CMSC 714
Lecture 17
Valgrind and DynInst

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Notes

- Still working on OpenMP project grading
  - Should be ready early next week
- Research project questions?
  - Feedback on proposals soon
- Sample midterm exam questions posted

Valgrind

- Framework for building dynamic binary analysis tools
  - works on program binaries
  - instrumentation inserted before the program runs
  - provides basic services that a tool writer can use to perform dynamic analyses
  - basic mechanism is *shadow values*
- Shadow values – heavyweight instrumentation
  - basic idea is to maintain a copy of all program state for an analysis tool to use (and tool can add more state needed for its analysis)
  - 9 requirements, 3 classes
    - shadow state – registers and memory
    - read/write operations – instrument instructions (loads and stores) and system calls – arguments and return values to/from registers/memory, and via pointers
    - allocation/deallocation operations – start-up (registers, static data), system calls (**brk**, **mmap**), stack pointer movement (function call/return), heap (esp. bookkeeping data)
    - transparent execution, but extra output – only effect on instrumented program is extra side-channel output

Valgrind

- Tool-specific code plugs into Valgrind core
  - to instrument code fragments that the core passes to it
- Dynamic binary recompilation
  - a tool loads client program, recompiles it a block at a time as the client program executes within Valgrind
  - core disassembles code block into IR, then tool plug-in instruments it, then core converts IR back to machine code to execute
    - can deal with dlls, shared libraries, and dynamically generated code – only problem is self-modifying code
    - dissassemble/resynthesize (D&R), vs. copy/annotate (C&A) – claim is that D&R better for heavyweight analyses
  - key issue, and reason for difficulty of implementation, is having the tool/core sharing memory with the (instrumented) client program
- Events system used to inform tools about system call activities not directly visible from IR
  - i.e. what state gets changed in the system call
- One big problem is that thread execution is serialized, to keep updates to main and shadow memory consistent always
  - not clear how to fix this and allow concurrent thread execution
- Tool performance (e.g., Memcheck) similar to that of other equivalent tools

Valgrind Tools

- Memcheck – detects memory problems in C/C++ programs
    - Access memory the program shouldn’t (areas not yet allocated, areas that have been freed, etc.)
    - Use uninitialized values in dangerous ways
    - Leak memory
    - Does bad frees of heap blocks (double frees, mismatched frees)
- Cachegrind – cache profiler to find sources of cache misses via simulation
- Massif - heap profiler, via snapshots
- Helgrind - thread debugger to find data races in multithreaded programs – uses Eraser algorithm

