Lawrence Livermore National Laboratory

Pianola: A script-based I/O benchmark

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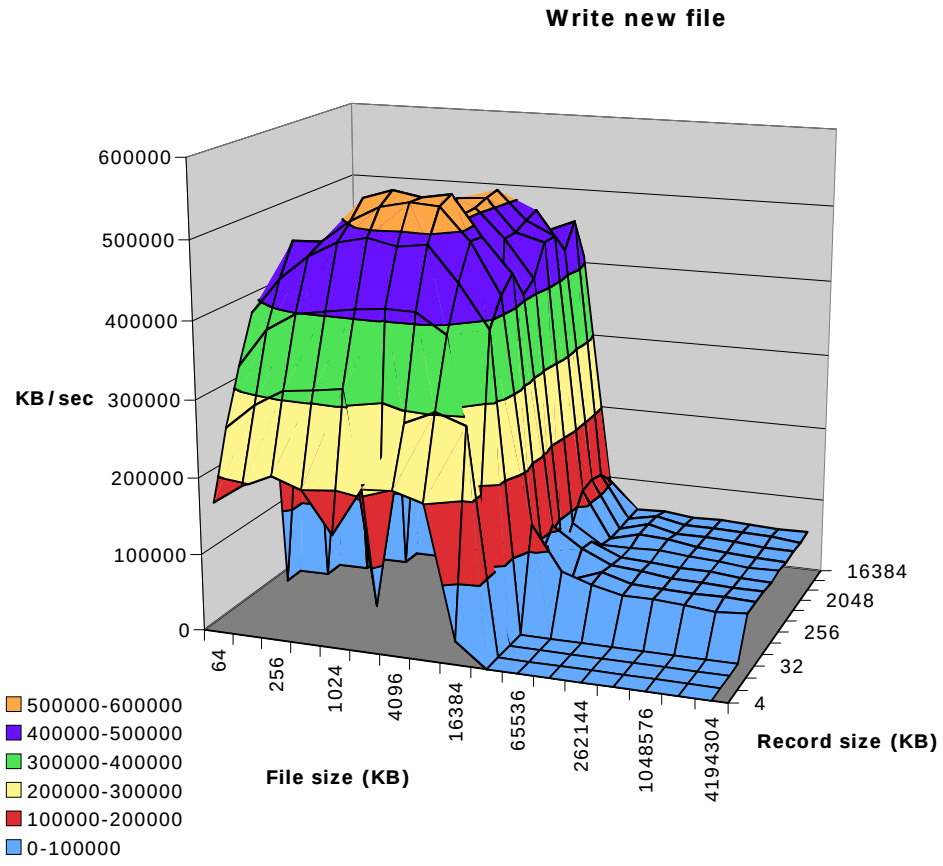
I/O benchmarking: What's going on here?

- Is my computer's I/O system "fast"?
- Is the I/O system keeping up with my application?
- Is the app using the I/O system effectively?
- What tools do I need to answer these questions?

- And what exactly do I mean by "I/O system" anyway?
  - For this talk, an I/O system is everything involved in storing data from the filesystem to the storage hardware

