Modeling and Simulation Applied for Robotics Manipulator's Driving

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Abstract: - The present paper will impose a driving strategy for a particular nonlinear system, for example for a robot consists of a single segment, which has a flexible hinge. Transmission is more accurate, with a line size of the input provided by engine torque. Because of the robot arm speed can not be measured accurately one estimate the desired state through an Observer system. System that is intended to be driven is nonlinear, more exactly an affine system with a mono-variable type with uncertainties of some parameters and also of a state functions. It is known that the robustness to model parameter uncertainties and external disturbances of the closed loop can be achieved with a variable structure controller. Maintaining the system on a sliding surface weakens the influence of the uncertainties in the closed loop performances and quickly leads to an equilibrium point.

Key-Words: - Arm, Joint, Nonlinear Command, Manipulator, Robot, Sliding observer, Sliding controller.

1 Introduction

The direct kinematics of robotic manipulators studies the concept of force and its causes. With helping of kinematics will study the displacement, speed, acceleration and all the displacement derivations. The manipulator's kinematics means the geometrical study and the time proprieties base on movement. Robot manipulators are used in series comprising a set of objects, called arms (links) connected by joints. Each joint has at least one degree of freedom, either translational or rotational [11].

For robotic manipulators with n-joints numbered from 1 to n, have n +1 arm, numbered from 0 to n. The link number 0 is generally fixed and n is the last arm of the industrial robot. The joint i made the connection between the arms i and i-1.

An arm (link) can be considered a rigid body defining the relationship between two neighboring joints robotic manipulator axis [14].

An arm can be specified by: the arm length and its curvature, which defines the location of two axes in space. Parameters for the first arm and the last arm are arbitrarily chosen, that means a value equal with zero. The joint is connected to a pair of bodies where the relative motion is characterized by two adjustable surfaces one held over another. Joint can be described by two parameters. The offset arm is the distance from one arm to the next, along the joint axis. Joint angle is described by rotation of the arm on the next joint axis To facilitate the description of the location of each arm, one fix the coordinate system, i coordinate which is attached to arm I [11], [14].

Denavit and Hartenberg (DH) propose a matrix method designating the coordinate system for each arm. The joint axis is aligned with z_{i-1}.

The x_{i-1} axis is directly over the normal z_{i-1} to z_i and for the crossing axis is parallel to $z_{i-1}*z_i$.

In terms of inverse kinematics for n axes of a rigid robotic manipulator, direct kinematics solution is given by the coordinate system or by the arrangement of the last arm [17].

The Robotic arm have 6 degrees of freedom in Cartesian space, 3 in translational way and 3 in rotational, so the robotic manipulators, therefore, usually have six joints or degrees of freedom [23].

The direct kinematics solution can be calculated for any robotic manipulator, irrespective of the number of joints or kinematic structure [7], [12].

2 The Robot driving with flexible joints when the relative degree is equal to the system order

In the following will apply a driving strategy for a particular nonlinear system, for example for a robot consists of a single segment, which has a flexible joint (see Fig. 1). The transmission is made more

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accurate, with an aid of spring; the input size will be provided by the engine torque [2], [3], [4], [8], [9].

Because the robot arm speed, respectively the rotor engine can not be measured exactly, the same thing being able to say about the angular position of the rotor DC motor; it wish the system state estimation of the system statement using an Observer [11], [14].

In Figure 2 is presented the principle scheme after that will be made the command of the robot with flexible joints.

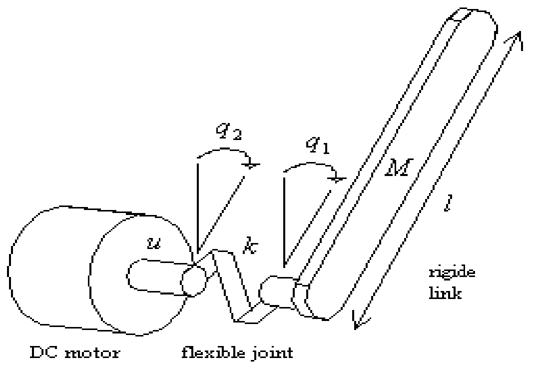

Fig. 1. The Robot with flexible joint

The system that is intended to be driven is nonlinear, namely an affine system with mono-variable type and uncertainties of state functions, and parameters, also [10]. Even the controller in the smoothed form and also the adaptive Observer in smoothed form, either, are designed to meet the requirement of proximity of a sliding surface [14].

