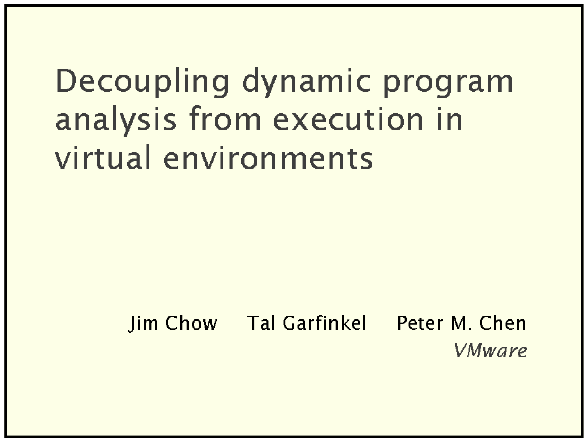
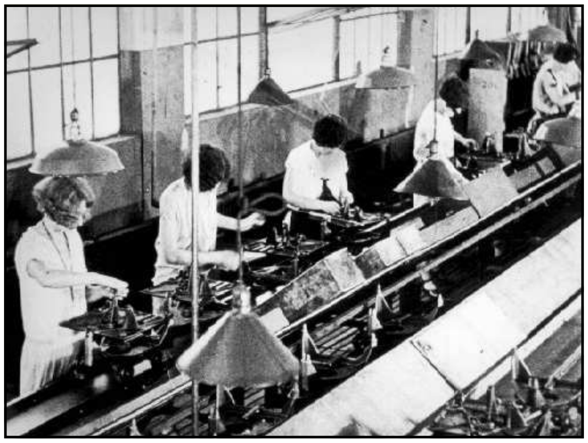
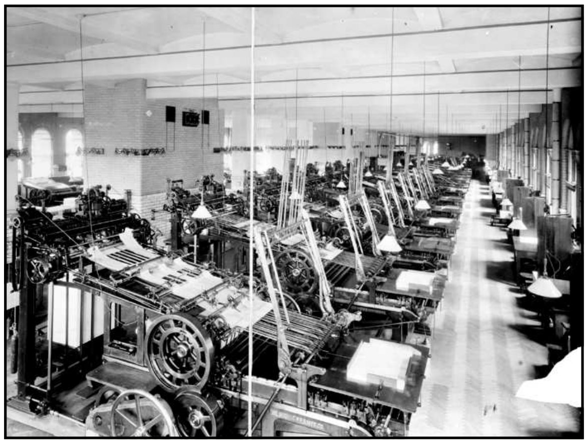
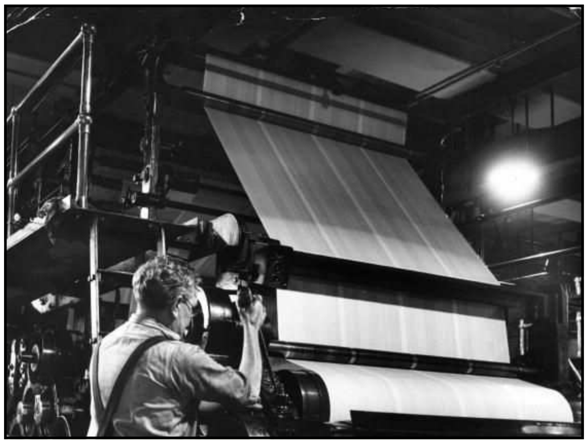


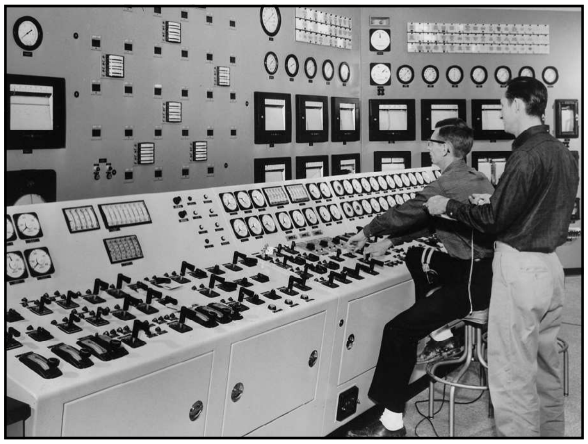
Decoupling dynamic program analysis from execution in virtual environments

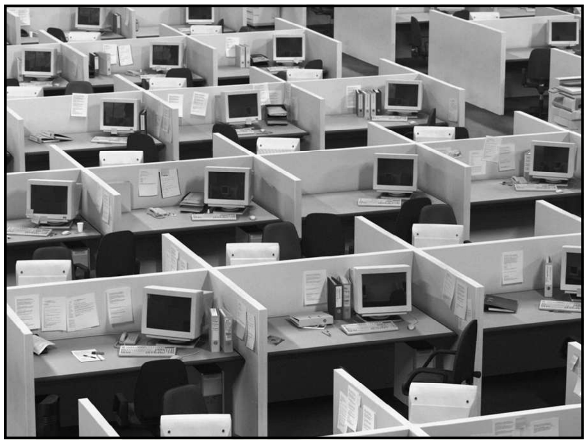
Jim Chow Tal Garfinkel Peter M. Chen
VMware

