CSDL Overview
&
Compiler Techniques to Improve Program Performance

by

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CSDL Lab at ITTC

- Focus on design, implementation and verification of computer systems
- People
  - Perry Alexander, Director
    - formal modeling of computer systems, security
  - Douglas Niehaus
    - real time and distributed systems, operating systems
  - Prasad Kulkarni
    - code optimization, parallelism, VM performance
  - Andy Gill
    - functional language design, extensions and implementation

Professional Background

- Experience
  - Assistant professor, EECS, University of Kansas (started in Fall 2007)
  - Intern, IBM T. J. Watson Research Lab (Fall 2006)
- Education
  - Ph.D. in computer science from Florida State University (Summer 2007)
- Research interests
  - compiler analysis & optimizations, profiling, architecture
  - to improve performance and security
  - in embedded, general-purpose, high-performance systems
- Teaching
  - compilers, operating systems, virtual machines

Java .NET C#

Higher-level programming languages

Safe & secure runtimes

Recent Trends in Computer Systems

Increased Internet use & accessibility

Growth in embedded systems

Multicore architectures

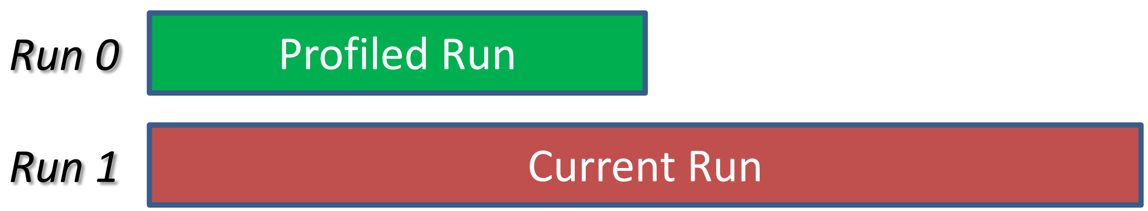
Research Projects

- Improve performance and security of managed language programs on multicore machines
  - *future* profiling for virtual machines
    - improving Java start-up performance
  - parallelization model for virtual machines
- Performance of embedded system applications
  - understanding compiler optimization phase interactions
  - providing faster & effective phase ordering searches
- Compiler-based program parallelization
  - interactive generation of thread-safe programs

Future Profiling for Improved Virtual Machine Performance

Traditional Program Profiling

- Profiling
  – monitor and understand program behavior to improve program characteristics
- *Offline* profiling uses information from past runs



  + no runtime overhead
  – requires user to find representative input, perform profile run, encode/use information
  – reactive, fails if profile and current input do not match

Profiling in Virtual Machines

- *Online* profiling monitors the current run

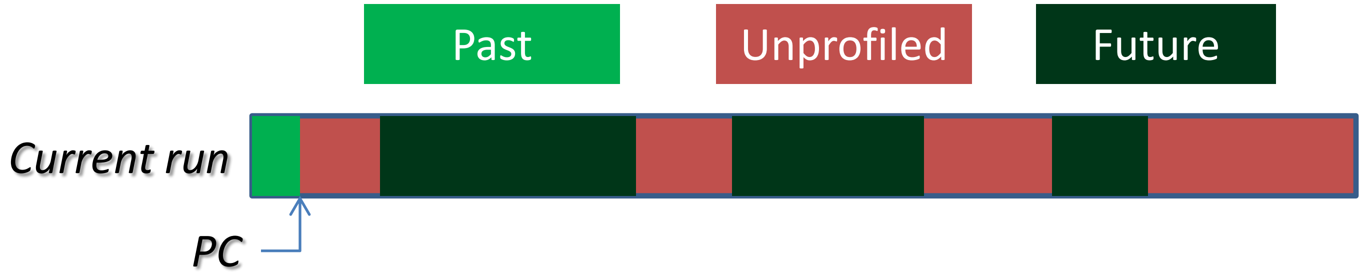
  + no prior program run needed
  + can better adapt to changing input
  – need runtime system and causes overhead
  – still reactive?
- Java virtual machines use online profiling
  – during *selective* compilation
  – feedback-driven optimization
  – security checks

Profiling During Selective Compilation

- Current online profiling schemes are still *reactive*
  - employ very simple prediction models
  - future behavior is same as past behavior
- Leads to incorrect *speculations*
  - unnecessary compilation overhead at runtime
  - delays compilation of *actual* hot methods
- Optimizations wait until profiling results available
  - delays decisions based on profiling
  - degrades performance at program *start-up*

Improving Online Profiling – Hypothesis

- Profiling to understand *future* program behavior!



