Hydraulic Model of a Lifting and Handling Manipulator

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Abstract:This publication concerns hydraulic robots used in flexible production lines, in fact in hydraulic systems, energy is transmitted and controlled by means of a pressurized fluid circulating in a circuit. which form a new series of applications pick & place (Patents: N° 9507799623622 AL 1996088,9622856 AL 19960801, 9620818 AL 19960711. . .). Circuit diagrams are an aid facilitating the understanding, study and description of production cells. The new, very simple structure of the hydraulic robot is a novelty in Algeria and has been adapted to the data of a production line made up of seven production lines. In order to avoid any confusion and error during development, production, installation and maintenance and in order to transform this production line into a flexible cell, it appears essential that these diagrams be linked to a standardized representation.

Keywords: CAD modification, trajectories, Pick & Place (Signals input-output).

1. INTRODUCTION

Used in industry for decades, the industrial robots currentlyin service are manipulator-type robots. They are wellestablished in modern manufacturing processes and are used toincrease production volume and improve product quality. Inthe assembly lines of the automotive industry, they replace workers in arduous, repetitive or dangerous tasks (painting, welding, etc.). The study relates to the description of ahydraulic model of pick & place robot for the automation of a system allowing to perform operations of dosing, lifting, distribution, handling, delivery, packaging and packaging forbiscuits or cheese… [1 et 2].

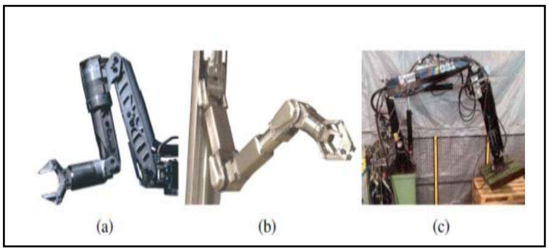


Fig. 1 Hydraulically actuated robotic serial manipulators: (a)Schilling ORION, (b) Cybernetics'sMAESTRO and (c) HIAB031 foracademic research purposes [3].

State-of-the-art commercial hydraulic manipulators arealways justified by controlling each actuator separately.Suchsystems are relatively energy efficient because they use anoffset center pressure compensated proportional control valvescombined with hydro-mechanical. In addition, some advanced smart systems are available. Itshould be noted that a similar system is quite difficult toachieve in high performance critical breaking servo valvesystems that require either some valves orcounterweight valves for state shutdown. These securityfeatures are often a requirement of standards for thecertification of commercial products, and are rarelyaddressed by academic research, with exceptions. [3].

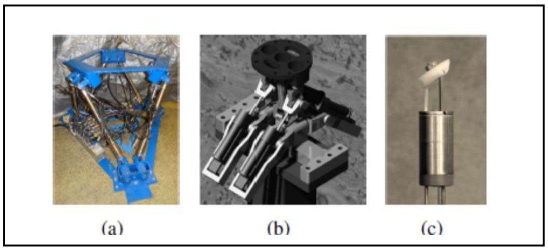


Fig. 2 Hydraulically actuated parallel manipulators: (a) IHA's six-DOF SGP, (b) Concept of a redundant shoulder [4] and (c) Aminiature three-DOF SGP as a part of an endoscope[5].

The hydraulic diagram shown is developed to describe therelationship between inlet and oil flow for each chamber andreplaced the data respectively corresponds to the jointconvention. Disregarding external and internal leaks, thehydraulic pressures at each chamber are defined by thedifferential equations.

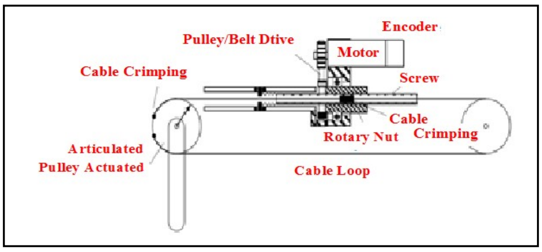


Fig. 3Cable cylinder [19].

The executive part (P.E.) and the desk are illustrated in theheart of this paper The experimental part of the automation isprovided by a Matlab Simulink environment.

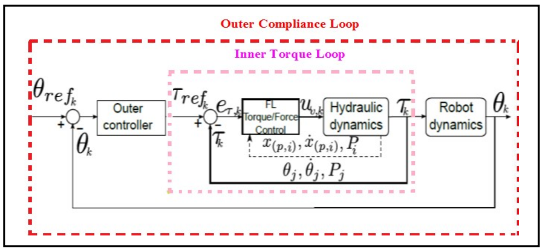


Fig. 4The internal loop schematic diagram of the HyQ control frame is a low level torque control joint with an external controller [8].