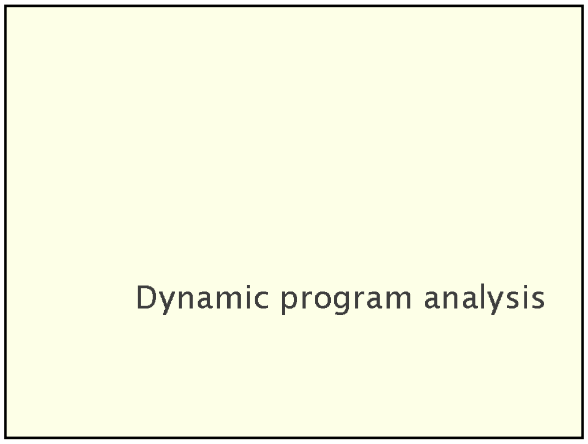






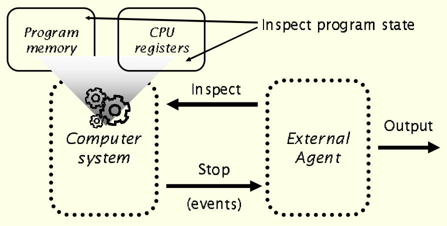






Dynamic program analysis

Dynamic program analysis



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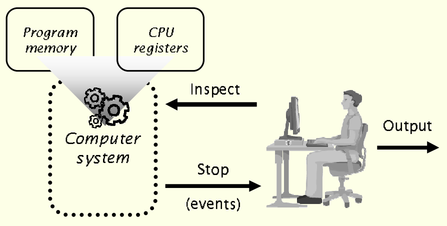
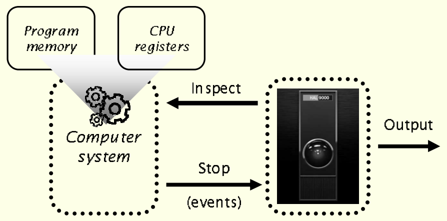


Dynamic program analysis



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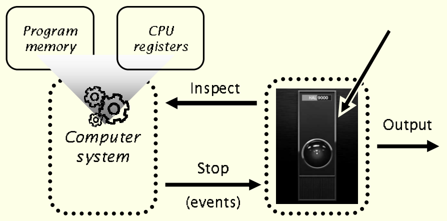
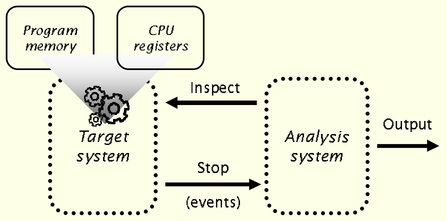


Dynamic program analysis

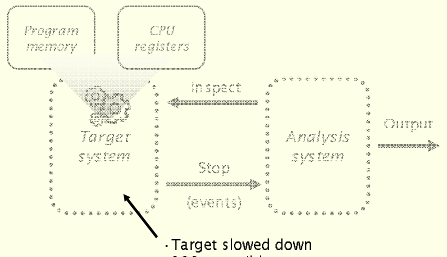
Many useful analysis tools

- Discovering races: *Intel ThreadChecker*, *Eraser*, *Helgrind*
- Finding bugs: *Purify*, *Valgrind*
- Checking security invariants: *TaintCheck*, *TaintBochs*, *Program Shepherding*
- Profiling: *VTune*, *DTrace*

Dynamic program analysis



Dynamic program analysis



- Target slowed down
- 100x possible

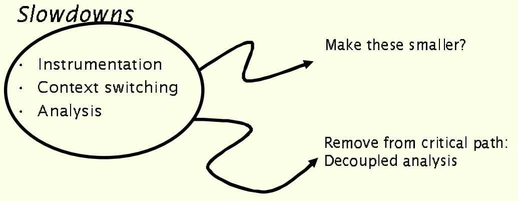
Dynamic program analysis

Can we do better?