In order to eliminate, or at least reduce the chattering effect was used for both controller and the Observer, a switching function such as hyperbolic tangent [21], [22], [23].

In addition, amplifications of the controller switching functions, respectively of the Observer, are adjustable adaptively function of the tracking error, respectively the estimation error of the parameters.

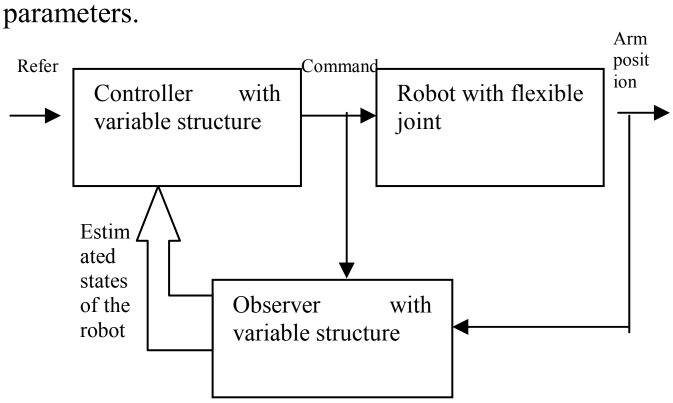

Fig. 2. The principle scheme for driving the robot with flexible joint

First, one calculates a nonlinear control law for the robotic manipulator with flexible joints [2], [3].

In terms, of command one project, using the accurate linear principle, making the assumption of knowledge of all states, without the need to use an Observer [4], [8], [9], [10].

The dynamic equations (see Formula 1) of a robot with one arm and flexible joint that can rotate in the vertical plane are given by:

$$\begin{cases} J_1\ddot{q}_1 + F_1\dot{q}_1 + k(q_1 - q_2) + Mgl\sin q_1 = 0 \\ J_m\ddot{q}_2 + F_m\dot{q}_2 - k(q_1 - q_2) = u \\ y = q_1 \end{cases} \quad (1)$$

In which q_1 and q_2 represent the displacement angle of the robot arm segment, respectively the displacement angle of the DC engine rotor. The Robotic arm inertia is J_1, the engine rotor inertia is J_m, elastic constant k, the robotic arm mass M, Gravity constant g, center of gravity l and viscous friction coefficients F_l, F_m are positive constants. The command u is the torque provided by the engine [1], [23].

According with Filipescu, Dugard and Stamatescu (2005, 2007) and, also, with Filipescu, Dugard and Dion (2004), the results of the simulation are presented in figure from below, Fig. 3, with the following parameters values: $J_l = 5\text{Nm}$, $J_m = 7\text{Nm}$, $l = 1\text{m}$, $k = 400\text{Nm}$, $F_m = F_l = 1\text{kgm/s}$, $M = 2\text{kg}$, $k1 = 25000$, $k2 = 6500$, $k3 = 725$, $k4 = 40$. The reference to be pursued is $2(1+\cos(2t))$. The values $k_i \quad i = 1,\cdots,4$ correspond to the next proper values of the linear system:

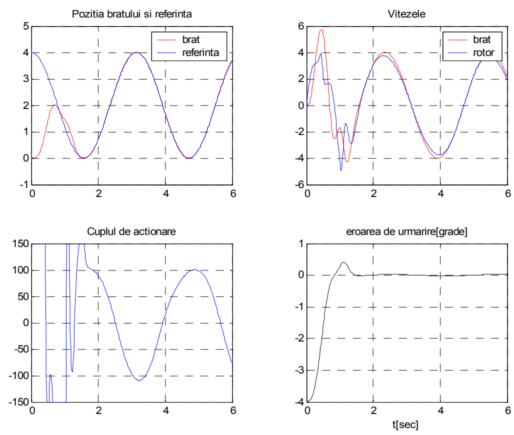

Fig. 3. The response of the robotic manipulator with flexible joints when apply a nonlinear command law

In the first chart, in Figure 3, one has represented the arm position and the reference, in the second is the speed, the third is drive torque an in the last one, can observe the tracking error, measured in degrees.

Seen from the chart properly tracking the reference size, although, initially, the arm and the reference start from different points. One considered all states and all known parameters, without needing to use an Observer [15], [16].