The production operation after optimization of hydraulic components including return valves, actuators, sensors, pumps, double-acting cylinders, and distributors for the realization of a wide variety of industrial consumer products is characterizedby a closed trajectory of a series of movement and stoppingwith delivery of product evacuation using the gripper and thisafter an improved choice of all the properties. The Ps and Pr are the supply and return pressures. While Pa and Pb representthe pressure in chambers A and B. Ignoring external andinternal leaks, the hydraulic pressures at each chamber aredefined by the differential equations.

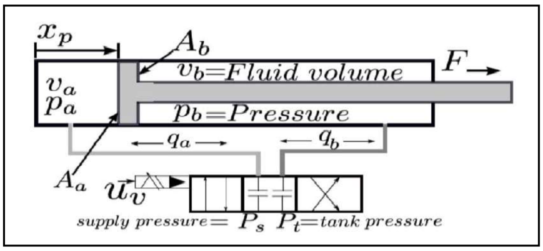


Fig. 5Cross section of asymmetric single rod hydraulic actuator showing the operating principle and the definition of the variables: uv is the control signal, pa and pb are the pressures of the chamber, va and vb are the volumes of the chamber Aa and Ab are the piston and ring zones, qa and qb are the flow entering and leaving the chambers A and B, Ps and Pt are the supply and return pressures of the reservoir, xp the position of the piston and F the force of the actuator.

2. PROBLEMS

Abbreviations and Acronyms

CTCComputer Torque Control
DOFdegré(s) of freedom
DHMDenavit-Hartenberg modifid
DMCDynamic Matrix Control
ETFEEmpirical Transfer Function
GPCGeneralized Predictive Control
HAC/LAC Structure Command
LQGLinéaire Quadratique Gaussienne
MCRMoindres Carrés Récursifs
MDIInverse Dynamic Model
MGDDirect GéométricModel
MIMOMultiple Input Multiple Output
MPCPredictive ControlModel
SISOSingle Input Single Output (system)
TFDFourier DiscreteTransforme
PFCPredictive Functional Control

A. Motion Control

The general issues of trajectory generation and learning by demonstration constitute fields of research in their own rightand go beyond the scope of this article. we can be interestedand refer for example to [10, 11]. Mechanical flexibilities,beneficial from a safety point of view, can induce unwantedvibrations and limit tracking performance. The synthesis ofcontrol laws must take this into account, particularly in thecontext where only motor sensors are available. A damped
rejection of disturbances is sought. The disturbances affectingthe system consist mainly of load variations or unintentionalnon-hazardous contact with the environment (not classified as acollision) during the various handling tasks. A zero static errorin steady

state should be ensured, in addition to a minimumerror in following the path.

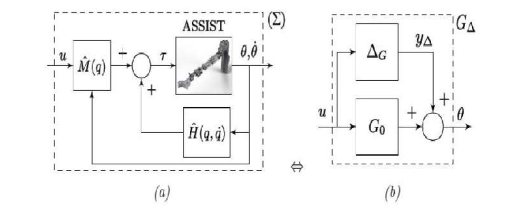


Fig. 6(a) Internal compensation loop applied to the ASSIST robotand (b) equivalent representation for the command [19].

The target applications mentioned in this section for a centaur robot required to interact with its surroundingenvironment or target objects without causing excessive forces.Using pure position / speed control for a limbs centaur typerobot is not sufficient for such applications. Interaction with theenvironment or target objects are best dealt with in the torque /force domain rather than in position [14 and 15]. HyQ (mobileplatform for a centaur-type robot) is a fully torque controlledrobot [8]. The block diagram of HyQ low level torque control(internal loop) with an external controller is illustrated in theabove discussion. The various operations that include thedescent, closing and ascent of the execution unit as well asunloading using the hydraulic circuits and the judiciousmodules produced [12].

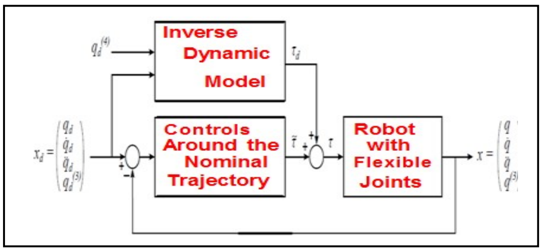


Fig. 7Command around a nominal trajectory [19].

