Model Based Parallel Programming with Profile-Guided Application Optimization

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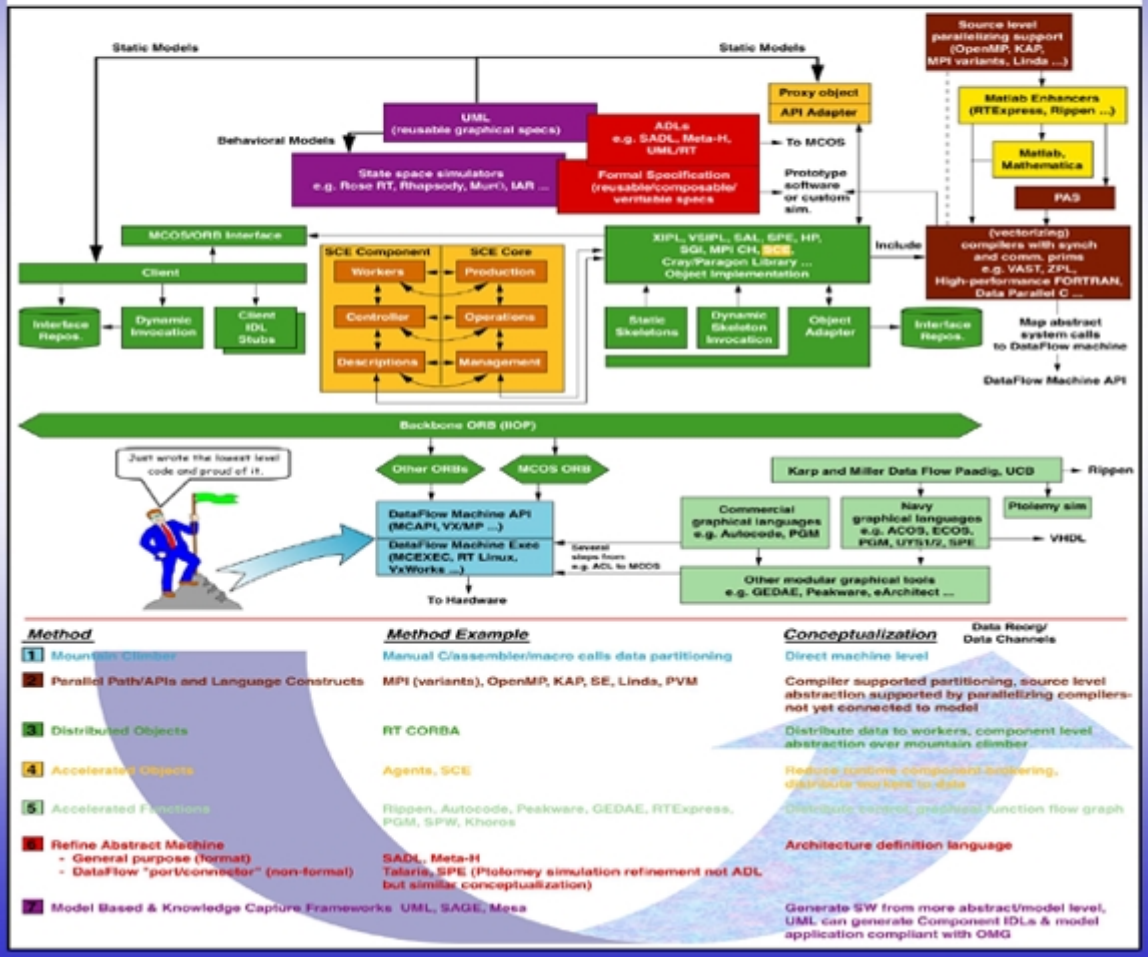
Methods to Conceptualize/Apply High Performance Data Flow Applications



Method	Method Example	Conceptualization
1 Mountain Climber	Manual C/assembler/macro calls data partitioning	Direct machine level
2 Parallel Path/APIs and Language Constructs	MPI (variants), OpenMP, KAP, SE, Linda, PVM	Compiler supported partitioning, source level abstraction supported by parallelizing compilers- not yet connected to model
3 Distributed Objects	RT CORBA	Distribute data to workers, component level abstraction over mountain climber
4 Accelerated Objects	Agents, SCE	Reduce runtime component bindering, distribute work/data to data
5 Accelerated Functions	Rippen, Autocode, Peakware, GEDAE, RTExpress, PGM, SPW, Khoros	Distribute control, graphical function flow graph
6 Refine Abstract Machine - General purpose (format) - DataFlow "port/connector" (non-formal)	SADL, Meta-H Talaria, SPE (Ptolomey simulation refinement not ADL but similar conceptualization)	Architecture definition language
7 Model Based & Knowledge Capture Frameworks UML, SAGE, Mesa		Generate SW from more abstract/model level, UML can generate Component IDLs & model application compliant with OMG

Data Reorg/ Data Channels

Problems with Described Development Approaches

- Development and maintenance costs associated with Method 1
- Conceptualizations/tools represent computation (e.g. graph) or communication (e.g. VI) model
- Lack of UML data flow support
- Multiple architecture and library standards to call functions with same signatures
- ADL application in streaming, high performance, data-flow domain
- Perception of inefficiency

