

Parallel computing for determining stable parameter domain in mechatronic applications

Content

The field of mechatronics engineering integrates mechanical systems and control; therefore, the main challenges of both subfields appear simultaneously. A typical task in mechatronics is position control, where the main goal is to reach the desired position or track a predefined trajectory. The primary design task is to determine the stability domain of the control parameters where the emerging vibrations converge to a stable equilibrium. A mechatronic system consists of a mechanical structure and digitally implemented control, resulting in combined effects of friction and sampling. Both of them can cause non-smooth dynamics, where the forces have discontinuities. The friction force can have discontinuities at velocity reversals, while the control force changes at every sampling instant. This dynamical behaviour makes it extremely hard to make the analysis analytically. Most of the time, approximating models are used where the friction effects are neglected. This approximation results in an inaccurate stability domain, limiting the design process. The stability analysis can be done with numerical simulation at each parameter combination, taking the friction effects into account. Still, this method is rarely used because of its high computational costs when high-resolution stability charts are needed.

In this study, a parallel computing approach is introduced for exploring the stability domain of mechatronics systems with simulations. Parallelization and the general-purpose application of GPUs can radically accelerate computing tasks where partial results can be computed simultaneously. In this specific case, simulations corresponding to different parameter combinations can be run independently from each other, allowing the possibility of parallelizing. GPU programs can have thousands of threads, making the simulations extremely efficient without the accuracy trade-off of different methods.

The study presents a GPU based method for determining the stability domain of a mechatronic system through an example of position control. The basic model of the system with Coulomb friction and the control law is shown, and a discrete-time model is presented. The simulations based on the mapping are implemented in OpenCL and tested on GPU. Results show that the proposed method efficiently produces high-resolution stability charts.

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