program tracing generation, manipulation, and analysis

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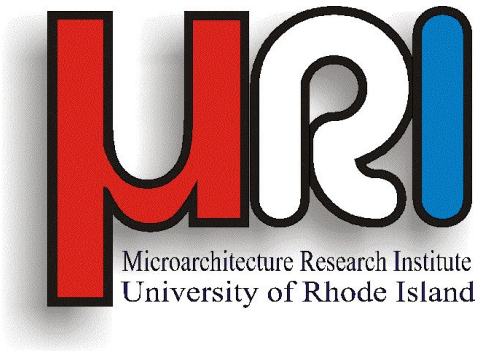

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outline

- **introduction**
- **generation**
- **manipulation**
  - filtering
  - conversion
- **analysis**
  - comparison
  - program characterization
  - microarchitectural simulation
  - secondary analysis
- **modularity**
  - code similarity and program pipe fitting
  - static and dynamic modules
- **summary**

introduction

- **process overview**
  - run a program somewhere
  - record various information from the executing program creating a trace of its execution history
  - store the trace for later use
  - transform the trace for input to other programs
  - perform various manipulations on the trace
  - analyze the trace (characterization or simulation)
- **alternatives to tracing**
  - analyze during execution
  - execution based simulation
- **advantages to tracing**
  - same trace analysed multiple times from a single stored copy
- **disadvantages**
  - trace needs to be stored (could be huge)

trace generators (1)

- **Pixie (SGI)**
  - provides
    - ⇒instruction addresses
    - ⇒provides partial memory addresses (lower 24 bits)
  - programs needed to convert to ET format (in order)
    - ⇒pixie2levo
    - ⇒tracepixie
  - runs fairly quickly
  - fairly low error rate

- **ET (Execution Trace):** is a common trace format that provides plug-in-play among various trace tools

trace generators (2)

- **DBX (SGI)**
  - provides
    - ⇒instruction addresses
    - ⇒instruction destination register values
    - ⇒memory source addresses for loads
    - ⇒memory destination addresses and values for stores
  - programs to convert to ET format (in order)
    - ⇒dbx
    - ⇒dbxvout
    - ⇒stripopgarb
    - ⇒tracedbx
  - runs very (very) slowly -- not really generally useful as a result
  - fairly high error rate -- not generally useful as a result

trace generators (3)

- **SimpleSim**
  - provides anything about program execution that one might want
    - ⇒instruction addresses
    - ⇒source register addresses and values
    - ⇒source memory addresses and values
    - ⇒destination register addresses and values
    - ⇒destination memory addresses and values
    - ⇒system calls and affected memory addresses and values
  - programs to convert to ET format (in order)
    - ⇒*none* -- produces ET format directly
  - runs fairly quickly
  - zero error rate on some programs
  - some errors on other programs may accumulate and lead to catastrophic program failure

trace generators (4)

- **DamMint**
  - a modified version of MINT that can run more programs without crashing
  - can provide
    - ⇒instruction addresses
    - ⇒source memory addresses
    - ⇒destination register addresses and values
    - ⇒destination memory addresses and values
  - programs to convert to ET format (in order)
    - ⇒*none* -- produces ET format directly
  - runs fairly quickly
  - very high error rate but can generally runs many programs -- not useful for verifying correct execution

trace manipulation (1)

- **copying and filtering**
  - can filter out some information from an input trace and create a new output trace
    - ⇒system calls (from point of view of programmer)
    - ⇒source or destination register or memory addresses or values
  - primary tool -- TRACECOPY -- ET to ET
  - for system-call filtering
    - ⇒a list of system calls to be filtered must also be supplied
    - ⇒the original program executable (machine object file) is needed for symbol lookup in its symbol table
    - ⇒useful for generating traces that can be compared from generators that do not provide system call information or that provide OS dependent system-call information

trace manipulation (2)

- **conversion to other formats**
  - since there are so many different trace formats, normally conversion would present an O(n^2) number of different conversions
  - but using a common trace format (ET) there only needs to be 2 * n conversions to cover all possibilities
  - other formats of interest

    ⇒various formats for input to FastLevo
  - conversion to ET has already been seen
  - conversion to other formats (from ET) using TRACEDUMP

trace analysis (1)

- **trace comparison**
  - compare two traces for equality
  - compare two traces for common subsequences
  - useful for verifying program execution or simulation integrity
  - primary tool: TRACECMP
- **program characterization**
  - instruction execution statistics

    ⇒counts for loads-stores, ALU, branches
  - values

    ⇒register and memory
  - branch behavior
  - subroutine function coverage
  - example tools: TRACESTAT, ICOUNT, FCOUNT

trace analysis (2)

- **microarchitectural simulation**
  - branch predictor behavior
  - cache behavior
  - machine units
  - you name it !
  - example tool: TRACESTAT
- **secondary analysis**
  - primary characterization or simulatorion analyzer creates output data that needs to be further analyzed between different trace-analysis runs
  - example: collating branch predictor results from various predictors or predictor configurations
  - example tool: BPSORT

other trace manipulation

- **creating source operands from destination operands**
  - Why ? -- FastLevo wanted it !
  - can create source register operands from destinations by maintaining a committed copy of the register file and the source operand addresses
  - can create source memory operands from
    - ⇒source operand addresses
    - ⇒destination memory operands
    - ⇒the original program executable object file
    - ⇒maintaining the entire program committed memory state in trace-reader programs (available as a module !)
- **with source operand creation**
  - no need to store source operand values (only source addresses)
  - smaller trace files ! (could be important due to space)

modularity

- **trace generation and reading**
  - using a common trace format (ET) provides opportunities for code modularity and program modularity
  - code for generating and reading traces is similar
  - programs can be fitted together to provide more complex analysis without duplicated specialized code
- **some analysis tools provide for the inclusion of**
  - statically linked code modules

