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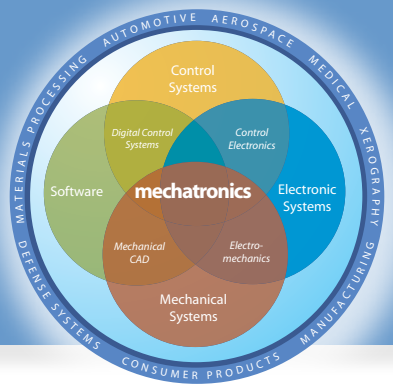
MECHATRONICS IN DESIGN

FRESH IDEAS ON INTEGRATING MECHANICAL SYSTEMS, ELECTRONICS, CONTROL SYSTEMS, AND SOFTWARE IN DESIGN



Trajectory planning with electronic cams

Is the mechanical engineer or the electrical engineer most responsible for understanding motion?

The cam—an irregularly shaped member on a rotating shaft that transfers motion—has been around since Leonardo da Vinci invented the cam hammer around 1497. Modern uses of the cam include the Nautilus exercise machine, which the late Arthur Jones invented around 1970. The machine uses a cam to modulate resistance. Until recently, the study of cam design and application was a foundation in mechanical-engineering curricula. Today, it seems that you can't find its study anywhere.

In mechatronics design, integration is the key as complexity moves from the mechanical domain to the electronic and computer-software domains. Cams are primary examples of that mechatronics principle as electronic cams gradually replace mechanical cams (**Figure 1**). Transfer implies that you first understand the fundamental principles in the mechanical domain, however. Mechanical engineers are no longer learning cam fundamentals, and they were never part of an electrical engineer's training, so motion systems today most often use crude motion trajectories that stress the machine and motor, produce unwanted vibrations, and result in poor performance.

Aderiano da Silva, an expert in motion control and automation-machine design for Rockwell Automation in Mequon, WI, believes that engineers don't typically understand—and therefore neglect—trajectory planning and its real-time implementation. It typically becomes a crude afterthought.

Trajectory planning is the computation of motion profiles for the actuation system of automatic machines—packaging machines, machine tools, assembly machines, and industrial robots, for example. Direct and inverse kinematic and dynamic models of the machine and its actuation system are necessary. Engineers typically specify desired motion in the operational realm, whereas motion occurs in the actuation space; these realms often differ. You usually express the trajectory as a parametric function of the time, which provides at each instant the corresponding desired position. Once you define the trajectory, implementation issues include time discretization, saturation of the actuation system, and vibrations on the load.

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In past decades, mechanical cams found wide use in transferring, coordinating, and changing the type of motion from a master device to one or more slave systems. Electronic cams are replacing them, with the goal of obtaining more flexible machines, with improved performances, ease of reprogramming, and lower costs. Electronic cams directly obtain motion by means of simpler mechanisms with properly programmed and controlled electric actuators to generate the desired motion profiles, which also allows synchronization of actuators on a position or a time basis.

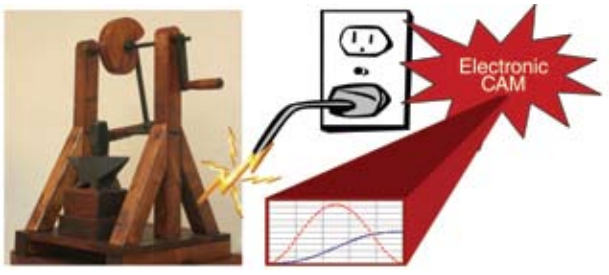

Figure 1 Electronic cams use simpler mechanisms with electric actuators, properly programmed and controlled to generate the desired motion profiles.

Once you have defined the displacement and its duration, the choice of the manner of motion from the initial to the final point has important implications with respect to the sizing of the actuators, the efforts on the structure, and the tracking error. Engineers must carefully consider the types of point-to-point trajectories that a system can employ. They must perform both time- and frequency-domain analyses on the complete system—that is, actuator, mechanism, and load, along with the motion profile—to achieve optimal performance. Input shaping and feedforward control are among the techniques engineers use to improve tracking performance.

A key reference is *Trajectory Planning for Automatic Machines and Robots* by Luigi Biagiotti and Claudio Melchiorri. Knowledge from the past combines with new technologies, resulting in innovation. Engineers must never forget this fact. EDN