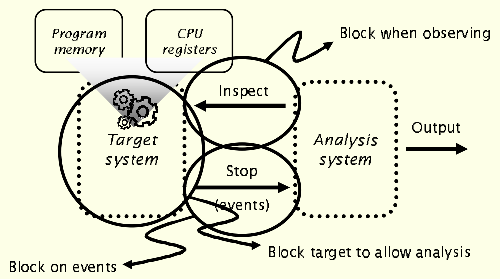
Dynamic program analysis

Slowdowns

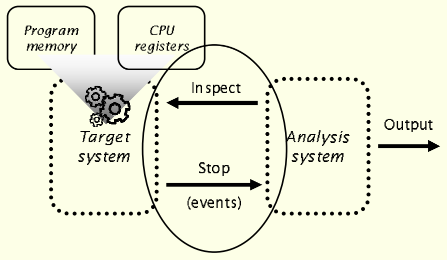
- Instrumentation
- Context switching
- Analysis



Dynamic program analysis



Decoupled analysis

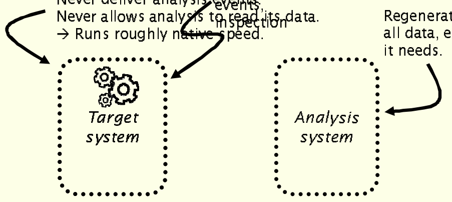


Decoupled analysis

Run freely.
Don't block for events, inspection

Never deliver analysis events.
Never allows analysis to read its data.
→ Runs roughly native speed.

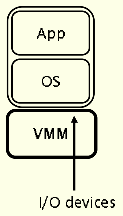
Regenerates all data, events it needs.



Recording

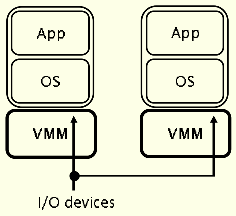
Analysis

Virtual machine record/replay



- Record all inputs from outside world
- When replayed from same starting point, VM execution will repeat instruction for instruction

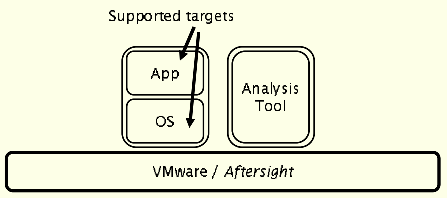
Virtual machine record/replay



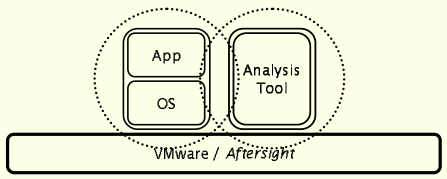
- Record all inputs from outside world
- When replayed from same starting point, VM execution will repeat instruction for instruction
- Not a lot of data:
- 1-10% runtime overhead
- KB/s data

Aftersight: an overview

Aftersight

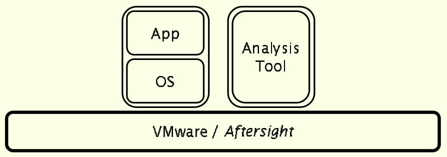


Decoupling properties



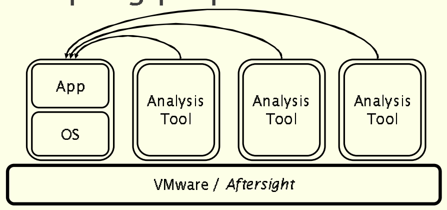
Isolation:
- Analysis is self-contained: events, data self-generated
- Eliminates communication bottleneck
- Faults and regressions
- Add analysis in-situ

Decoupling properties



Parallelism:
- Analysis and target can run separately
  - Make analysis go faster
- Many analyses can run in parallel

Decoupling properties



Parallelism:
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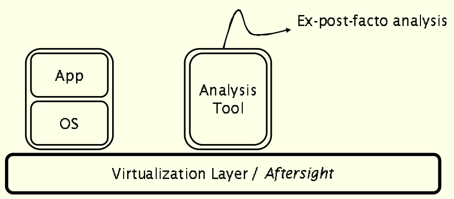
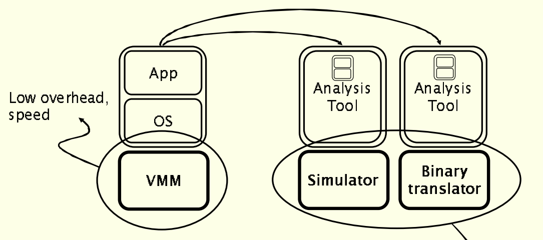
Decoupling properties



- Ex-post-facto:
  - Analysis not known at the time of recording can be created and applied to prior runs

Challenging implications

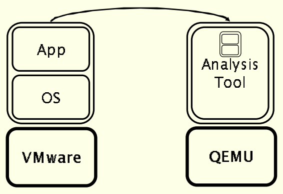
Separating environments



- Important ability: different environments for recording and replaying
- Tuned to their task
- Rich analysis environment