Next, one consider a Sliding Observer - Sliding Controller scheme - for robotic manipulator's driving with flexible joints where the quantity measured is the arm position [18], [20].

One choose the same state variables as in the previous case, resulting the same system. In this simulation the manipulator states are given by an Observer operating under the sliding mode.

U is an input voltage of DC motor that moves the arm. Parameters are defined as: $M_1 = \frac{Mgl}{J_1}$, $K_1 = \frac{k}{J_1}$, $K_2 = \frac{k}{J_m}$, $B_1 = \frac{F_l}{J_l}$, $B_2 = \frac{F_m}{J_m}$. The measurable output is the position of the arm. Reference to be pursued is $2(1+\cos(2t))$.

The simulation results, made in Matlab are shown in Figure 4 and 5.

One use the same parameter values as in the previous simulation. The response is observed less oscillating than that obtained when using non-linear commands. The amplification is given by the laws presented below:

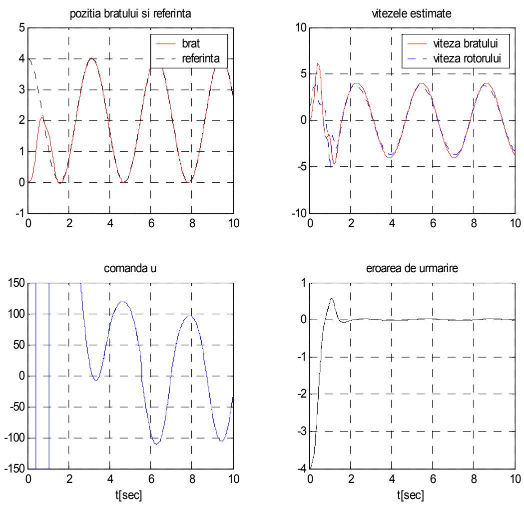

Fig. 4. The response of the robot in close loop, Observer-Controller Smooth-Sliding, switching function k-tanh $k_o = 25$, $k_c = 1$, $\lambda_o = 1$, $\vartheta_o = 1$, $\lambda_c = 1$, $\vartheta_c = 1$

In the first chart, from Figure 4, one has represented the arm position and the reference, in the second is the estimated speed, the third is command u an in the last one, can observe the tracking error.

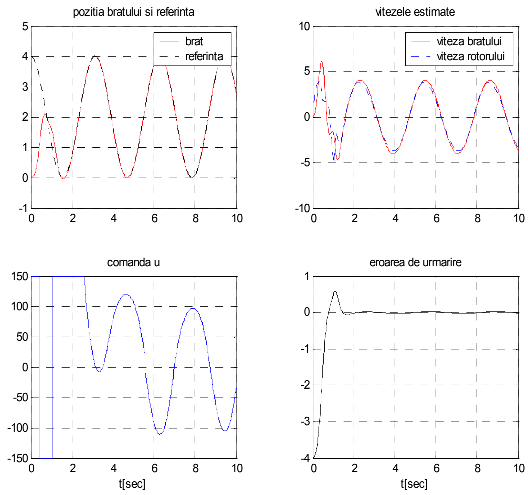

Fig. 5. The response of the robot in close loop, Observer-Controller Smooth-Sliding, switching function k-tanh $k_o = 1$, $k_c = 25$, $\lambda_o = 1$, $\vartheta_o = 1$, $\lambda_c = 1$, $\vartheta_c = 1$

In the first chart, from Figure 5, one has represented the arm position and the reference, in the second is shown the estimated speed, the third is command u an in the last one, can observe the tracking error.

4 Conclusion

A smooth Observer-Controller, under the sliding mode, with adaptive adjustable amplification is proposed in driving of the nonlinear systems.

As a switching function is generally used a hyperbolic tangent.

The lead system equations also contain an additional term, adjustable and adaptive, too, to obtain useful information on errors.

The hyperbolic tangent function provides reduction or complete elimination of chattering.

An appropriate choice of Observer and Controller parameters allow to Observer to converge faster than the Controller.

The adaptive gains lead to a smaller error estimation and reference tracking and, also, increase the robustness.

Convergence rate for both the Observer and Controller has been established. Applications were presented for a single-arm robot with flexible joints and for a robotic manipulator with a rigid arm and

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joints. Closed-loop response obtained by simulation confirms the theoretical results.

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