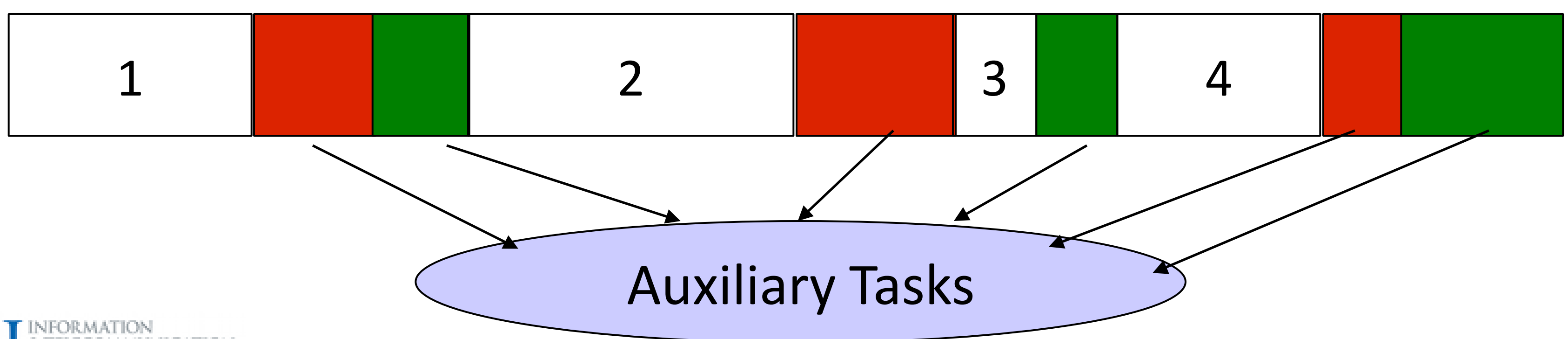
- For each online prediction task
  – construct program models
  – that use values of *key* variables
  – to *know* future program behavior

Parallelization Model for Virtual Machines

Inline Auxiliary Tasks

- Virtual machines perform several profiling tasks and security checks during program execution
  - profiling for improved performance
  - checks like taint propagation, on-access virus-scans
- Checks performed *inline* with the main program
  - introduces overhead