Existing tools can measure general or application-specific performance



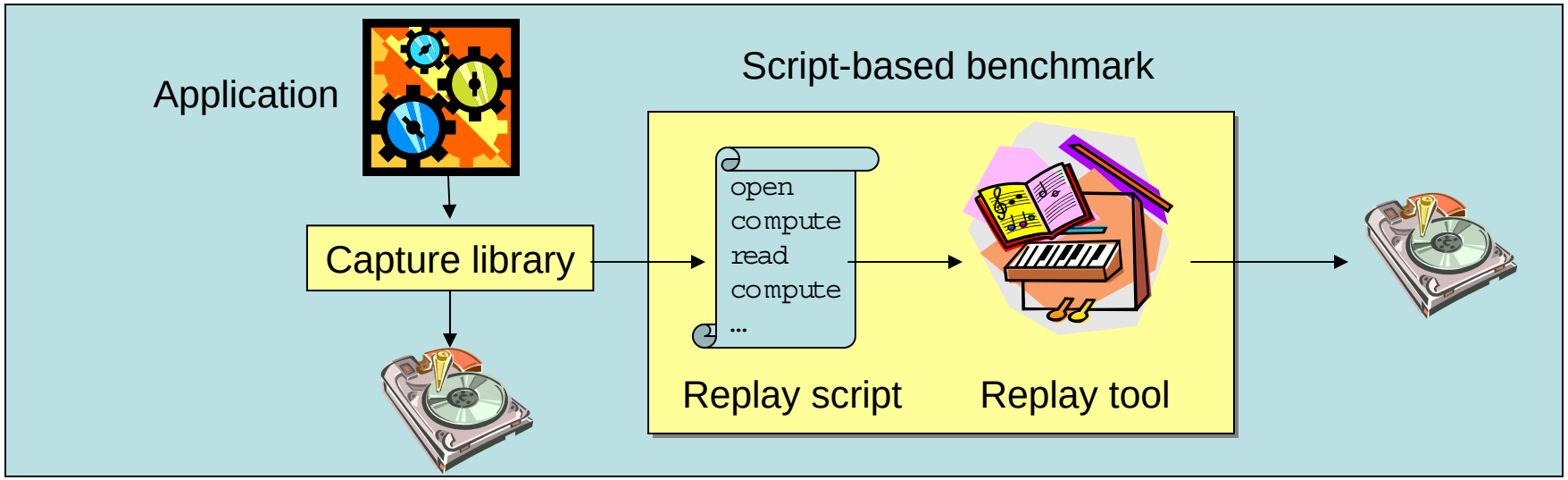
- IOzone automatically measures I/O system performance for different operations and parameters
- Relatively little ability to customize I/O requests

- Many application-oriented benchmarks
  - SWarp, MADbench2…
- Interface-specific benchmarks
  - IOR, //TRACE

Measuring the performance that matters

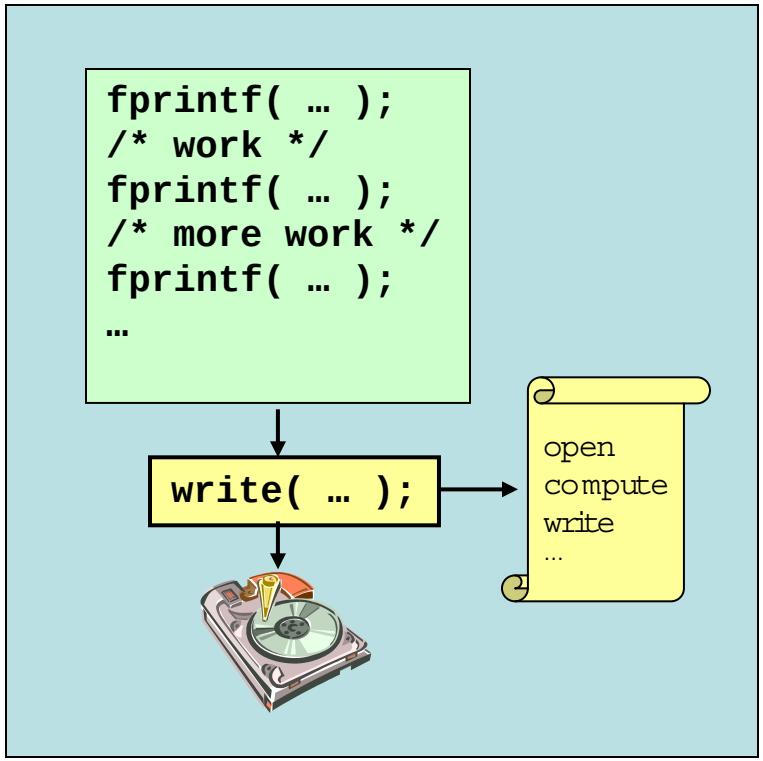
- System benchmarks only measure general response, not application-specific response
- Third-party application-based benchmarks may not generate the stimulus you care about
- In-house applications may not be practical benchmarks
  - Difficult for nonexperts to build and run
  - Nonpublic source cannot be distributed to vendors and collaborators
- Need benchmarks that…
  - Can be generated and used easily
  - Model application-specific characteristics

Script-based benchmarks emulate real apps



- Capture trace data from application and generate the same sequence of operations in a replay-benchmark
- We began with //TRACE from CMU (Ganger's group)
  - Records I/O events and intervening "compute" times
  - Focused on parallel I/O, but much of the infrastructure is useful for our *sequential* I/O work