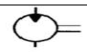
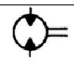
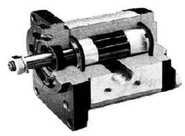
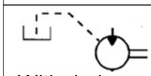
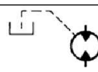
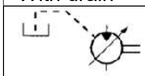
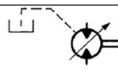
Motion control must allow precise and robust positioning and path following against modeling uncertainties throughout the workspace. The trajectories considered in the application context of human-robot interaction can in particular be learned by the user for the execution of a task at a sustained speed. [19] The manipulator arm is the positioning system where the forces acting at the joints are produced by hydraulic actuators INAPIPatent Filed in our article we are particularly interested in the case of hydraulic motors.

B. Overview of the technological study

Hydraulic Motor

In this type of actuator, hydraulic energy supplied by apressurized fluid is transformed into mechanical energy. Thisresults in rotational movement on the output shaft. Theintermediate phases are those of the triggering of the Transband in the different phases and the evacuation to the dosingand packaging stations.

Table 1 Hydraulic Motor.

Motor with one direction of rotation	Motor with two directions of rotation	
 Hydraulic Motor		
 With drain		
 Variable displacement		

Hydraulic Robot

The industrial robot (fig. 8) is secured to a base (1), held at its lower part by a body (2), which also serves as a support for the column of the vertical displacement module and for it's interior are notched the elements of the hydraulic circuit.

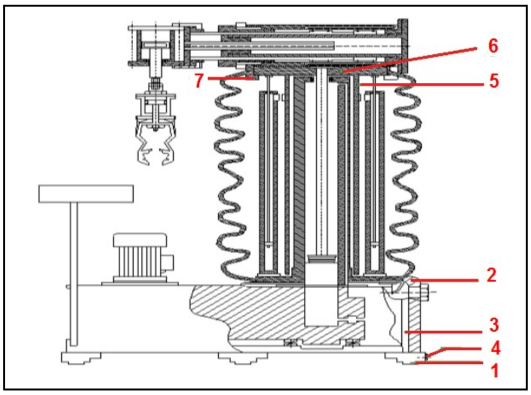


Fig. 8 Elevation view and partially in section of a manipulatorrobot, with its modules and part of the hydraulic circuit [12].

A CAD software can be used to model all hydraulicsystems in 3D; from the tank to the actuators, including thedistribution network. With a basic version it is possible tomodel and integrate the hydraulic circuits.
However, software vendors develop specific applications tooptimize easy integration into a complex machine environment.4/2 directional valves driven directly by inductive positioncontrol solenoids are used in relevant safety applications.
The start and end positions can be checked. Position control is available on single and double solenoid valves.

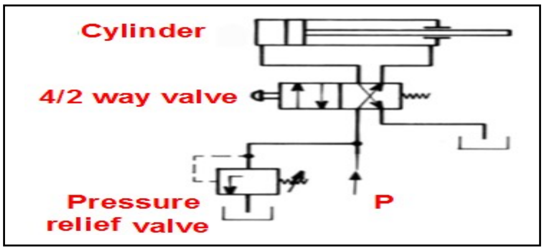


Fig. 9Differential cylinder in normal assembly.

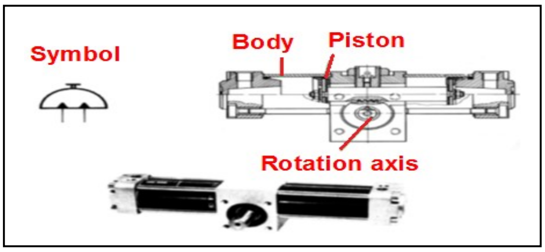


Fig. 10Rotary cylinder.

Role

The principle of this cylinder is to transform the rectilinearmovement of a piston into a rotary movement around an axis.

