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Implementation of distributed iterative algorithm for optimal control problems on several parallel architectures

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Abstract

We consider an optimal control problem without constraint. The solution of this problem leads to a large scale block linear system. We present a two-stage method which is well suited to an asynchronous implementation with flexible communication whereby every processor can have access at any time and without any fixed rule to the current value of the components of the iteration vector updated by any other processor. The implementation is carried out on three types of architecture: a super computer with distributed memory CRAY T3E, a shared memory symmetric multiprocessor (SMP) and a high speed network of SMP. © 2002 Elsevier Science Inc. All rights reserved.

Keywords: Optimal control; Two-stage method; Asynchronous iterations with flexible communication; CRAY T3E; SMP; Network of SMP

1. Introduction

The need for optimal control of continuous complex dynamic process subject to some disturbance can require the solution of a large scale system. Taking into account the current development of computer architectures, it appears very useful to obtain optimal control law by iterative methods which are well adapted to parallel computation. We present in this paper the solution of an optimal control problem without constraint by a two-stage method (see Frommer and Szyld, 1994). This method is well suited to an asynchronous implementation with flexible communication. This new class of asynchronous iterative algorithms was proposed in Miellou et al. (1998) for the solution of boundary value problems in the M-function context. It was applied in El Baz (1996) to the solution of nonlinear network flow problems. In this context, every processor can have access at any time and without any fixed rule to the current value of the components of the iteration vector updated by any other processor; this value can correspond to a new update or a partial update which is not labelled explicitly by an iteration number. Asynchronous iterations with flexible communication are tightly bound to the concept of submappings and supermappings which is associated to the generation of monotone sequence of vectors. This is the reason that led us to consider the approach proposed in Jacquemard (1977). This approach generates an increasing sequence of subsolutions and a decreasing sequence of supersolutions which converge towards a single solution of the problem.

The implementation is carried out on three types of architecture: a super computer with distributed memory CRAY T3E by using message-passing libraries such as MPI or SHMEM, a shared memory symmetric multiprocessor (SMP) by using a POSIX thread library and a network of SMP by using a message-passing and POSIX thread libraries. The later implementation permits us to use all the material resources of the distributed system. We thus considered two types of parallelism: one between the different machines of the local network and the other between the processors of the SMP.

Sections 2 and 3 deal with the description and study of the optimal control problem. An asynchronous two-stage algorithm with flexible communication is presented in Section 4. The implementation and the experimental results are presented and analyzed in Section 5.

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2. Description of the problem

Let us consider a vertical oven with 12 heating zones (see Spiteri, 1984). The study consists in bringing temperature z raised on n points of the oven at a temperature z_d within finite time $(T' - t_0)$ which represents the horizon of the command. It is thus necessary to obtain the command u that corresponds to the intensity of the currents of regulations, such that, at time T', temperature z of the oven is uniformly equal to z_d. We consider the following criterion:

$$J = \frac{1}{2} \int_{t_0}^{T'} (|Cy(t) - z_d|_2^2 + k|u(t) - u_d|_2^2) \, \mathrm{d}t$$