Computer-Assisted Parallel Program Generation

Shigeo Kawata
Utsunomiya University, Japan

INTRODUCTION

Parallel computation is widely employed in scientific researches, engineering activities and product development. Parallel program writing itself is not always a simple task depending on problems solved. Large-scale scientific computing, huge data analyses and precise visualizations, for example, would require parallel computations, and the parallel computing needs the parallelization techniques. In this Chapter a parallel program generation support is discussed, and a computer-assisted parallel program generation system P-NCAS is introduced.

Computer assisted problem solving is one of key methods to promote innovations in science and engineering, and contributes to enrich our society and our life toward a programming-free environment in computing science. Problem solving environments (PSE) research activities had started to enhance the programming power in 1970's. The P-NCAS is one of the PSEs; The PSE concept provides an integrated human-friendly computational software and hardware system to solve a target class of problems (Kawata, 2014). For example, a PSE generates a computer program automatically to solve differential equations (Boonmee et al., 1998a; Boonmee et al., 1998b; Fujio et al., 1998; Fujita et al., 2000; Gallopoulos, et al., 1991; Gallopoulos et al., 1994; Hirayama et al., 1988; Houstis et al., 1992; Kawata et al., 2000; Okochi et al., 1994; Rice et al., 1984; Umetani, 1985). In the PSE concept, human concentrates on target problems, and a part of problem solving, which can be solved mechanically, is performed by computers or machines or software.

The concept of the computer-assisted program generation has been opening the new style of the computer programing to reduce the programing hard task. Huge computer software may include errors and bugs. The errors or malfunction of the software infrastructure may induce uncertainty and accordingly serious accidents in our society (Einarsson, 2005; Kawata et al, 2012). The programing process tends to include mechanical parts, that means, mechanically programmable parts. When the application area of the software is limited in a reasonable size, a part of the software would be mechanically generated. For example, scientific research-oriented programs would have a similar program structure depending on the numerical scheme.

P-NCAS supports scientists and engineers to generate parallel programs for problems described by partial differential equations (PDEs). P-NCAS presents a remarkable capability of visualization and steering of all the processes required for the generation of parallel programs. In P-NCAS users input problem description information including PDEs, initial and boundary conditions, discretization scheme, algorithm and also comments on the problem itself as well as the parallelization information. P-NCAS supports a domain decomposition method for the parallelization, and the SPMD (single program multi data) model is employed. In P-NCAS users can see and edit all the information through the visualization and editing windows. The program flow is also visualized by a Problem Analysis Diagram (PAD). Even through the flow visualization window users can modify the program flow. Finally P-NCAS outputs the corresponding parallel program in the C language,

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and at the same time a document for the program including the problem itself, the program flow, the PDEs, the initial and boundary conditions, the discretization method, the numerical algorithm employed and the variable definitions.

In this chapter first the PSE concept is briefly introduced, and then the details of the P-NCAS system is described for the parallel program generation support. Finally an example application result is presented including a load balancing result.

BACKGROUND OF COMPUTER-ASSISTED PROBLEM SOLVING ENVIRONMENT (PSE) IN SCIENTIFIC COMPUTING

PSE is defined as follows: "A system that provides all the computational facilities necessary to solve a target class of problems. It uses the language of the target class and users need not have specialized knowledge of the underlying hardware or software" (Gallopoulos, Houstis & Rice, 1994). In computing sciences, we need computer power, excellent algorithms and programming power in order to solve scientific and engineering problems leading to scientific discoveries and development of innovative new products. The computer power and the computing algorithms have been developed extraordinarily, and have provided tremendous contributions to sciences, engineering and productions. On the other hand, the programming power has not been developed well, compared with the computer power and the algorithm power. The concept of PSE was initially proposed to support the programming power in science and engineering, and has been explored for decades.

So far computer simulation has contributed to researches, productions and developments as well as experimental and theoretical methods. New researches tend to require new computer programs to simulate phenomena concerned. In developing new products engineers would also need new computer programs to develop new products effectively. They may have to develop the new programs or learn how to use the programs for the product development. Human power still contributes greatly to develop and write the new computer software. They like to devote themselves to solve their target problems, but not to develop or learn the computer programs. The PSEs would also help them develop the computer software including parallel programs or learn how to use the software system.

In these days PSE covers a various wide area, for example, computer-assisted program generation, education support, CAE (Computer Aided Engineering) software learning support, grid/cloud computing support, factory management support including plant factory management, program execution support, uncertainty management in scientific computing, etc. There are many PSE examples studied so far. In the references of (Ford & Chatelin, 1987; Fuju et al., 2006; Gaffney, & Houstis, 1992; houstis et al, 1997; Houstis, Rice, Gallopoulos & Bramley, 2000; Kawata, Tago, Umetani & Minami, 2005; Kawata et al., 2012; Kawata, 2014; Gaffney & Pool, 2007; Teramoto et al., 2007) one can find the example PSEs.

COMPUTER-ASSISTED PARALLEL PROGRAM GENERATION PSE - P-NCAS -

P-NCAS supports computer-assisted parallel program generation for PDEs-based problems in FDM (Finite Difference Method) based on a domain decomposition and MPI (Message-Passing Interface) functions (MPI, 2012). In addition, parallel programs generated in P-NCAS have load-balancing functions; one is a function for a static load balance and the other is that for the dynamic load balance. Figure 1 shows the P-NCAS work flow for the parallel program generation.

Through the interface of the PSE system of P-NCAS (Boonmee et al., 1998a; Boonmee et al., 1998b; Kawata et al., 2000; Fujita et al., 2000; Kawata, 2014) users input problem information

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