Rotation Module

The rotation module (fig. 11) consists of two cylinders (1) and (2) installed in the body (3) using the fixing elements (4) and (5). The transmission by rack and the toothed wheel (6) and (7) transforms the rectilinear movement of theplungers(double-acting) into a rotational movement of the column. Itis a reversible system having the advantages of a simple realization which can withstand large loads. The part (8)serves at the same time for the guide of the rack and for the fixing the cylinder to the body. The protruding part of the cover (9) allows the movement of the piston (10) to be damped byforming a bed of the oil once it is engaged in the hollow made in the piston. The development of the necessary effort is taken into account in the event of contact. The hand can have arotational movement actuated by the hydraulic circuit and the positioning of the terminal member on the part to be lifted is carried out by a limit switch contact.

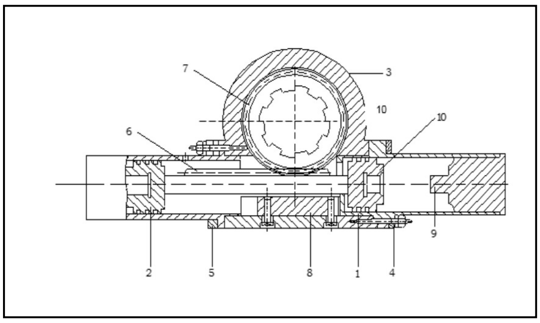


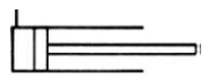
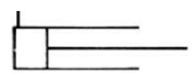
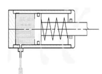
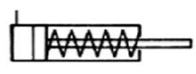
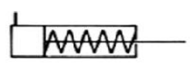
Fig. 11 Two-cylinder rotation module [12].

Actuators

Actuators are the driving force of the system; they transform hydraulic energy into mechanical energy. The mostcommon are jacks and motors. Jacks we can classify jacks intothree main categories, depending on their use.

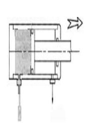
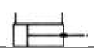
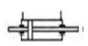
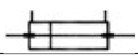
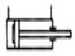
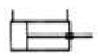
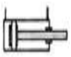
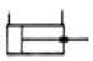
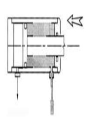
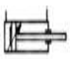
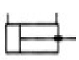
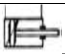
SAC Single-Acting Cylinders

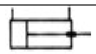
Table 1 Table caption

Detailed symbol	Simplified symbol	
		
		

DAC Double acting cylinder

Table 3DAC

Detailed symbol	**Simplified symbol**	**Symbolizations** Non-cushioned cylinders. 1. Single rod. 2. Double rod. transverse. Cylinders with cushioning. 3. Fixed cushioning in back. 4. Damping at the front and in back. 5. Adjustable cushioningin back. 6. Adjustable amortization	
			
			
			
			
			
			

		front and back.	

Hydraulic rotary motor model

The hydraulic motor diagrams shown in Fig.12 consist of aservo valve and a hydraulic motor.A uv control input, chose the direction and amplitude of theoil flow qa and qb in each chamber A and B.

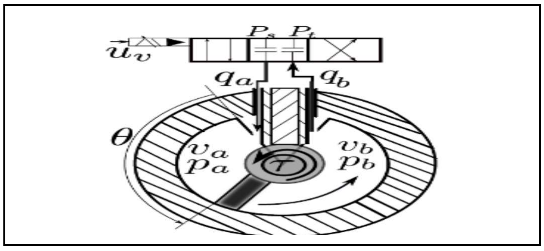


Fig. 12Cross section of a single vane rotary hydraulic actuatorshowing the operating principle and definition of the variables: uv is the control signal, pa and pb are the pressures of the chamber, va and vb are the volumes of the chamber, qa and qb are the flow of liquid into and out of chambers A and B, Ps and Pt are the supply and returnpressures of the reservoir [6].

Expression of joint error

Let us analyze the dynamics of joint error as a function ofmotor error in the proposed control diagram. The joint equationis evaluated as a function of the reference trajectory qd,compared with that actually obtained as a function of q, makesit possible to express the dynamics of the joint error ea= qd– qas a function of the motor error em.

$$M(q_d)\ddot{q}_d + H(q_d,\dot{q}_d) + F_v\dot{q}_d + \tau_{f_{a_d}} + K(q_d-\theta_d) = 0 \quad (1)$$
$$M(q)\ddot{q} + H(q,\dot{q}) + F_v\dot{q} + \tau_{f_a} + K(q-\theta) = 0 \quad (2)$$
$$\Rightarrow M(q)\ddot{e}_a + F_v\dot{e}_a + Ke_a + \underbrace{\Delta \boldsymbol{M}\ddot{\boldsymbol{q}}_{\boldsymbol{d}} + \Delta \boldsymbol{H} + \Delta\boldsymbol{\tau}_{\boldsymbol{f_a}}}_{d(\ddot{q}_d,e_a,\dot{e}_a)} = Ke_m (3)$$

3. HYDRODYNAMIC STUDY

The forward dynamics of the manipulator takes torque as aninput to generate a desired articulation movement.In order toachieve high performance precision to follow the torque of thedesired joint, we must provide the desired reference torque tothe robot with the highest possible precision.