An example of a Profiling System: DSPTune for the SHARC DSP Family

- A set of library routines that enable the user to instrument C and assembly programs
- Function calls can be inserted at various locations in the application code, enabling execution driven simulation and instrumentation
- The user provides:
  - •instrumentation routines, which specify the selected instrumentation events (e.g., loads, branches, traps)
  - •analysis routines, which carry out the desired simulation (e.g., caches, stacks, branch predictors)
- Latest version (BDSPTune) allows the user to directly modify the binary ELF files

Cache Line Coloring call graph edges (A-B, B-C, A-D, C-D)

A	A	A	A	D	D	D	D
1	2	3	4	1	2	2	4
		C	C	B	B	B	
		1	2	1	1	2	

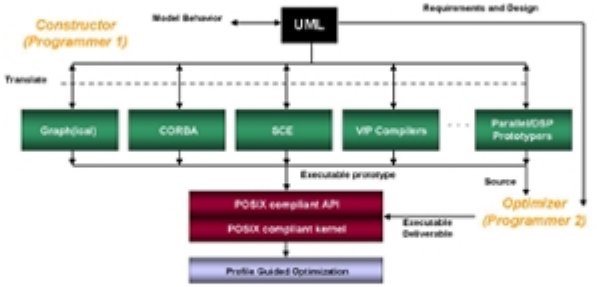
Cache Size

No Conflicts

Observations

- UML doesn't include data flow … yet
- You can translate UML diagrams to any source - might be an avenue of tool support worth exploring
- Specifications (signature) of varied libraries constant
- Graph notation deterministic when combined with ADL target to parallel machine - distributes itself based on queue information
- The trade between block and graph language graphical techniques is that GEDAE-like tools use fixed time line scheduling vs PGM-like tools who stick to the data flow model for run time flexibility
- All of the graphical (light green) techniques shown outgrowth from seminal paper, R.M. Karp and R. E. Miller dating from 1961

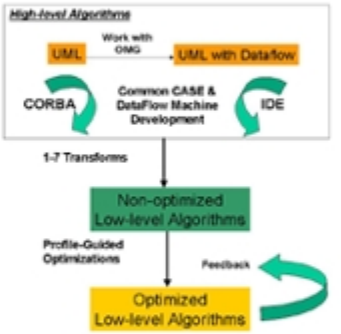
Goals: Component Reuse, Software Productivity, Leverage Existing Investments and Wider Programming Base

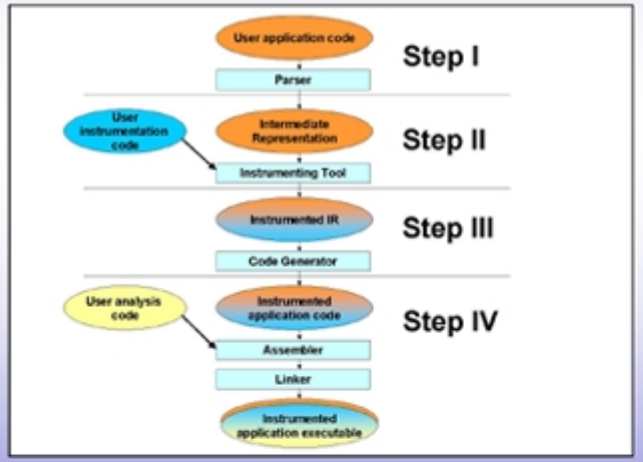


Dynamic Compilation Can Provide a Solution

Collect runtime execution behavior

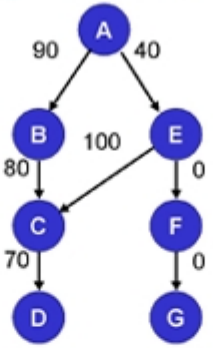
- Memory usage
  - instruction and data caches
  - translation lookaside buffers
- Control flow
  - branch probabilities
  - program "traces"
- Call graphs
  - gprof statistics
- Data dependencies
  - data-dependent control flow
- Variable values
  - value locality
  - interprocedural dataflow
- Hardware counters
  - pipeline stalls





Dynamic Compilation Model is Well-suited for the High Performance Embedded Computing Environment

- Profiles can be used to:
  - Generate control and dataflow graphs
  - Identify program "hot-spots"
  - Reorganize code and data
  - Selectively apply aggressive compilation techniques
    - procedure inlining
    - loop unrolling
    - procedure specialization
    - procedure cloning
  - Reschedule code



An Example of A Dynamic Compilation System Cache Line Coloring

- Attempts to reorder a program executable by coloring the cache space, avoiding caller-callee conflicts in a cache
- Can be driven with both static call graphs and profile data
- Improves upon the work of Pettis and Hansen by considering the organization of the cache space (i.e., cache size, line size, associativity)
- Can be used with different levels of granularity (procedures, basic blocks) and applied both intra- and inter- procedurally
- Programs can be sped up by as much as 100%

Next Steps

- Application to IR formation, fusion, template matching
- Collect software productivity metrics on above and MITRE benchmarks
- Experiment with optimization of UML transformed (through data parallel CORBA or specialized data parallel compiler IDEs) software to efficient Mercury platforms
- Work with OMG in introducing Data Flow, in a way that supports streaming high performance data flow distributed computers (see us for viewgraphs)
- Examine possibility of embedding dynamic profile optimization into run-time system
- Work with CASE and IDE vendor to integrate model-based development of efficient streaming high performance data flow distributed computer targets

Citations

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