Parallel Model Checking

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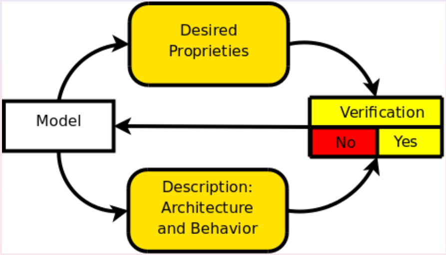
Planning

- Introduction
- Multiprocessor Computer Architecture
- State Space Construction
- Considerations

Model Checking



Model Checking : Automatic System Analysis.

Verification :

- System Description
  - Behavior.
  - Architecture.
- Desired Property.
- Counter-Example.

Model Checking

Definition

Model Checking : Given a Kripke structure $M = (S, R, L)$ that represents a finite-state concurrent system and a temporal logic formula f expressing some desired specification, find the set of all states in S that satisfy f : $\{s \in S \mid M, s \models f\}$

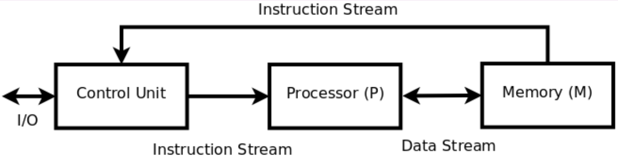
Two steps :

- State Space Construction (Kripke structure)
- Property Verification ($\{s \in S \mid M, s \models f\}$)

Flynn's Taxonomy of Computer Architecture

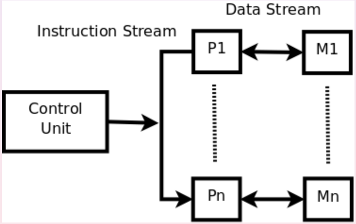
Notion of a stream of information :

- SISD : single-instruction single-data

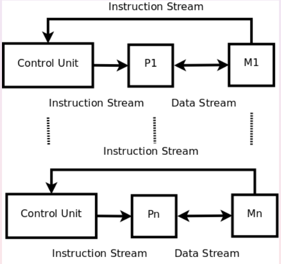


Flynn's Taxonomy ...

- SIMD : single-instruction multiple-data

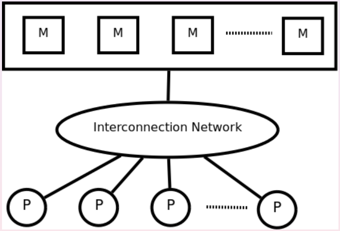


- MIMD : multiple-instruction multiple-data

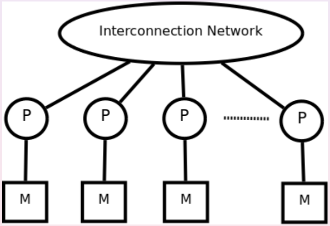


MIMD Architecture

Shared Memory :



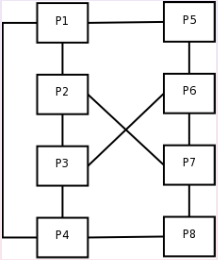
Distributed Memory :



SUN FIRE X4600 M2

Brutus :

- Shared Memory
- 8 Processors Dual Core AMD Opteron
- NUMA : Non-Uniform Memory Access
- Minimum hop distance : Enhanced Twisted Ladder

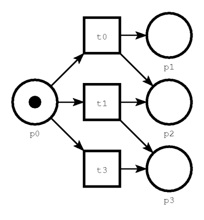


Enhanced Twisted Ladder

State Space Construction

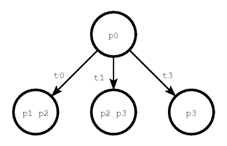
Complexity :

- Irregular Problem
- Size is unknown by advance
- The model under consideration is a key performance issue



Petri Net

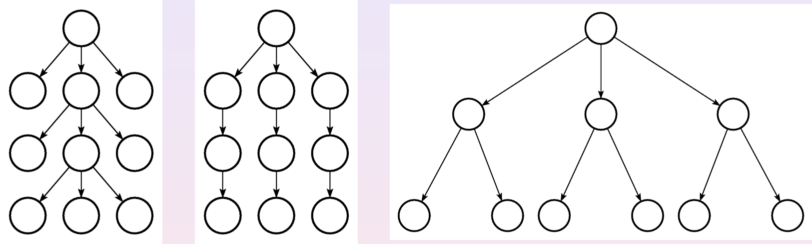
$\Longrightarrow$

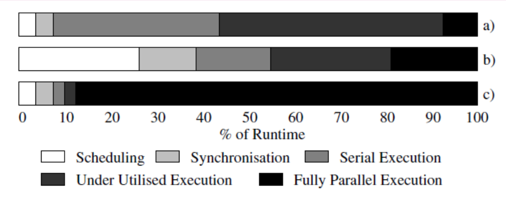


State Space

State Space Construction ...