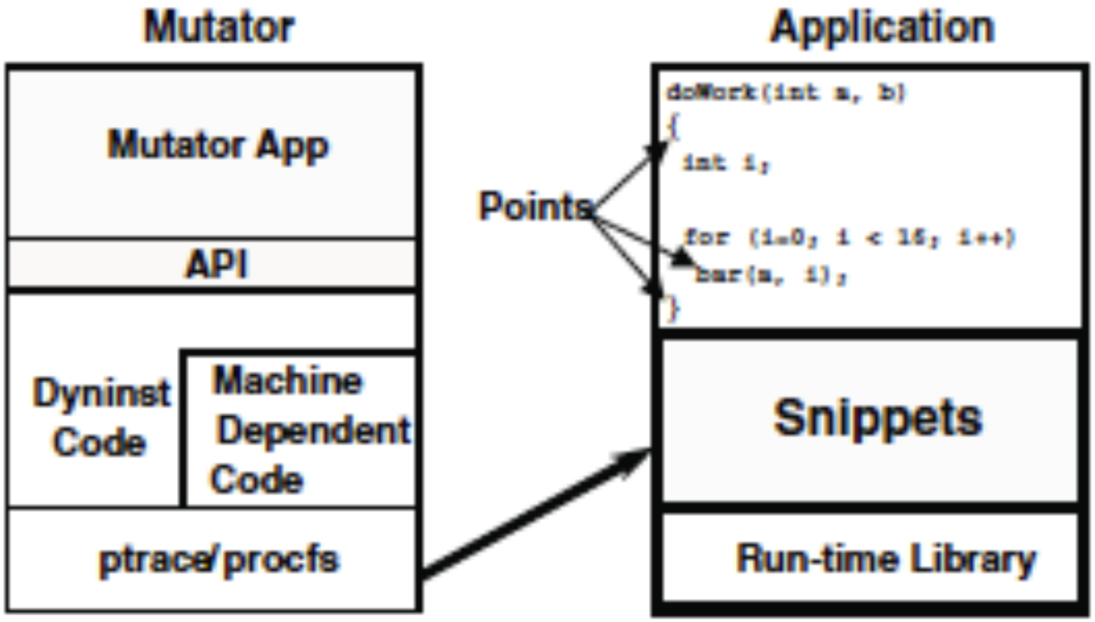
DynInst

- C++ class library for binary static and dynamic instrumentation
  - lightweight infrastructure for building dynamic analysis tools
  - differs from earlier instrumentation tools because can work on executing program, and uses machine independent description of inserted code
  - Targeted at tool developers, not really for direct use by application developers
- Insert *snippets* into one or more client processes
  - at instrumentation *points*
  - *mutator* process inserts snippets into the application program, which was linked with the Dyninst runtime library, either before or at runtime
- Implementation for runtime patching uses similar OS services as a debugger, for controlling activity of another process
  - control process execution
  - read/write address space

DynInst

- Generate code from snippet calls into machine language of host machine in the mutator, then copy into space allocated in application address space
  - use trampoline code – base tramp with pointers to pre and post code surrounding one relocated instruction from the point of insertion
  - mini-tramp for pre or post code snippet, to save/restore registers and set up arguments for snippet function code
    - multiple snippets can be chained at one point
- Conditional breakpoint example shows power of the method, and how it can reduce execution cost for expensive operations by directly inserting code into the application at runtime

How does DynInst work?



```
doWork(int a, b)
{
 int i;

 for (i=0; i < 16; i++)
  bar(a, i);
}
```

Fig. 1 Abstractions used in the API

https://journals.sagepub.com/doi/pdf/10.1177/109434200001400404

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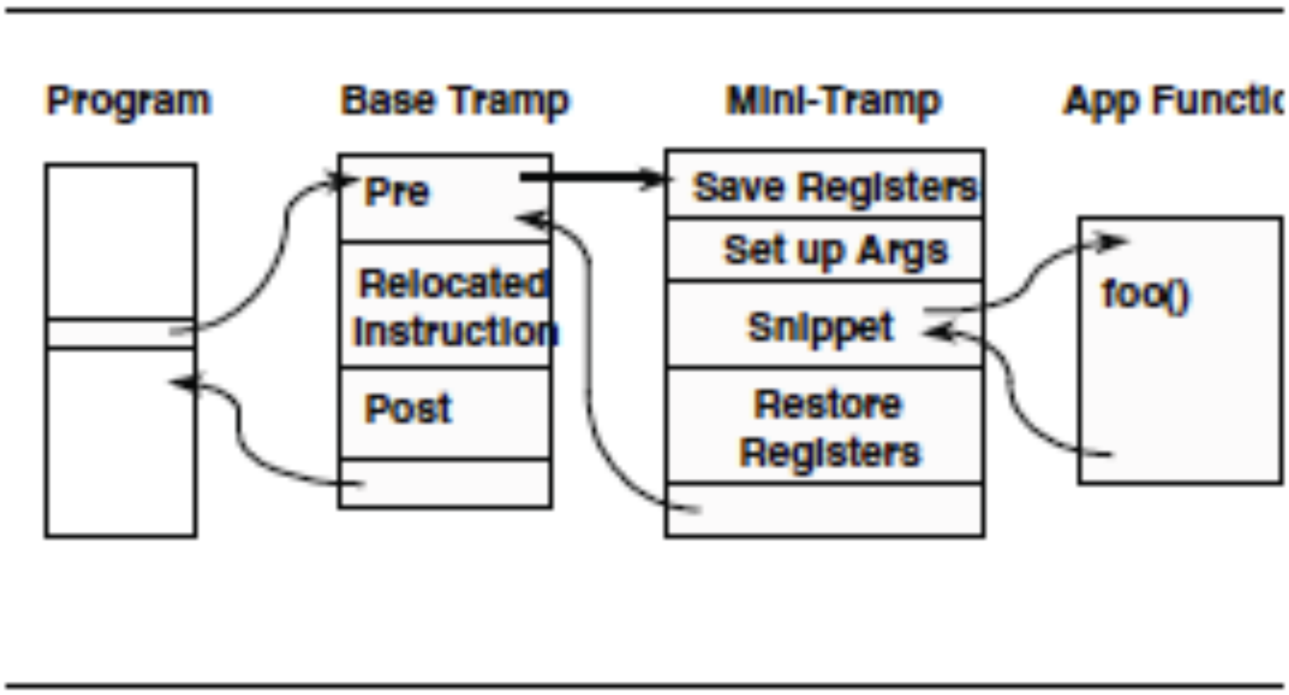

Fig. 2 Inserting code into a running program

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