In a simplemechanical case, the force is transmitted to loads by aconforming transmission element. Therefore, force dynamicsdepend on three elements: an actuator, a transmission sourceand a load dynamic.In the case of hydraulics, the pump andvalve together are the speed source. The hydraulic pumppressurizes the fluid and the servo valve controls the flow offluid within the chambers of the hydraulic actuator.
Thehydraulic actuator (cylinder and motor) which describes therelationship between control input and servo valve.

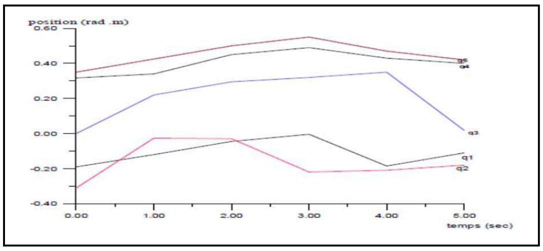


Fig. 13 Position (rad. or m.) [12].

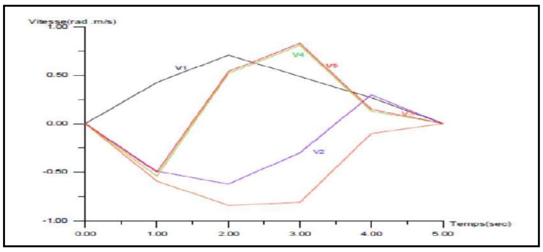


Fig. 14 Velocity (rad/s or m/s).

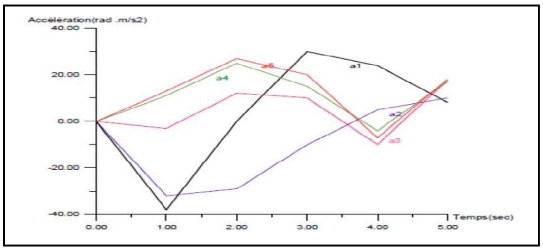


Fig. 15 Accelerations (rad / s2 or m / s²) [12].

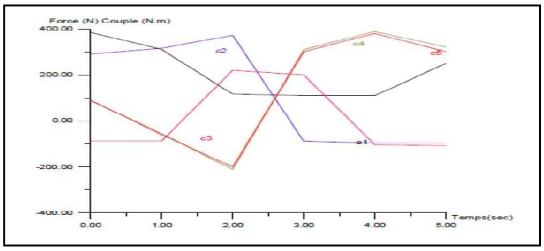
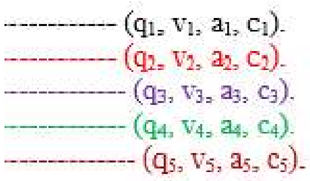


Fig. 16Strengths / Couples (N. M) [12].

-Five link simulation graphs:



Interpretation of results

A simulation program has been finalized which encompasses the various study steps, including the geometric part illustrated by the different position curves of our manipulator robot (Fig.13). An adequate operating regime of the robot has been indicated, including the kinematic part (Fig.14) and (Fig. 15). And at the end the dynamic curves (Fig. 16), where we couldnot determine the verification characteristics of the module to resistance and rigidity as well as the reliability of our robot.
This program allows us to study any industrial robots for different machining stations, the goal of which is to increasethe productivity of any flexible machine shop. It is thereforeobvious that the studied models are very far from reality, if thespeeds increase.
On the other hand, inertial, centrifugal and coupling forces appear and on the other hand the games due to friction and elasticity of all origins are no longer neglected.
It is therefore necessary to review the modeling taking into account these dynamic phenomena. The studied model determined the articular variables as a function of the generalized forces (or / and torques). The calculation of these variables was done by solving the systems of nonlinear differential equations. For the resolution of these systems of equations, the Runge - Kutta method was used.In the case offlexible manipulators, the actual positioning of a manipulator,whether statically or dynamically (pursues trajectories)inevitably deviates from its desired position, and for variousreasons. Likewise, a manipulator never positions him in thesame place when the same trajectory is repeated several times.Compensation is essential and the study of a deformationmodel is therefore necessary; similarly, wear is complex set of phenomena that are difficult to interpret, leading to anemission of debris with loss of mass, dimension, shape, andbeing accompanied by physical and chemical transformationsof surfaces. It generally does not vary gradually depending onparameters such as speed, temperature or time. While certainforms of wear are relatively regular, others, on the contrary,experience very sudden jumps, in ratios which can sometimes
range from 1 to 100,000 or more, when certain critical valuesare exceeded.