Ease of instrumentation, flexibility

Heterogenous replay



- Interpreted execution
- Different virtual HW

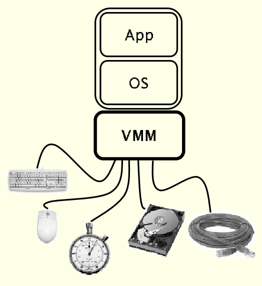
- Important ability: different environments for recording and replaying
- Tuned to their task
- Rich analysis environment

Hardware to software

- Interpreted execution: lack hardware performance counters on replaying end
  - Emulate counters in software: emit translations to increment counts, check for event delivery

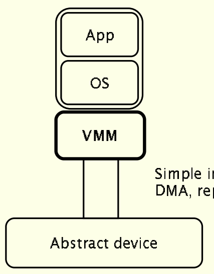
- Different virtual HW: replay log unusable

Heterogenous replay



- Modify VM replay: make it simpler
- Lump all devices into one big abstract device, never processes output

Heterogenous replay



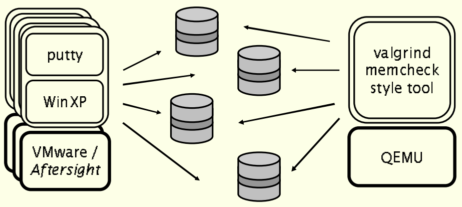
- Modify VM replay: make it simpler
- Lump all devices into one big abstract device, never processes output

- Input only
- May not be as efficient

Simple interface: interrupts, DMA, reply to MM reads, port IN

Benefits of heterogenous replay

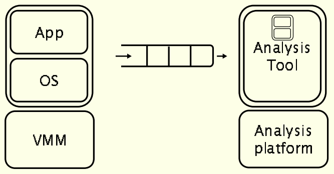
- Use analyses impractical to do in VMM



Lots of bugs: ESX (critical pre-production), Linux (old undiagnosed), putty

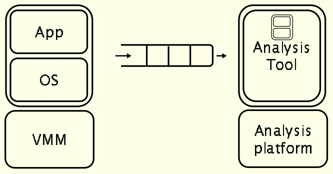
Parallel analysis

- Made easy with recording
- Important capability: timeliness
- Compelling: performance (more cores)



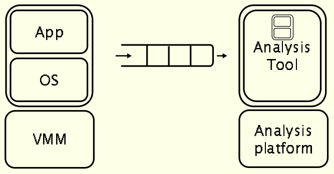
Implications of parallel analysis

- Different rates
- Stacked odds
- Block target (slow but not all lost)



Implications of parallel analysis

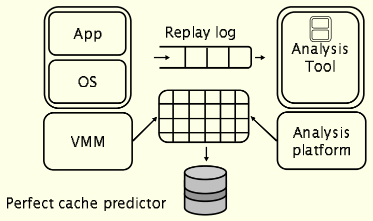
- Blocking is unavoidable, but with buffering it's possible we never have to do it
- Key: make analysis faster (play catch up)



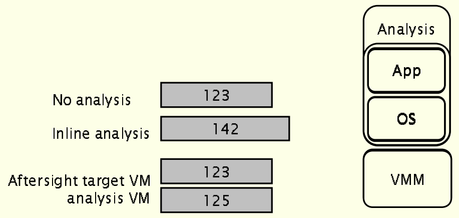
- → Slow analysis but keeps up (intuition: oracle)

Playing catchup

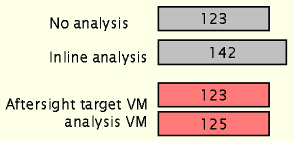
- Faster instructions: wait for interrupts (HLT)
- Speculation: memoize/forward cache

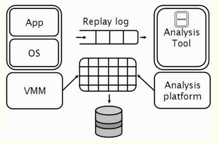


Keeping pace: web crawling



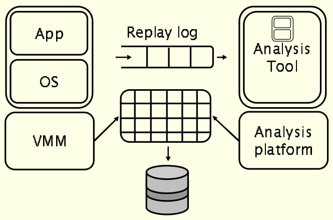
Keeping pace: web crawling





Keeping pace

- Analysis results can be timely
- Implication: must speed up analysis



Aftersight

- System presents *decoupled analysis*
- Shows *heterogenous replay* as a method for extending scope of analysis tools
- Enables *parallel analysis* and examines its impact on analysis
- … and more: *synchronous safety*, *relogging*, *idle-time boost*, *feedback modes*, *memoizing simulation…*

Synchronous safety

- Security important part of some dynamic analysis
  - Key attribute: block target before it does damage
- Synchronous systems block for mixed reasons
  - Deliver events/data, block target to prevent damage
- Asynchronous systems are better
  - At least as good, because blocking is a choice
  - Better, avoid blocking for irrelevant items: events/data
  - Key: choosing to block target before it does damage
  - In record/replay: most damage can be undone the only damage that can't be undone is output to the outside world