Challenges for script-based benchmarking: Recording I/O calls at the the right level



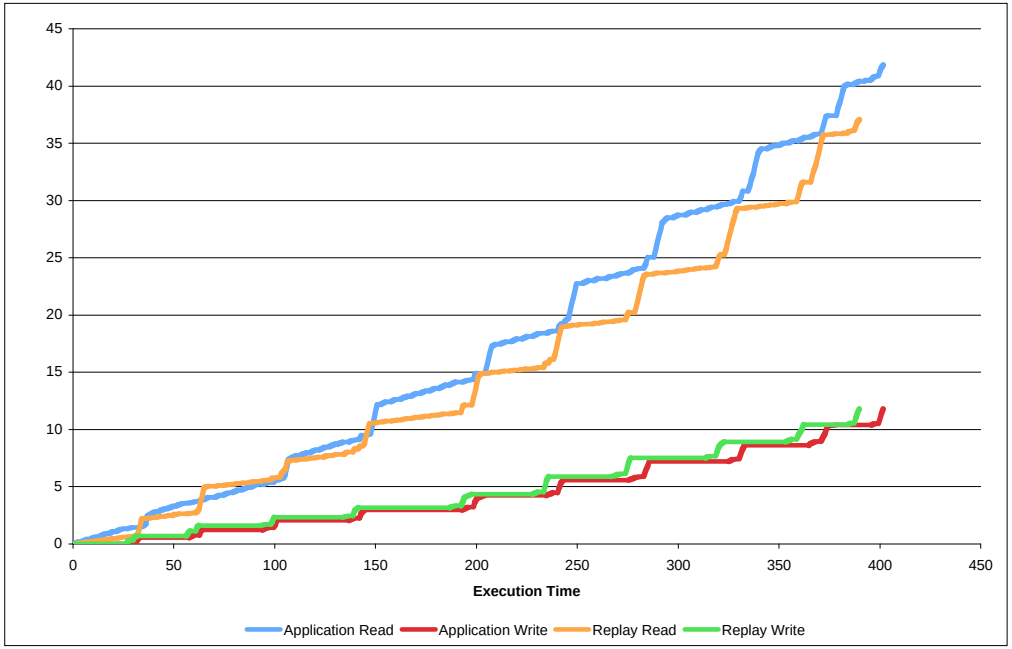
- Instrumenting at high level
  - + Easy with LD_PRELOAD
  - - Typically generates more events, so logs are bigger
  - - Need to replicate formatting
  - - Timing includes computation
- Instrumenting at low level
  - + Fewer types of calls to capture
  - + Instrumentation is at I/O system interface
  - - Cannot use LD_PRELOAD to intercept all calls

First attempt at capturing system calls: Linux strace utility

```
$ strace -r -T -s 0 -e trace=file,desc ls
     0.000000 execve("/bin/ls", [, ...], [/* 29 vars */]) = 0 <0.000237>
     0.000297 open("/etc/ld.so.cache", O_RDONLY) = 3 <0.000047>
     0.000257 fstat64(3, {st_mode=S_IFREG|0644, st_size=64677, ...}) = 0 <0.000033>
     0.000394 close(3)                  = 0 <0.000015>
     0.000230 open("/lib/librt.so.1", O_RDONLY) = 3 <0.000046>
     0.000289 read(3, ""..., 512)       = 512 <0.000028>
     ...
```

