**Parallelism Detection and Scheduling Strategies for Reliable and Efficient Execution on Multicomputers**

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**Abstract**
Introduced a new concurrent object-oriented language called CORE which solves the inheritance anomaly problem.

By separating and localizing the synchronization schemes from the main bodies of the program components, CORE allows a high degree of encapsulation and re-use for the synchronization code and the program modules.

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Brief Research Outline

The popularity of Distributed Memory Multiprocessors (DMM) has been on the rise in recent years. The increase can be attributed to the advances in VLSI technology, better inter-processor communication networks and more efficient routing algorithms. Some of the applications using DMMs are fluid flow, weather modeling, database systems, etc. The object-oriented design methodology is being widely used to solve these practical problems.

To obtain the maximum benefits of DMMs, an efficient task partitioning and scheduling strategy is essential. The task partitioning algorithm partitions the application into separate tasks by detecting the parallelism in the program and represents them in the form of a Directed Acyclic Graph (DAG). After the application is transformed to a DAG, the tasks are scheduled onto the processors. This work deals with automating the process of parallelism detection to obtain better partitions of the applications and then scheduling the partitioned tasks to achieve reduced overall execution time.

As the title of the project suggests, there are two main objectives of this research. Those two objectives are described below in detail.

1 Parallelism Detection

There are several object-oriented languages but they fail to integrate concurrency and object-orientation. Even the available concurrent object-oriented languages suffer from inheritance anomaly, which forces non-trivial class re-definitions because the synchronization code cannot be effectively inherited. This research has led to the development of a new concurrent object-oriented language, CORE, which does not suffer from inheritance anomaly and allows a programmer to specify parallel tasks at the inter- and intra-object levels. To achieve the best results of running any program on a parallel machine, the compiler needs to automatically detect the inherent parallelism in the program. The current goals of this research are to investigate the techniques for automatically detecting parallelism in object-oriented programs at the compile time.

A concurrent object-oriented language CORE has been developed which minimizes inheritance anomaly, promotes code reuse of both the sequential and parallel components, and offers mechanisms for controlling computational granularity. The methodology presented in this research is extensible to any class based language.

2 Scheduling

Efficient use of resources requires proper scheduling algorithm. There can be several goals of any scheduling algorithm. This research considers reducing the overall execution time of any program as the primary goal. A Threshold Scheduling scheme has been proposed for DMMs. In this scheduling scheme the compile time schedule is found using a new concept of threshold of a task that quantifies a trade-off between the schedule length and the degree of parallelism. In case of multiple tasks competing for the same processor, the tie is broken using a merit function of the tasks on the processor that examines a match between a task and a processor. The threshold is varied globally, and the best value to satisfy one of the following scheduling goals is found:

- Compiling for minimizing schedule length: Suitable for large systems.
- Compiling for processor requirements below a given maximum number of available processors in the system: Suitable for small systems.
A run-time support for Sisal compiler has been developed for Intel Gamma, Delta and Paragon machines. The run-time support helped correlate the compile time estimated results versus the actual run-time results. The run-time results for Sisal compiler using threshold scheduling scheme were comparable to the compile-time-estimated results. The speedups obtained on all three machines were lower than the predicted values. This is primarily due to the run-time overheads and also due to the assumptions made in modeling communications. Of the three machines, i.e. Intel Delta, Gamma and Paragon, Paragon was closest to the predicted values followed by Delta and Gamma. Paragon was better than the other two because of better hardware and also because it allows multiprogramming. The results obtained are promising and this scheme could be used for compiling programs for varying sizes of DMMs.

Another scheduling algorithm for DMMs, namely Search and Duplication Based Scheduling (SDBS) algorithm, has been developed. This algorithm is based on certain realistic assumptions and if they are satisfied, the algorithm generates an optimal time schedule. If the conditions are satisfied then no lower execution time schedule can be generated, and this has been proved. Even if the assumptions are not satisfied, the SDBS algorithm generates a schedule which is close to optimal. The results for such a case have been obtained with the help of extensive simulations. SDBS algorithm has been enhanced to generate optimal schedule in cases where the task execution times are varying. A task encapsulates control dependencies within it. Thus for tasks which encapsulate loops or if-then-else type of statements, the execution time could vary. The enhanced SDBS algorithm takes such tasks into consideration and produces an optimal schedule.

The schedule time obtained by using SDBS algorithm for random DAGs was compared against the level of the entry node. The level of the entry node is the lowest possible schedule time because the communication times are neglected when calculating levels. The schedule time obtained by SDBS algorithm was 11% over the absolute lowerbound on the average. The lowerbound cannot be achieved in most of the cases because of the communication time. The performance of enhanced SDBS algorithm was compared against the SDBS algorithm for cases where the task execution times were varying. For a small DAG the enhanced SDBS algorithm is better than SDBS algorithm by 4% on the average. This figure is low because this comparison was performed on a small DAG with only a few tasks having varying execution times. For larger DAGs with more number of varying execution time tasks we would expect the enhanced SDBS algorithm to perform much better then SDBS algorithm.

3 Significant Research Results

- Introduced a new concurrent object-oriented language called CORE which solves the inheritance anomaly problem.

- By separating and localizing the synchronization schemes from the main bodies of the program components, CORE allows a high degree of encapsulation and re-use for the synchronization code and the program modules.

- Introduced a new compile time method to schedule functional parallelism in a program on distributed memory machines.

- Scheduling goals for the scheduling method can be either to reduce execution time or to generate a schedule to meet the system size.

- Concept of threshold introduced to quantify the trade-off between the completion time and the degree of parallelism in the schedule.
• Scheduler incorporated in the compiler backend for targeting Sisal to Intel Touchstone i860 systems.

• Introduced a new scheduling scheme. SDBS for scheduling tasks represented in the form of a DAG onto Distributed Memory Machines.

• SDBS algorithm is optimal and if assumptions are satisfied a lower execution time schedule cannot be generated.

• Enhanced SDBS algorithm developed which takes tasks with varying execution times into account.

4 List of Publications


5 Scientific Personnel Supported by this Project

5.1 Graduated Students


2. Chienhua Chen. Ph.D. Degree. (Summer support only)

3. James Michael Conrad. Ph.D. Degree. (Summer support only)

4. Viswanath Ramakrishnan. M.S. Degree. (Summer support only)

5. Nita Kini Sharma. Ph.D Degree. (Summer support only)

5.2 Current Students


3. Hyumin Park. Ph.D Student. (Summer support only)

4. Yashovardhan Potlapalli. Ph.D Student. (Summer support only)