Improved Real-time Vehicle Simulations using Parallel Processing based on Subsystem Synthesis Method with Explicit-Implicit Integrator

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Abstract

Real-time vehicle analysis is essential in the Hardware-in-the loop simulations and in the driving simulator applications. Several efficient formulations for real-time vehicle models have been developed. The subsystem synthesis method is one of the efficient formulations for real-time vehicle models [1], since it produces the suspension subsystem equations of motion and the chassis body equations of motion separately and allows to solve several small sized subsystem equations of motion consequently. In the real-time simulations, solution stability is an important issue. It is highly dependent upon the integration methods. Implicit integrators are known to be stable even with larger integration steps. An explicit-Implicit integration method has been developed in the subsystem synthesis method, in order to enhance efficiency of real-time vehicle models and at the same time to obtain stable solutions [2,3]. In the explicit-implicit integration method, an explicit integrator is applied to the base body equations of motion and an implicit integrator is utilized to solve the subsystem equations of motion. In this paper, in order to improve real-time analysis, parallel processing using OpenMP [4] with a multi-core CPU machine is applied to the vehicle model generated by the subsystem synthesis method with the explicit-implicit integrator. Implementation issues associated with OpenMP such as overheads due to parallel thread creation and extinction, and data synchronization have been addressed.

In order to investigate the efficiency gained by parallel processing, a 6 x 6 unmanned robot vehicle model has been generated using the subsystem synthesis method with the explicit-implicit integrator. A parallel program of the model has been also implemented as shown in Figure 1.

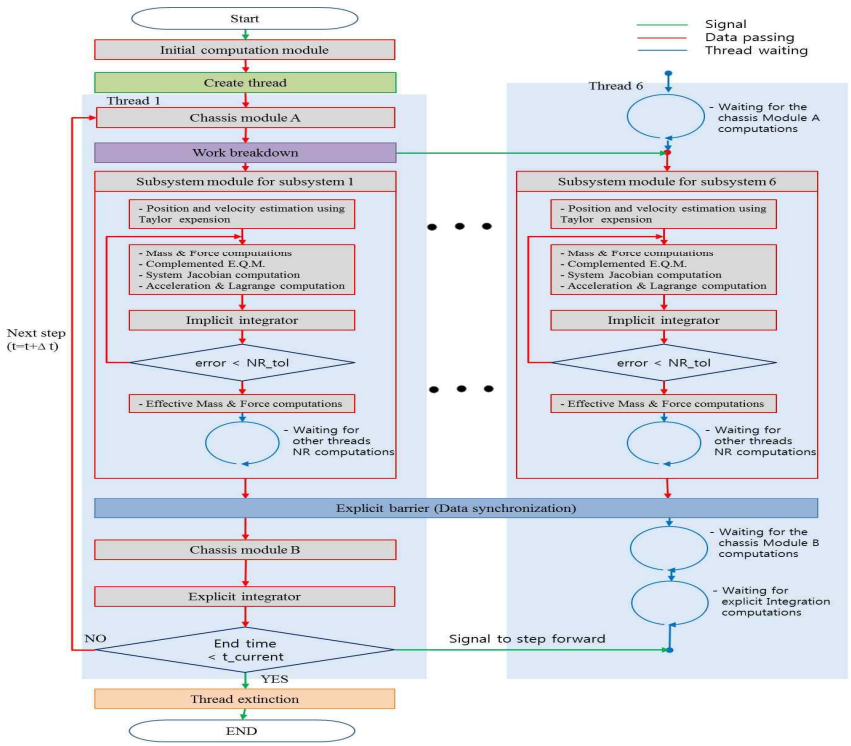

Figure 1: Parallel processing program of ex-implicit subsystem synthesis method model.

In order to avoid overhead due to the thread creation and extinction in every integration time step, threads were created and extinct only once in the program as shown in Fig. 1. Further, to minimize overhead due to the data synchronization, all the implicit barriers that are automatically created with work modules in the parallel area were removed and only the minimum number of explicit barriers were placed.

To identify efficiency of the parallel processing with OpenMP, 35-second rough terrain run simulations of the robot vehicle have been conducted in the PC with Windows 7 32bit OS, Intel i7-4770k Quad-Core 3.40 GHz, 6GB RAM. CPU times have been compared for the two, four, six suspension subsystem models as shown in Fig. 2. Effects of implementation overhead due to thread creation and extinction, and data synchronization have been also investigated. Without proper treatment of overheads, parallel processing degenerates the efficiency relative to the sequential programming. With the optimized parallel computation, the efficiency of the real-time simulations with serial computation have been improved about 74.7%.

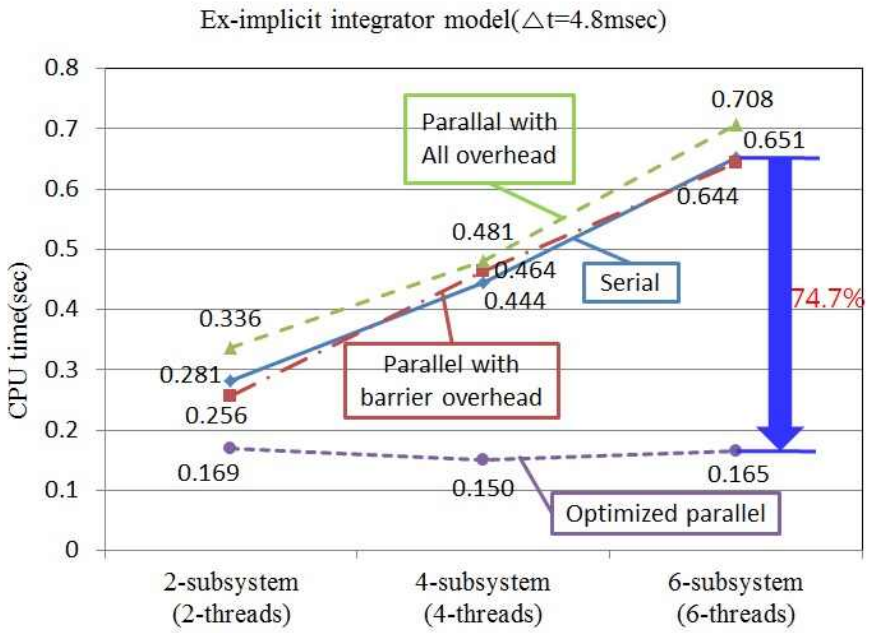

Figure 2: CPU time results of parallel processing program with ex-implicit integrator vehicle model.

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