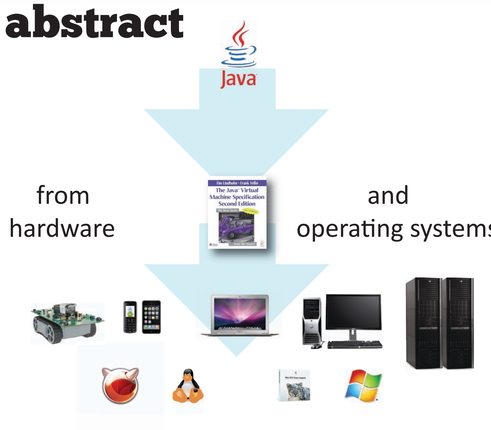
Many-Core Virtual Machines

Decoupling Abstract From Concrete Concurrency

Virtual Machines

abstract



for multiple languages

- powered by fast JIT compilers, and great GCs
  - foundation for multi-language VMs
  - allow to reuse existing infrastructure
- require huge investments
  - reuse is economically necessary

Abstraction by ILs

- VM Intermediate Languages (ILs)
  - often defined as bytecodes
  - expressive abstraction for various target languages
  - state of the art is very diverse

	Abstraction	Model	#Register	Execution Mode	Length	in Byte	#Opcodes
CLI	Bytecode	stack	0	-	variable	>= 1	217
CPython	Bytecode	stack	0	switch	variable	1 or 3	102
Dalvik VM	Bytecode	register	∞	threaded	variable	>= 2	218
Dis VM	Bytecode	memory-to-memory	0	-	variable	1 - 33	158
Erlang	Bytecode	register	1024	threaded, JIT	fixed	4	148
JVM	Bytecode	stack	0	-	variable	>= 1	201
Lua	Bytecode	register	255	switch	fixed	4	38
Mozart	Bytecode	register-memory	∞	threaded	variable	4 - 24	97
Parrot	Bytecode	register	∞	switch, threaded, JIT	variable	>= 4	>1200
PHP	Bytecode	register-memory	∞	threaded	fixed	76	136
Rubinius	Bytecode	stack	0	JIT	variable	4 -16	89
Ruby 1.8	AST	stack	0	switch	-	-	105
Ruby 1.9	Bytecode	stack	2	threaded	variable	>= 32	77
Self	Bytecode	stack	0	JIT	fixed	1	17
Squeak	Bytecode	stack	0	switch, threaded	variable	1 or 2	71
TraceMonkey	Bytecode	stack	1	threaded, JIT	variable	>= 1	234
V8	AST	-	-	JIT	-	-	38

but...

Concurrency

concurrency support is limited

- VM support is minimal
  - only one specific concurrency model is supported
  - only few ILs provide notion of concurrency
  - no comprehensive abstraction

	.NET	inferno	ERLANG	mozart
Model	Threads/Locks	CSP	Actors	Data-flow
IL Support	Marginal	High-level	High-level	Marginal
StdLib	Low/high-level	High-level	High-level	High-level

Stefan Marr, Michael Haupt, and Theo D'Hondt
Intermediate Language Design of High-level Language Virtual Machines:
Towards Comprehensive Concurrency Support
In: Proc. of the 3rd Workshop on Virtual Machines and Intermediate Languages, ACM, October (2009)

a VM has to:

decouple abstract concurrency models

- abstract concurrency models are defined by languages or libraries
- used by application developers

- wide range of models supported by VM is necessary
  - implementing unsupported models on top is hard
    - restrictions hinder efficient implementation
  - support at VM-level allows reuse and optimization

and concrete concurrency models

concrete concurrency models are provided by the underlying system

Single-Core
- preemptive OS threads
- instruction-level parallelism
- VM challenges
  - deep cache hierarchies
  - cache-consciousness required

Multi-Core
- uniform memory access
- native support for thread-level parallelism
- and cache coherency
- locality and cache hierarchy must be considered
  - avoid cache thrashing

Many-Core
- non-uniform memory access architectures
- can have explicit core-to-core communication
- very diverse designs
  - with/out cache coher.
  - explicit inter-core com.

