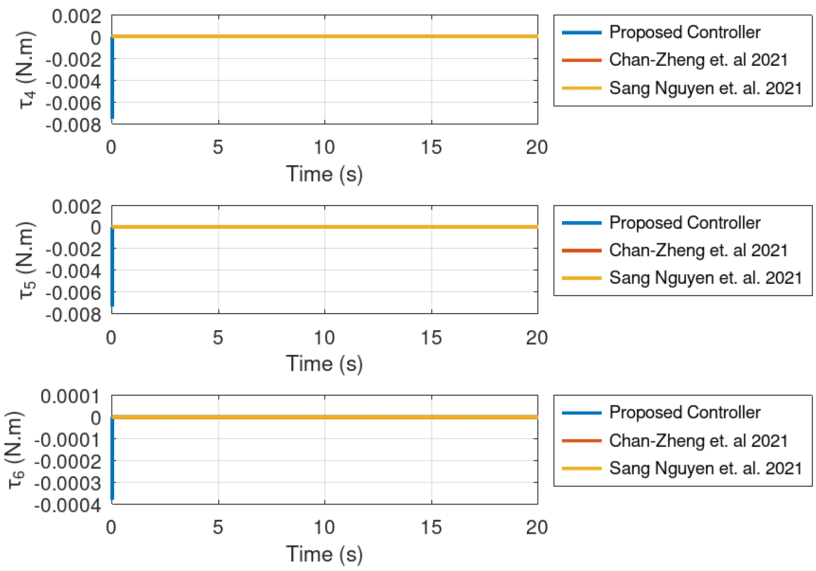

Figure 12. Actuator torque for experiment 2.

In Figures 13 and 14 are shown the actuator angles generated by the proposed control strategy and the strategies which appears in [61,62].

Finally, in Figure 15 the end effector trajectory of the robot Mitsubishi RV-3SB is evinced. The trajectory with the proposed controller is compared with the trajectory generated by the strategies shown in [61,62] proving that the results with the proposed controller are superior in comparison with the other strategies used in this benchmark.

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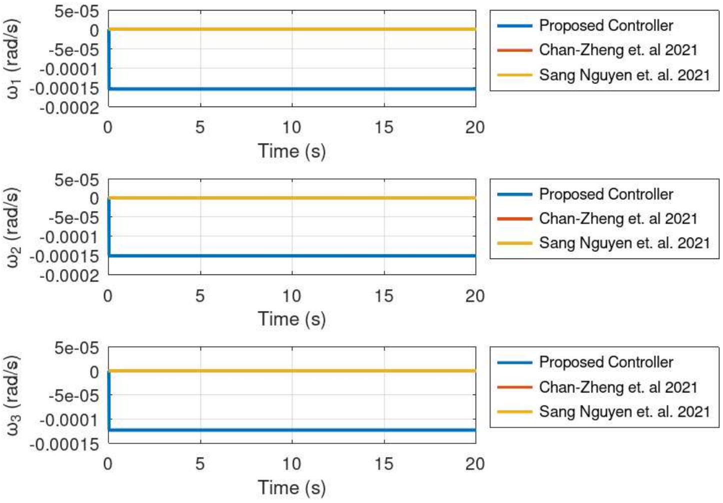

Figure 13. Actuator Angles ω_1, ω_2 and ω_3.

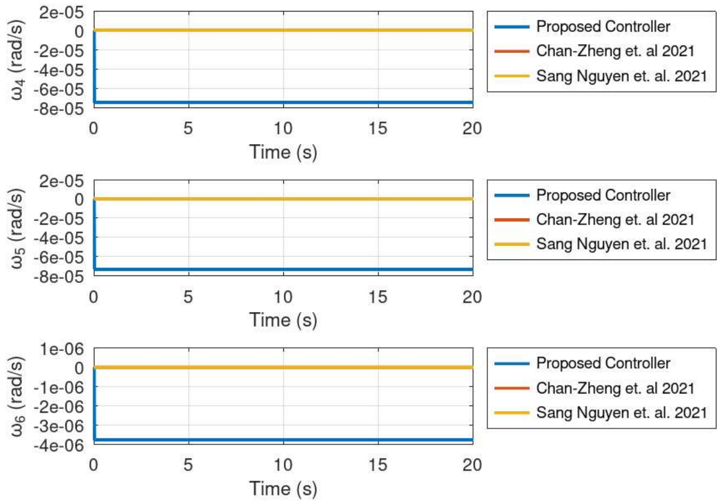

Figure 14. Actuator Angles ω_1, ω_2 and ω_3.

