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Simulation in robotics

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Abstract

Simulation has been recognized as an important research tool since the beginning of the 20th century. However, the "good times" for simulation started with the development of computers and now the simulation is a powerful visualization, planning, and strategic tool in different areas of research and development. The simulation has also a very important role in robotics. Different tools are used for the analysis of kinematics and dynamics of robotic manipulators, for off-line programming, to design different control algorithms, to design mechanical structure of robots, to design robotic cells and production lines, etc.

In the paper an overview of the simulation in robotics is given and some topics like: how simulation makes things easier, advantages and backdraws of the simulation in robotics, virtual and real world, are pointed out. The scope of the lecture is the role of the simulation, simulation in different fields of robotics, integrated environment for dynamic simulation of robot manipulators, the simulation of robot manipulators in MATLAB/Simulink (a case study), and simulation and visualization of robot systems using general dynamic engines and graphic languages.

Keywords: Simulation; Robot systems; Multi-body dynamics; Visualization; Modelling

1. Introduction

Simulation has been recognized as an important research tool since the beginning of the 20th century. In the beginning, simulation was first of all an academic research tool. The "good times" for simulation started with the development of computers. First the analog computers and later the digital computers have boosted simulation to new levels. So, the simulation is now a powerful tool supporting the design, planning, analysis, and decisions in different areas of research and development. Simulation has become a strategic tool in many fields, used by many researchers, developers and by many manufacturers. Of course, robotics as a modern technological branch is no exception. Actually, in robotics simulation plays a very important role, perhaps more important than in many other fields and we like to present in the following some insight in the robotics from the simulation point of view.

First, the role of the simulation in general is discussed as well as an overview of the simulation in robotics. We present some typical simulation examples in different fields of robotics. Topics like how simulation makes things easier, advantages and backdraws of the simulation in robotics, virtual and real world, are pointed out. More in detail we present the simulation of kinematics and dynamics of robotic manipulators, and integrated environments for dynamic simulation of robot manipulators. We present and compare some tools for the simulation of robot manipulators in MATLAB/Simulink. Finally, we give an overview of simulation and visualization tools suitable for the simulation of robot systems using general dynamic engines and graphic languages.

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2. The role of simulation

Simulation is the process of designing a model of an actual or theoretical physical system, executing the model, and analysing the execution output. Actually, the simulation is very common in our lives—to understand reality and all of its complexity, we try to build artificial objects and dynamically act out roles with them. I am sure that all of us came across with simulation very early. Namely, playing a game in our youth, e.g. being a parent, a fireman, etc., is just a simulation where a child is playing a role in a virtual environment with toys. The principle "learning" is essential in simulation. Using simulation we can learn about something in a very effective way and while modifying "rules" we can observe the effects of our interaction. As it is in our nature that "seeing is believing" the visualization in the simulation is the other paramount in simulation.

Being able to simulate opens a wide range of options for solving many problems creatively. You can investigate, design, visualize, and test an object or even if it does not exists. You can see the results of a system yet to be built. It is possible that your solutions may fail or even blow up, but only in simulation. So, using the simulation tools one can avoid injuries and damages, unnecessary changes in design after the production of parts has already started, to long cycle times in manufacturing process, and even unnecessary paper work. Simulation enables us to work even in four dimensions. For example, one can observe within a few minutes how a planned production will be realized in next month, or a fast process can be slowed down to observe all details in "slow motion". All these make things easier and cheaper.

One of the problems in classical design and planning are "what–if" questions. Many of them are due to the system complexity often unasked or not answered. With up-to-date simulation tools one can deal with exact geometry, consider the dynamic characteristics of a system, include the man–machine interfaces, and visualize object in 3D in detail. Having all these in mind there is no reason for avoiding any "what–if" question. The boundaries for what is possible or not are pushed far away especially in advanced virtual reality tools. Using simulator researchers may build experimental environments according to their own imagination. Complexity, reality, specificity can be gradually increased to a level where virtual systems can head to real challenges of the physical world and even beyond tomorrow.

Simulation is a highly interdisciplinary field since it is widely used in all fields of research from engineering and computer science to economics and social science, and at different levels from academic research to manufactures. Of course, simulation has been also recognized as an important tool in robotics: in designing new products, investigating its performances and in designing applications of these products. Simulation allows us to study the structure, characteristics and the function of a robot system at different levels of details each posing different requirements for the simulation tools. As the complexity of the system under investigation increases the role of the simulation becomes more and more important. Advanced robotic systems are quite complex systems. Hence, the simulation tools can certainly enhance the design, development, and even the operation of robotic systems. Augmenting the simulation with visualization tools and interfaces, one can simulate the operation of the robotic systems in a very realistic way. Depending on the particular application different structural attributes and functional parameters have to be modelled. Therefore, a variety of simulation tools has been developed for the robotic systems which are used in mechanical design of robotic manipulators, design of control systems, off-line programming systems, to design and test the robot cells, etc.

3. Simulation of robot manipulators

A large amount of simulation software is available for robot systems, and it is already being used extensively. The majority of the robot simulation tools focus on the motion of the robotic manipulator in different environments. As the motion simulation has a central role in all simulation systems they all include kinematic or dynamic models of robot manipulators. Which type of models will be used depends on the objective of the simulation system. For example, trajectory planning algorithms rely on kinematic models. Similarly, the construction of a robotized cell can be simulated efficiently by using only kinematic models of robot manipulators, without considering the dynamics or drives. On the other hand, to design the actuators dynamic models are needed. Modern control systems of robotic manipulators use internally different robot kinematic and dynamic models to improve the performance.

To model and simulate a robot manipulator different approaches are possible. They can differ in the way the user builds the model. Block diagram-oriented simulation software requires that the user describes the system by combining the blocks, and there are other packages requiring the manual coding. To overcome the problems which arise when the