Intel Banias

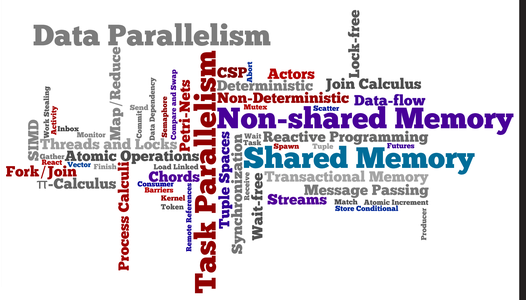
Intel Nehalem

IBM Cell B.E.

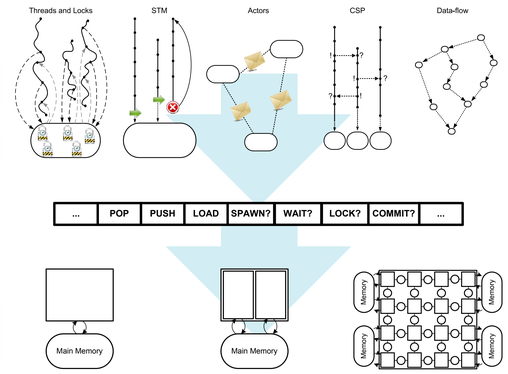
So Many Models

what to include in ILs?

there are various ways to express concurrency and solutions are domain-specific



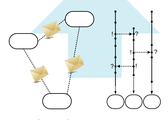
how to combine the various models?



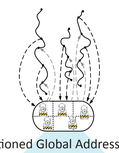
what are the fundamental problems?

NUMA is the dominating hardware characteristic

Is the notion of locality inevitable for a VM?



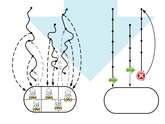
Non-shared Memory Languages natural fit for NUMA



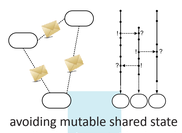
Partitioned Global Address Space locality explicit in shared-memory

Non-Uniform Memory Access

Shared Mutable State



protecting and isolating shared state



avoiding mutable shared state perhaps allowing immutable shared state

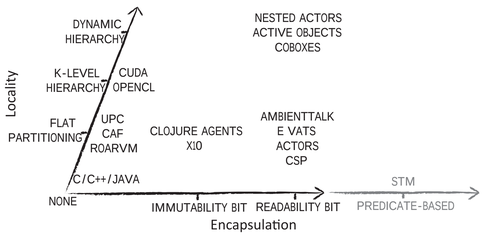
Can a VM support this better by some notion of Encapsulation?

in some form explicit or implied in languages

Experiments

Locality and Encapsulation?

A Foundation for Concurrency Support in Multi-Language VMs?
Exploring the Design Space:



earlier experiments: an IL for threads/locks, and an IL for Actors

Stefan Marr et al.
Virtual Machine Support for Many-Core Architectures: Decoupling Abstract From Concrete Concurrency Models
In: 2nd International Workshop on Programming Languages Approaches to Concurrency and Communication-cEntric Software, York, UK, March (2009)

Hans Schippers, Tom Van Cutsem, Stefan Marr, Michael Haupt, and Robert Hirschfeld
Towards an Actor-based Concurrent Machine Model
In: Proc. of the 4th Workshop on the Implementation, Compilation, Optimization of Object-Oriented Languages, Programs and Systems, ACM (2009)

Approach and Evaluation

Top-Down from a Language Perspective

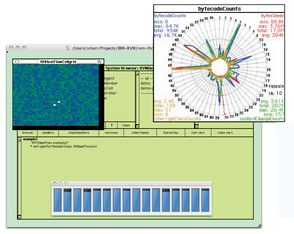
1. Implement relevant concepts on-top of the RoarVM
   - X10 inter-place operations
   - Clojure Agents
   - Nesting of Actors or CoBoxes
2. Abstract from experiments and extend the VM model

3. Assess and evaluate benefits of VM Support
   - Language engineering effort
     - Avoid duplication in different language implementations
     - Trade-off to VM complexity
   - Performance benefits
   - Memory/cache utilization

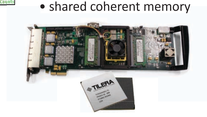
The Manycore RoarVM

Our Platform for Experiments

- A Smalltalk VM for multi- and manycore systems
- runs on the 64-core TILE architecture
- runs on standard x86 systems
- supports Linux and OS X
- released under the Eclipse Public License at http://github.com/smarr/RoarVM



On a TILEPro64
- 64 cores on a single chip
- explicit core-to-core communication
- small caches
- shared coherent memory



In cooperation with David Ungar and Sam Adams from IBM Research

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