Comparison

(P1) The left side of the system of equations (1, 2 and 3) canbe expressed in the form linear with respect to the physicalparameters. This property is fundamental for the identificationand adaptive control.
(P2) The inertia matrix M (q) is symmetric, positive definite. M (q) as well as its inverse can be bounded by a function of q for a large class of robots.
(P3) For an appropriate definition of the matrix C (q, q˙)describing the Coriolis terms and centrifuges C (q, ˙ q) ˙ q, thematrix ˙M (q) - 2C (q, q˙) is anti-symmetric.

Table 4TSummary of the results obtained (Comparisons of control laws synthesized in [11]).

Polynomials	Link displacement (mm)		Link acceleration	
	01	02	01	02
Degree three: Robot. $0 \leq t \leq 6$ s 6 sec. $\Theta_1(t) = 20 + 83.3333\, t^2 - 92.5956\, t^3$ $\Theta_2(t) = 5 + 166.6667\, t^2 - 185.1852 t^3$	20° at 30°	5° at 25°	170 0 -170	340 0 -340
Degree three: Robot. $0 \leq t \leq 9$s 9 Sec. $\Theta_1(t)=20+37.0370\, t^2-27.4348\, t^3$ $\Theta_2(t)=5+74.0741\, t^2-54.8697 t^3$ N.B. This robot differs from the first by a trajectory which requires an ascent along the OZ axis and this up to the level of the working space of the milling station (position of the hydraulic locking system along the OY axis).	20° at 30°	5° at 25°	70 0 -70	150 0 -150

The correctors implemented are:

CTC1:proportional-derivative without internal loop, slow adjustment;
CTC2:proportional-derivative without internal loop, rapid adjustment;
GPCbefore robustification, adjustment maxi. the gain (with internal loop);
GPCafter robustification, with modeled KSy and Sy G tr.(with internal loop);
H 1to **2**DOF and anticipation (with internal loop).

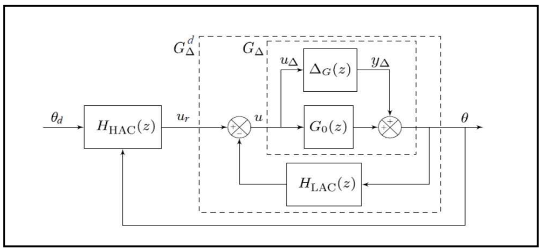


Fig. 1 Block diagram of the HAC / LAC command structure [19].

4. CONCLUSION

In conclusion, a large study on hydraulic manipulators was presented. The end effectors combine flexible properties,palletizing, dosage and packaging during practical evolution onthe pick & place robot. A state of the art and has been proposed to compare the different methods in the free space movement control branch of hydraulic manipulators.The behavior of the system was analyzed and the basic equations were exposed in terms of mastery of the kinematic couples. The optimized PNC hydraulic controls and HAC (2D) and (3D) in simulation being merged under similar constants, comparable performance isobserved, the HAC control being slightly more reliable withfewer errors at the couplings, and the optimized PNC controlbeing slightly more efficient in generalized coordinateconfiguration. Finally, let us note that it is stronglyrecommended to make an extension towards more unified andmore efficient evaluation methods in the robotics community tohighlight the main specifications of the current methods andthe achievements in future research contributions.The performance of the production line has been improvedhere for a given energy criterion, the origin in the case study ofempirical simulation, and probably insufficient. A moredetailed study of the power, by considering for example astructured description of the dynamic uncertainties, shouldagree to consolidate this constraint to improve the energyconsumption during the change of configuration. Thefundamental challenges of hydraulic robotic systems have beenidentified the choice of the prediction horizon is not equivalentbetween the experimental approaches and the real environment,which significantly increases the order and complexity of theenergy problem.

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