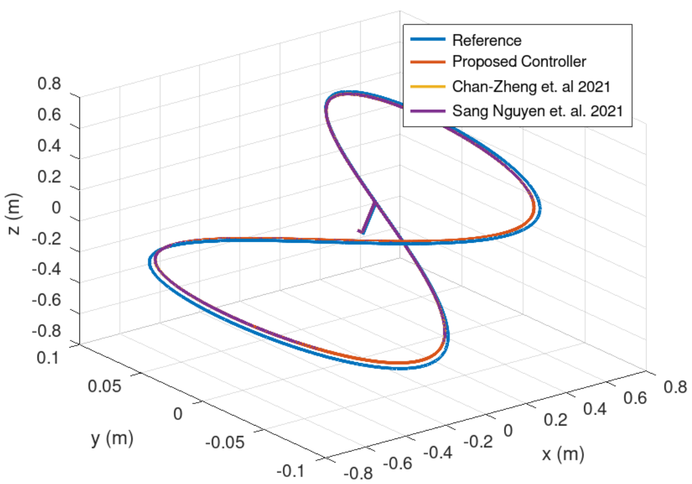

Figure 15. 3D trajectory of the robot RV-3SB.

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Table 3. Integral square error of experiment 2.

Controller approach	ISE x	ISE y	ISE z
Proposed Controller	1.1830×10^{-2}	2.5795×10^{-3}	1.4096×10^{-2}
Chan Zheng et. al. 2021	1.2001×10^{-2}	2.6106×10^{-3}	1.4366×10^{-2}
Nguyen 2021	1.2001×10^{-2}	2.6106×10^{-3}	1.4366×10^{-2}

Finally in Table 3 the integral square error of the variables x, y and z are presented. It is noticed that the ISE of the variables x, y and z for the proposed controller posses a small integral square error in comparison with the ISE of the strategies which appears in [61,62]. Despite these values are similar the ISE obtained with the proposed control strategy is smaller.

5. Discussion

In this research study it is proved theoretically and experimental a novel passivity based controller for the robot Mitsubishi RV-3SB. Considering that this robot is used experimentally in laboratories in universities around the world, one of the main contributions of this research study is that the kinematics, dynamics and control of this robot have not been obtained before. The dyamics of the robot is obtained by using the Euler-Lagrange approach, considering the tractability of the problem. It is important to mention that the selected passivity based controller is selected due to its relative simplicity, energy considerations and easiness to implement. The passivity based controller is designed by implementing an appropriate storage function in order to find the passivity control law in order to stabilize the systema variable or for trajectory tracking purpose of the robot Mitsubishi RV-3SB. Theoretically the passivity based controller suffice for trajectory tracking purposes due to the stability conditions of the controller are met for trajectory tracking purpose in order to drive the energy of the system to zero.

It is important to mention that in the numerical experiment section, two experiments were conducted, the integral square error of the variables x, y and z were computed in order to verify that the traking error approaches as much as possible to the origin in finite time. One of the drawback in these two numerical experiments, is that the integral square error ISE must be as small as possible. It is important to mention that to solve this, as verified in experiment 1, the gains of the controllers must be selected as long as they are positive definite. This condition ensures the stability of the error dynamics, but at the same time as proved in experiment 2, the error can be drive accurately to zero by implementing some tuning or optimization algorithm. This issue will be improved in future research studies considering that the stability of the tracking error is minimized accurately only by selecting a positive definite gain.

6. Conclusion

In this research study is synthetized a passivity based controller for a Mitsubishi RV-3SB robot. Considering that in many laboratories in universities in the world are implemented this robot mechanism for academic or research purposes, it is crucial to design a novel but at the same time implementable controller in order to drive the error variable with its dynamics to zero and finite time. Taking advantages of the energy considerations of passivity based controllers, a relatively simple control law is obtained taking into consideration that the resulting controller must be implementable in affordable hardware independently if it is a small laboratory with lack of equipment. In order to design the passivity based controller it is implemented a storage function in order to obtain the passivity based controller. Two numerical experiments are performed in order to validate the theoretical results with two experiments in order to validate the trajectory tracking performance in order that the error variables of the end effector approaches the origin in finite time with a small integral square error.

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