Programming Models

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Outline

- Motivation
- Existing sequential languages
- Discussion about papers
- Conclusions and things to ponder over

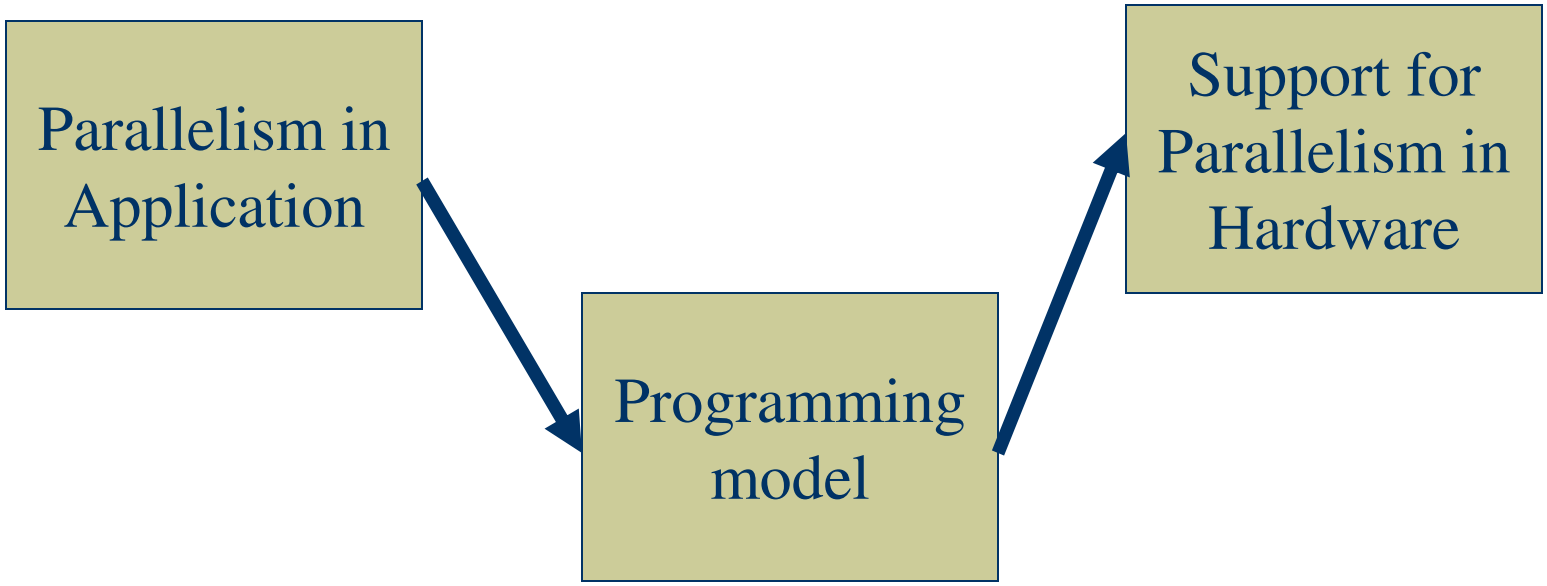
Principles of programming language design:

- One way is to make it so simple that there are obviously no deficiencies, and

- The other way is to make it so complicated that there are no obvious deficiencies.

(C. A. R. Hoare)

The Role of the Programming Model



Motivation

- View of a *programmer*
  - Ease of programming
  - At times can distinguish *parallel/independent* code segments (not always)
    - *Compiler can leverage this fact (whenever possible)*
  - Doesn't want to know the details of the underlying system
  - Hates to care about the locality of data usage

Problems with *common* imperative languages

- Inherently sequential
  - We love to think sequentially (step-by-step)
- Difficult for the compiler to exploit parallelism from the structure of the program
  - Possible Solutions
    - Make programming language restrictive and boost performance
    - More information from the programmer to the compiler (implicitly/explicitly)\

Containers

- Motivation
  - Many techniques devised to automatically parallelize numerical array based applications
  - Does not work well on most non-numerical applications
- Main Idea
  - Part of the problem is there are too many degrees of freedom at the individual instruction level
  - Provide compiler with more information with how you are going to use data

What is a container?

