岩石力学与工程学报 2006 25 (08): 1591 ISSN: 1000-6915 CN: 42-1397/O3

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串并行显式拉格朗日有限差分法研究及实现

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收稿日期 2005-4-12 修回日期 2005-7-11 网络版发布日期 2006-12-15 接受日期

摘要 显式拉格朗日有限差分法作为一种新的数值分析方法，近年来在岩土和水利工程中得到普遍的认同和广泛的应用，然而关于该算法的具体实现及进一步研究的文献较为鲜见。虽然计算机硬件发展速度很快，但当前超大规模岩土及水利工程的高仿真度计算和实时快速反馈分析的要求，对常规串行数值分析技术提出挑战。因而，基于网络信息传输技术的并行算法研究得到人们的广泛关注。迄今为止，对于并行有限元或并行边界元的研究已经取得一些成果，但关于并行显式拉格朗日有限差分法的研究则鲜见报导。首先，在对该算法进行深入研究的基础上，编写串行程序。然后，进一步对该算法的可并行性、数据分配、通信模式和计算次序进行研究，采用区域分解法、主从模式和非阻塞通信设计并行显式拉格朗日有限差分法，并用C语言和MPI(消息传递接口)在机群上予以实现。圆形隧洞和条形基础的算例证明，串并行算法的实现是正确的。对并行程序在深超－21C机群上的进一步测试表明，在单元数为921 600，计算节点数为32的情况下，仍能获得0.8以上的并行效率，算法的可扩放性较好，对串并行显式拉格朗日有限差分法的研究使之可应用于岩土和水利工程的大规模数值计算。

关键词 数值分析 串并行 显式拉格朗日有限差分法 区域分解法

分类号

RESEARCH AND IMPLEMENTATION OF SERIAL-PARALLEL EXPLICIT LAGRANGIAN FINITE DIFFERENCE METHOD

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Abstract

As a new numerical method，explicit Lagrangian finite difference method(FDM) is accepted abroad and applied widely in geotechnical and hydraulic engineering in recent years. However，code implementation and careful investigation on the method are rarely reported. Despite the fast development of computer hardware，it is still a great challenge for regular serial numerical analytical technology to perform either highly simulated numerical analysis or real-time fast back analysis on super-scale geotechnical and hydraulic engineering. Hence，the research on parallel algorithm based on network information transfer is received great attention. Up to now，studies on parallel finite element method or parallel boundary element method have gained great success，but on parallel explicit Lagrangian FDM，there are still many things to do. Thus the method is investigated and serial code is developed. The method¢s parallel ability，data assignment，communication mode and calculation order are examined. Parallel explicit Lagrangian FDM is designed in domain decomposition method，master-slave mode and non-block communication. The parallel code is also implemented in C language and MPI(message passing interface) on parallel cluster. Two numerical examples，i.e. circular tunnel and strip footing，are presented to demonstrate that the serial and parallel methods are implemented correctly. More tests with parallel code are undertaken on DeepSuper–21C supercomputer and parallel efficiency above 0.8 can be obtained under condition that number of elements is 912 000 and the number of computing nodes is 32，which shows that the parallel method has good scalability. Research on the serial and parallel explicit Lagrangian FDM can be used in large-scale numerical simulation in geotechnical and hydraulic engineering practices.

Key words numerical analysis serial-parallel explicit Lagrangian finite difference method domain decomposition method

DOI:

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