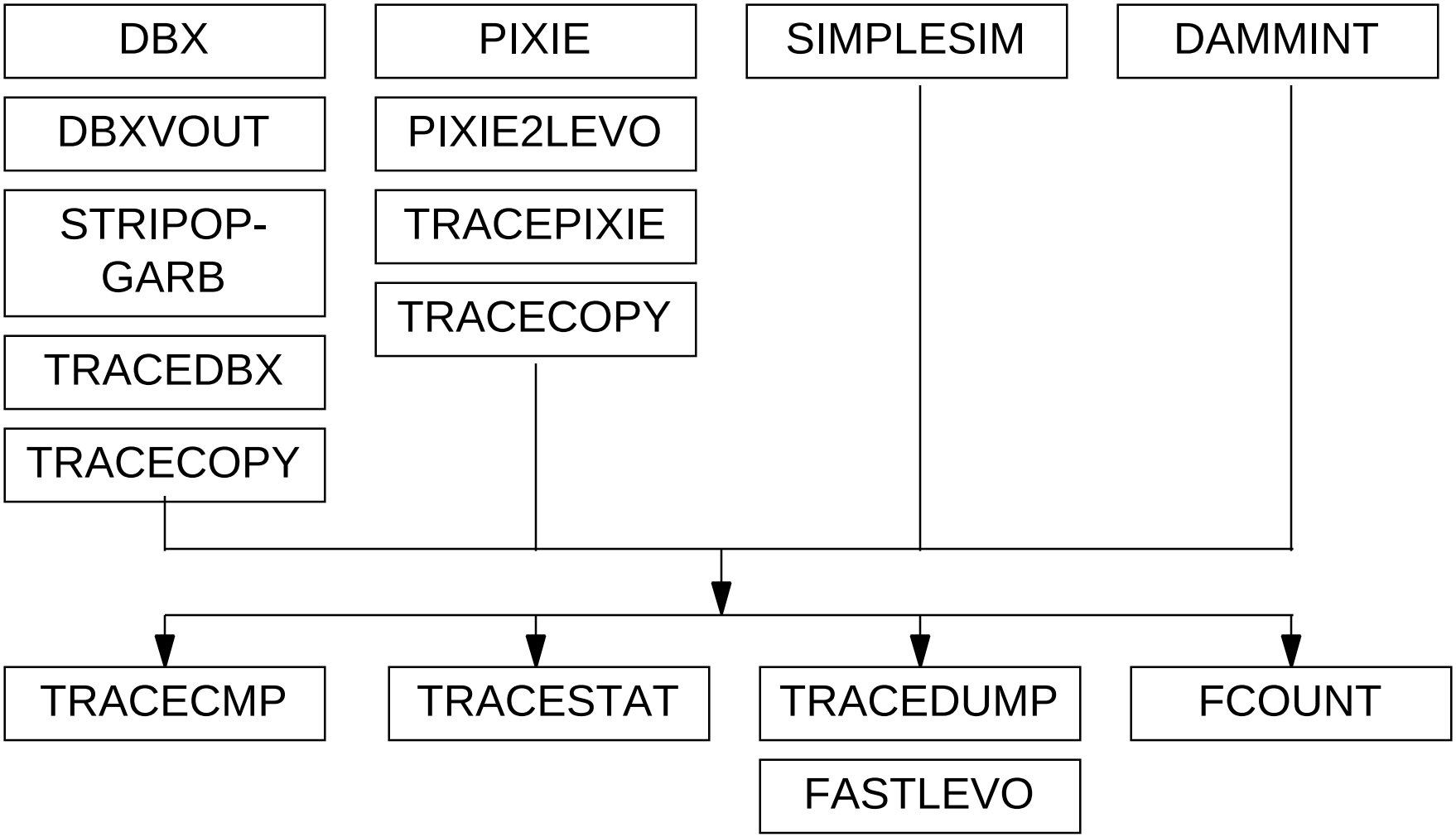
    ⇒TRACESTAT, LevoSim, SimpleSim, FastLevo
  - dynamically (run-time) linked code modules

    ⇒TRACESTAT
  - example modules

    ⇒SS Hammock branch detection and characterization

    ⇒branch predictor simulation

modularity (typical pipelines)



summary (tool programs)

- **SIMPLESIM** -- simulator and trace generator
- **DAMMINT --** trace generator
- **DBXVOUT --** DBX post-processor
- **STRIPOPGARB --** DBXVOUT post-processor
- **TRACEDBX** -- STRIPOPGARB post-processor
- **PIXIE2LEVO --** Pixie post-processor
- **TRACEPIXIE --** PIXIE2LEVO post-processor
- **TRACECOPY --** trace filtering and copying
- **TRACECMP --** trace comparator
- **ICOUNT --** instruction characterization
- **FCOUNT --** subroutine function coverage analyzer (also module)
- **TRACESTAT --** characterization and simulation (also uses dynamic plugins)

summary

- **when developing simulators, verifying program execution integrity is often both difficult and important -- good trace handling tools helps a lot**
- **a common trace format (ET) and modular trace tools allow for more complex trace generations, manipulations, and analyses**
- **I spent about a year handling traces ! :-)**