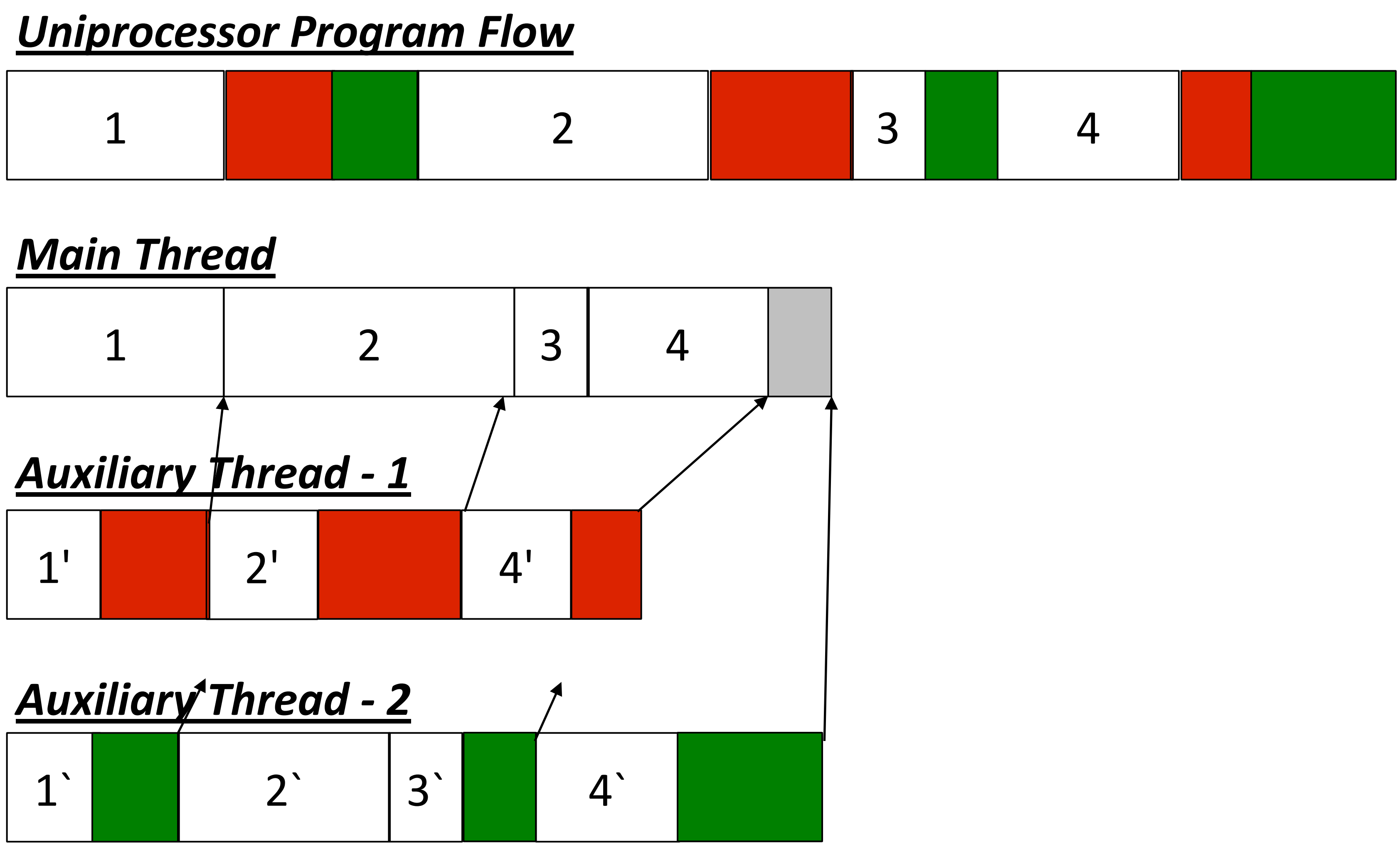
Uniprocessor Program Flow



Parallelizing Security Checks

- Algorithm
  1. program *slicing* to determine code statements necessary for each security check
  2. minimize slice using other optimizations
  3. factor out each security thread with its program slice into new *auxiliary* thread
  4. Run auxiliary threads concurrently with main thread

Parallelizing Auxiliary Tasks



Research Directions

- Techniques to find the smallest program slice
  - automatically determine the slicing *criteria* for different security constraints
- Slice representation in program binary
  - conserve binary size
- VM framework to concurrently execute auxiliary slices with main program thread
  - interpret new binary file
  - prevent auxiliary threads from changing global state
  - ensure correct program execution

Understanding Optimization Phase Interactions for Faster Phase Ordering Searches

Optimization Phase Ordering

- Changing order of phases affects code generated
  - large speed/size variations
- Current approach
  - optimization phases considered as black boxes
  - use heuristics to search *part* of phase order space
- Problems
  - optimal phase ordering not guaranteed
  - focus more on heuristic search techniques
  - no understanding of phase ordering issues
  - how to implement phases in future compilers?

Solution Approach

- Understand impact of registers on phase order space
  - explore techniques to reduce *false* register dependences
  - copy propagation applied after every relevant phase reduces phase order search space by 27%, on average
  - locally remapping registers during optimizations improves performance by up to 14%
- Study partitioning of independent or cleanup phases
  - removing DAE from the search space reduces search space by 49% on average
- Generate rules for implementing phases at compiler build time
  - changing implementation later is difficult

Questions ?