A Simulation Tool for Computing Energy Optimal Motion Parameters of Industrial Robots

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Abstract

This paper presents a novel robot simulation tool, fully interfaced with a common Robot Offline Programming software (i.e. Delmia Robotics), which allows to automatically compute energy-optimal motion parameters, for a given end-effector path, by tuning the joint speed/acceleration during point-to-point motions whenever allowed by the manufacturing constraints. The main advantage of this method, as compared to other optimization routines that are not conceived for a seamless integration with commercial industrial manipulators, is that the computed parameters are the same required by the robot controls, so that the results can generate ready-to-use energy-optimal robot code.

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1. Introduction

Sustainable manufacturing may be defined as a production model where both present and future needs are contemporarily accounted for, implying that social, ecological and economic impacts should be quantitatively
In the following, we focus on the latter approach and, in particular, on IR smart programming. The first consideration to be underlined is that many factories still do not employ the latest generation of energy-optimized IR, which, unfortunately, are rather energy intensive. Present researches dealing with energy efficiency improvement in this engineering field, basically follow two different approaches:

- In a medium-long term perspective, the development of innovative technologies that would ensure a reduced energy consumption (EC) as compared to the actuals ones. This approach includes the introduction of renewable/green energy sources [4,5] or energy-efficient equipment (such as low consumption electric motors and drives [6]), and the improvement of the plant architecture so as to minimize the rejection rate of products which may not comply with quality standards [7]. Such strategies have been classified as eco-efficient design methods [8], since they all require substantial modifications of existing plants;

- In a short term perspective, the development of innovative methods and tools for an efficient use of the actual technologies, offering the possibility to reduce the EC also on existing plants, which are liable of small possibilities for adjustments/modifications. This approach includes the optimization of the overall production planning and/or operations scheduling [9-11] and the energy-optimal IR control [12-14]. Such strategies have been classified as eco-efficient programming methods [8], since they do not require the introduction of new components.

In the following, we focus on the latter approach and, in particular, on IR smart programming. The first consideration to be underlined is that many factories still do not employ the latest generation of energy-optimized and (possibly) freely programmable robot arms. Most small/medium enterprises are surely willing to employ/re-use their in-house IR until the end of their overall lifecycle. The second consideration, which has been clearly underlined in the part literature [13], is that these IR may consume on the order of hundreds of kWh per day, so that a very slight EC reduction may lead to a very substantial cost decrease in the long term.

For what concerns IR programming tools and engineering practices commonly employed by IR programmers, the following aspects should be taken into account:

- In most cases, IR motions are programmed offline via dedicated robot simulation packages, such as Delmia Robotics (from Dassault Systèmes [15]), RobotStudio (from ABB [16]) or KUKA.Sim (from KUKA AG [17]), which can simulate the IR movement in a virtual plant and, subsequently, provide (as a direct output) the robot code that can be readily uploaded on the physical system. Some of these software are vendor-specific tools (i.e. they can simulate only IR produced and sold by one vendor), whereas others are conceived as general purpose simulators. In the latter case, these tools actually provide a rough approximation of the real IR end-effector trajectory. On the other hand, the simulations can be highly improved by employing a vendor-specific plug-in (the so called RCS module [19]), which basically acts as a black-box model that computes the IR trajectories with the same proprietary algorithms employed in the physical controller. In addition, (although the trend is rapidly changing) several robot simulation tools are mainly kinematic in nature, so that the dynamic IR behaviour and any possible knowledge about EC remains hidden to the end-user.

- Commonly, IR programmers are not totally free to impose a complex end-effector trajectory, the IR motions mostly employed in practice being Point-to-Point (PtP), Linear and Circular movements. For what concerns PtP commands, the robot simulation package computes an end-effector path that cannot be adjusted in any other way rather than dividing the path itself into series of small PtP motions.

- For what concerns the IR motion laws, the only tool available to the programmer is a control on the percentage of maximum velocity and acceleration imposed to the end-effector. Since any information about the IR energy consumption may not be available, also skilled operators usually program their robots to follow a path in the quickest possible way, despite the fact that such execution speed may be actually unnecessary. For instance, it has been shown that, in a robotic cell composed of several robots, many IR spend most of their time in standstill mode of operation, thus wasting electrical energy that is used to provide the motor torque that counterbalance the IR own weight [19]. This strategy is surely not energy-optimal nor required to actually increase the plant production rate. The same consideration also applies to a single IR performing a series of PtP motions. An energy aware robot programming would employ the correct value of velocity and acceleration parameters that allow to perform each operation within the right amount of time (e.g. reducing standstills to a minimum).

As for related literature dealing with optimal IR motions, several theoretical studies have been presented in the past.
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