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Study and modelling of new control strategies for industrial robot manipulators

One of the most important research field in mechatronics, and particularly in robotics, regards the estimation of the dynamic parameters of a general mechanical system. Many researchers have tried to understand how obtain a good dynamic parameters estimation and what are the best methodologies to apply in order to find them; now some already tested methods are widely available (see, for example, [1] and [2]). Examples of dynamic parameters to find are motor effective force/torque without friction components, links centre of mass and inertia, applied load, friction force/torque in each joint, elasticity in each joint, etc.
Their knowledge is fundamental in order to understand how a mechanical system (e.g. an industrial robot) behaves, and how it is possible, by the use of an advanced control strategy, to improve its performance, and furthermore to know what can be the future mechanical design techniques to apply in order to avoid, or decrease, the undesired effects.
During the doctorate work it is proposed to focus on the modelling and compensation of both friction and elasticities effects in the joint of an industrial robot manipulator.
The research proposal activity can be subdivided into three main parts:
- the study and modelling of the friction effects;
- the study and modelling of the elasticities effects;
- the development of a control strategy that will be able, by taking into account friction and elasticities, to improve robot performance.

STUDY AND MODELLING OF FRICTION
The first part concerns the study and modelling of the friction present in each joint of the robot.
In this phase the main friction models are studied and ad hoc trials are performed in order to understand what are the relations between friction force/torque and motion velocity, inertia of the body, robot configuration, warm-up time, temperature, etc.
The main models, already present in literature and that it is necessary to investigate are, for example, the Coulomb-viscous-Stribeck one, the polynomial one, the Dahl one, the LuGre one (see, for example, [8] [9] [10] [12]).
Trials have to be made for each joint and they can be summarised as follows:
- in order to understand what is the robot warm up time, it is possible to move each joint for some hours extracting the data every 5 minutes. This operation will be performed at different speeds and the warm up time for each velocity is considered as the time when the friction torque becomes almost constant. At the end of the tests it will be possible to understand the relation between velocity and warm up time.
- to estimate how velocity affects the friction torque, each joint can be moved, after the warm up time, from 0% up to 100% of its maximum velocity in both the directions;
by measuring both velocity and torque during the motion, and considering only the time intervals with constant velocity, it is possible to plot the relation between speed and friction torque, while by the application of the different models in literature it is possible to understand what is the model that best fits the velocity torque relation.
- to understand how inertia influences the velocity-torque relation, it is necessary to repeat the experiments to model the velocity torque relation with different robot configurations;
- to see if the friction curve of a particular path does not change during the work, even though there are other trajectories to follow between two identical motions, it is possible to move the robot after the warm up time along a desired trajectory; then the robot moves in other directions until a certain time is elapsed. At the end, the robot manipulator follows again the trajectory under investigation.
By repeating this cycle for some trials and for different “intermediate” trajectory time it is possible to understand if the friction remains constant for a particular motion or not.
The robot in these experiments is considered as a 1 degree of freedom manipulator and for each tests it is positioned in order to have different inertia at the joint.

STUDY AND MODELLING OF ELASTICITIES

The second part is related to the study and modelling of elasticity effects in the robot joints.

During this step the robot will be modelled by taking into account its elasticity; as in the first part, the relations between this elasticity and the joint position, velocity, inertia… will be investigated (see, for example, [7]).

As for the friction analysis, also elasticity will be analysed for each joint of the robot.

The procedure of this analysis will be as follows:

after the warm up time, each joint will be moved independently with different velocities and, by considering the elasticity models in literature, it will be possible to discover what model best fits the part of the robot under investigation and what are the relations between elasticity effects and motion speed. Of course, like for the friction analysis, the inertial effects have to be considered.

- to understand how motion speed influences the elasticity of the robot, it is possible to move the desired joint with a "sinusoidal" like motion with different velocities (e.g. 5%,10%,15%...); the analyses of all the acquired data allow to see the relation between speed and the undesired elasticity effect (e.g. joint position…).
- to analyse how inertia affects the velocity-position curve, it is possible to repeat the previous trials with different inertia.
- to see how warm up affects the elasticity effects, it is possible, as for the friction analyses, to extract data also before warm up is completed. Comparing them with the data obtained after the warm up time it is possible to highlight if the warm up changes the elasticity effects or not.

DEVELOPMENT OF NEW CONTROL STRATEGIES

The last part concerns the development of a different control strategy that, by considering the friction and elasticity relations, is able to improve motion speed or trajectory selection in order to increase the robot performance.

In order to do that, the previous two steps are mandatory.

Therefore, both friction and the elasticity effects have to be taken into account to implement the expected control strategy (see, for example, [4] [5] [6]).

Different control structures to compensate friction and elasticities effects have already been developed. Trials using neural networks [14], reduced order observer [13], adaptive control and other methods have studied (see, for example, [7] [8] [9] [10] [11] [12]), but there is still a lack of a fast, always working and applicable technique.

As mentioned before, this control strategy will be particularly important for robot manipulator manufacturers because it can improve the robot performances, and this fact can open new application possibilities for the industrial manipulators (e.g. milling) expanding their market.

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