Three stereotypical types of model[Ezekiel08] :





Related Work - SIMD

State Space construction on a SIMD Machine :

- Caseli 1994
- Function Decomposition Model
  - Transition Firing
  - Reachability Graph Construction
    - Search Action
    - New State Creation

Related Work - MIMD Distributed Memory

Distributed State Space Generation

- Ciardo97m, Hoverkor99, Lerdo 99, Caseli99, Hubert01
- Message Passing Interface (MPI)
- Objective : Expand Memory
- All threads executes same program in parallel

Complexity

- Balance Workload
- Minimize Communication (Overhead)

Related Work - MIMD Distributed Memory

Partition Function is :

- $Proc : S \Rightarrow \{0, ..., N-1\}$
- $Proc(s)$ is the owner of state s

And must have :

- Spatial Balance
- Locality
- Temporal Balance

Related Work - MIMD Distributed Memory

Partition Function can be :

- Static (User Provided)
- Dynamic

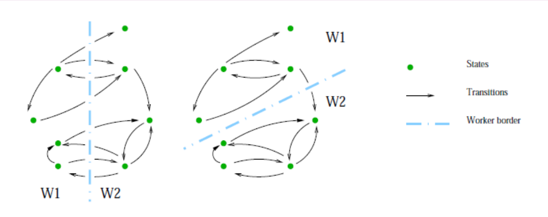
Example of a Partition Function :

- $M = \{PL_1, PL_2, ..., PL_n\}$
- $C_s = \{PL_1, PL_5, PL_7\}$
- $(\#PL_1 + q * \#PL_5 + q^2 * \#PL_7) mod\ N$
  - $\#PL_n$ = number of tokens at place Pl_n
  - q is a prime number

Related Work - MIMD Distributed Memory

First Approximation :

- Orzan05
- Small approximation based on a set of abstraction interpretation



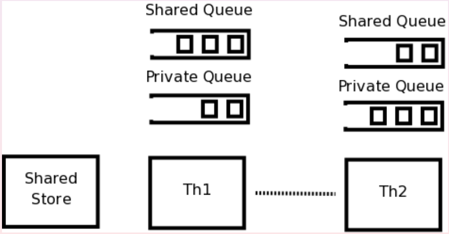
Related Work - MIMD Shared Memory

Complexity :

- Data Consistency
- Synchronization
- Thread Creation Overhead
- Bus Contention
- Data Race
- False Sharing

Related Work - MIMD Shared Memory

- Global Shared Storage Data
- Allmeier97 :
  - Storage Structure : Balance Tree with Splitting in advance
- Inggs02 :
  - Work Stealing



Considerations

Objectives :

- Bigger Models
- Speed up

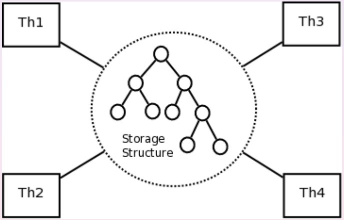
Problematics

- Temporal Balance
- Memory Location

Storage Structure

1 - Global Storage Structure :

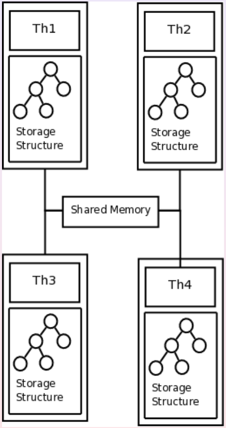
- low complexity
- better “all case” temporal balance
- irregular memory distribution
- synchronization and locks overhead



Storage Structure

1 - Local Storage Structure per processor :

- high complexity (Partition Function)
- worst “all case” temporal balance
- uniform memory distribution



Perspective

Mixed of Distributed and Shared Solution :

- Local Storage Structures
- Small amount of shared memory
- Heuristic Policies for On-the-fly Temporal Balance

Thankyou

Thankyou

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