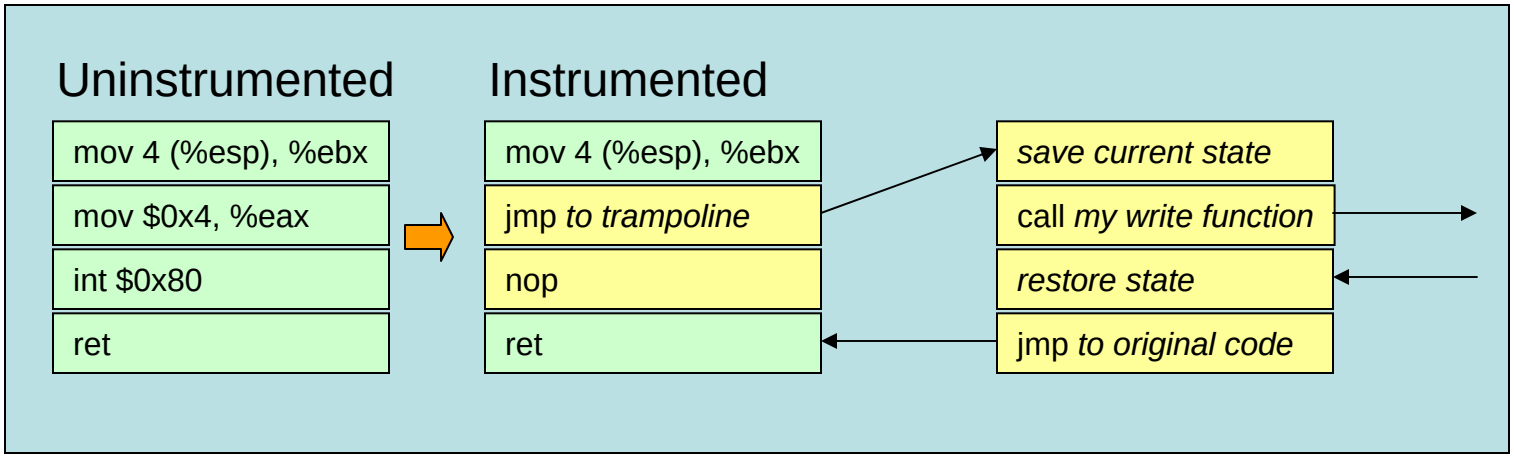
- Records any selected set of system calls
- Easy to use: just add to command line
- Produces easily parsed output

Strace results look reasonably accurate, but overall runtime is exaggerated



	Read (sec.)	Write (sec.)	Elapsed (sec.)
Uninstrumented	--	--	324
Instrumented Application	41.8	11.8	402
Replay	37.0	11.8	390

For accurate recording, gather I/O calls using binary instrumentation

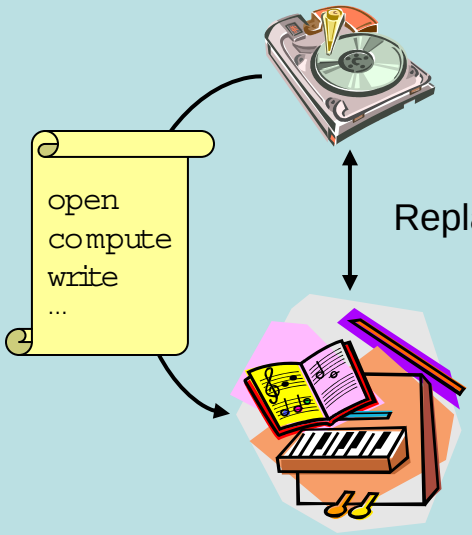


- Can intercept and instrument specific system-level calls
- Overhead of instrumentation is paid at program startup
- Existing Jockey library works well for x86_32, but not ported to other platforms
- Replay can be portable, though

Issues for accurate replay

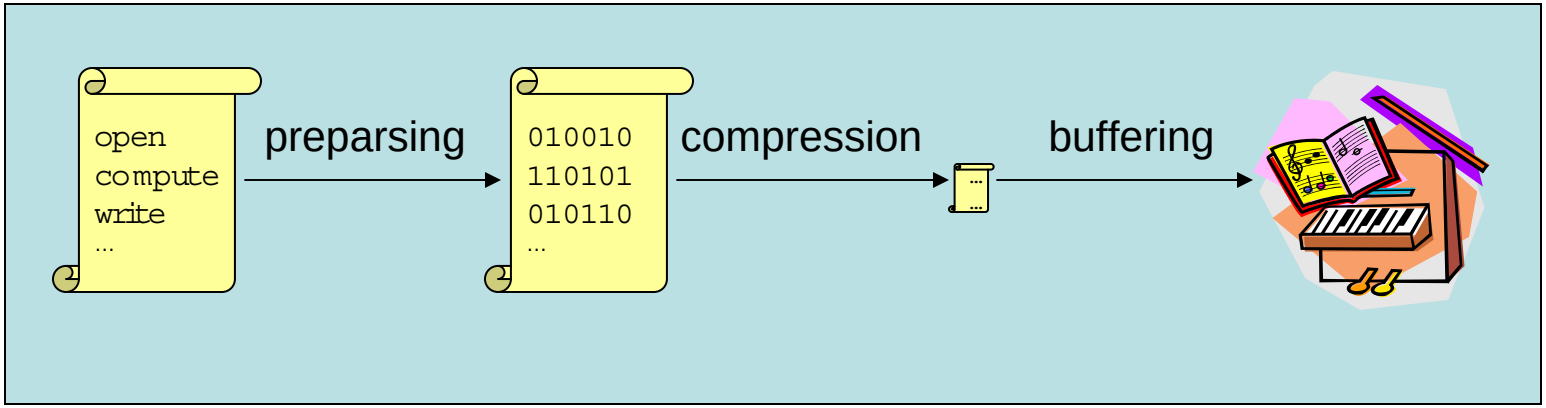
- Replay engine must be able to read and parse events quickly
- Reading script must not interfere significantly with I/O activities being replicated
- Script must be portable across platforms