- Any general-purpose aggregate data type
  - Matrices, lists, stacks, trees, graphs, I/O streams, hash tables, etc.
  - Paper focuses on linear containers, content-addressable containers

Abstract containers

- Container behavior is specified using abstract containers and abstract methods
- Abstract container/methods are what the compiler will understand and know how to deal with
- Need to be general enough to be useful

Parallelization techniques

- Loop parallelization
- Container privatization
- Exploit Associativity
  - Used to eliminate update structural dependence

Dependency tests

- For linear containers
  - Range checks
- For content addressable containers
  - Disjoint key analysis: need to assure memory independence
  - Overlapped keys: generally hard, but some patterns

Critique

- Good
  - No additional work for programmer when using already defined library such as STL
- Bad
  - Less generality $\Rightarrow$ lost opportunities to parallelize
  - Another thing to get wrong (specifications)
- Conclusion
  - Relatively easy way to eke out more out of compilers without burdening programmers (once someone figures out how to do it)
  - Compiler analysis also performed at the container level

Programming in *Jade*

- Data-oriented language for parallelizing programs written in a imperative programming language

  The most important thing in the programming language is the name. A language will not succeed without a good name. I have recently invented a very good name and now I am looking for a suitable language. ☺

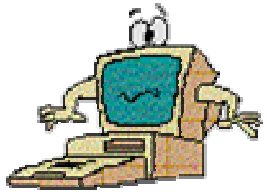
  (Donald E. Knuth)

- Difficult to program in an "explicit" parallel programming language

Parallel Programming = Parallel "Thinking" ?

There is not now, and never will be, a language in which it is the least bit difficult to write bad programs ☺

- Anonymous



...a language is intended not so much to inspire programmers as to protect them from their own not inconsiderable frailties.

- Anonymous

Features of *Jade*

- Augmenting sections of code to be parallelized with data usage information
- Tasks interact through accesses to shared objects
- *Jade* implementation uses this local data usage info to relax program sequential order

Features…

Jade_construct *{side effect specification}*

(parameters for the task body)

{

Task Body

}

Jade constructs

- ***withth***
- ***withonly***
  - **Doesn't specify the task will immediately carry out any of the specified effects**
- ***with***
  - **Use *with* and *withonly* and hope that this will reduce the conflicts**
- ***without***

Critique

- **Strengths**
  - No burden of *parallel* thought process
  - Achieves speedup comparable to efficient *parallel* programs (*Authors' claim*)
- **Weaknesses/Deficiencies**
  - Programmer has to identify the tasks to be parallelized
  - Cannot express algorithms requires bi-directional task communication
  - Implementation (discussed in the paper) assumes single address space

Motivation for StreamIt

- High level language for streaming applications
  - Compiler can infer parallelism and communication simply
  - Programmer can ignore architectural details like granularity and topology
- Current backend is RAW, also intended for other parallel architectures

The Programming Model

- Programmer expresses stream graph explicitly
  - *filter* – node in the stream graph (single input, single output)
  - *pipeline, splitjoin, feedbackloop* – connections between nodes
- Communicate between filters via infinite FIFO
- Requires a static-rate streams (I/O rate of each filter known at compile time)
- Programmer need not know details of the underlying topology

The Compiler

- Hierarchical stream graph easy to analyze
- Three phase process
  - **Partitioning** – merge and split filters to get *N* load balanced filters (*N* = number of processing units)
  - **Layout** – use simulated annealing and communication cost function to arrange filters
  - **Scheduling** – map infinite FIFO abstraction to actual communication network

StreamIt on the RAW Architecture

- Construct initialization and steady state schedule for the filter
  - Determines code size, buffer sizes etc.
- Complete the partition, layout and communication scheduling steps
  - One filter per tile
  - Can’t exploit parallelism at the tile

Strengths

- Programming Model
  - Programming model is simple, a graph of single-input, single-output nodes connected by predefined constructs
- Compiler
  - Adapts to changes in number of processors, communication network (to some extent)

Weaknesses

- Programming model
  - Requires programmer to learn a new programming model
  - Filters can not interleave sends and receives, all data must be received before execution
  - Requires static-rate streams
- Compiler
  - Partitioning, layout and scheduling steps assume architecture similar to RAW

Crux of the Story

- Best performance if programming model maps well onto the hardware (StreamIt)
- Large performance gains if some additional information is provided by the programmer (Containers, Jade)

Food for thought

- Where to draw the line between *generality* and *efficiency/performance*
  - **Trade-off** (e.g., StreamIt)
- A new language in the market, **C++--** ☺
  - **How much of a performance boost do you expect before you use it**
  - **What other features do you expect**