Accurate replay
Minimize I/O impact of reading script



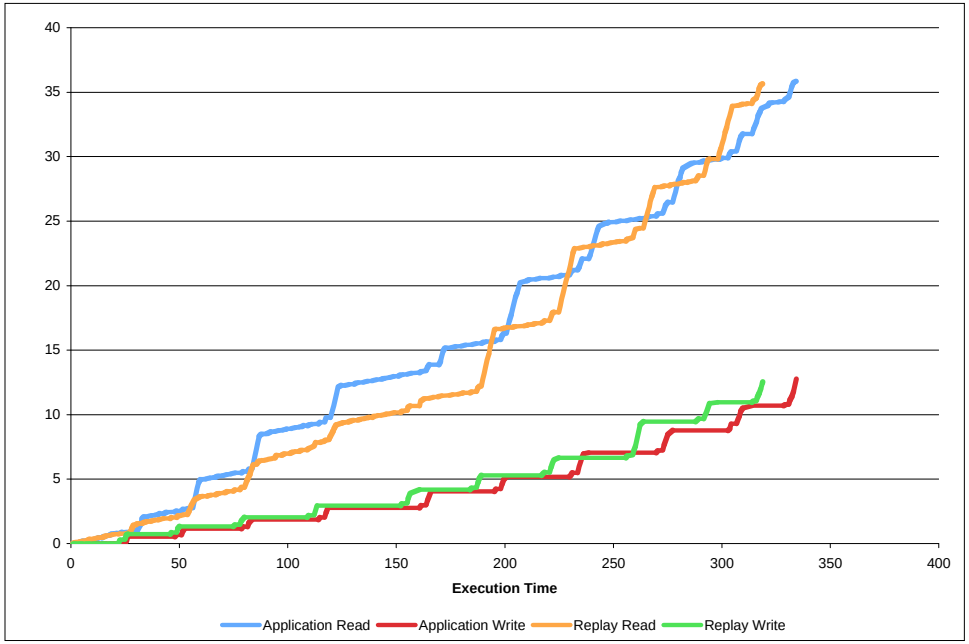
Correctly reproduce inter-event delays

Accurate replay: Preparsing, compression, and buffering



- Text-formatted output script is portable across platforms
- Instrumentation output is parsed into binary format and compressed (~30:1)
  - Conversion done on target platform
- Replay engine reads and buffers script data during “compute” phases between I/O events

Replay timing and profile match original application well



	Read (sec.)	Write (sec.)	Elapsed(sec.)
Uninstrumented	--	--	314
Instrumented Application	35.8	12.8	334
Replay	35.7	12.5	319

Things that didn't help

- Compressing text script as it's generated
  - Only 2:1 compression
  - Time of I/O events themselves are not what's very important during instrumentation phase
- Replicating the memory footprint
  - Memory used by application is taken from same pool as I/O buffer cache
  - Smaller application (like the replay engine) should go faster because more buffer space available
  - Replicated memory footprint by tracking brk() and mmap() calls, but it made no difference!

Conclusions on script-based I/O benchmarking

- Gathering accurate I/O traces is harder than it seems
  - Currently, no solution is both portable and efficient
- Replay is easier, but efficiency still matters
- Many possibilities for future work—which matter most?
  - File name transformation
  - Parallel trace and replay
  - More portable instrumentation
  - How to monitor mmap'd I/O?