Virtual Application Profiler (VAPP)

Problem

- Increasing hardware complexity
- Programmers need to understand interactions between architecture and their software

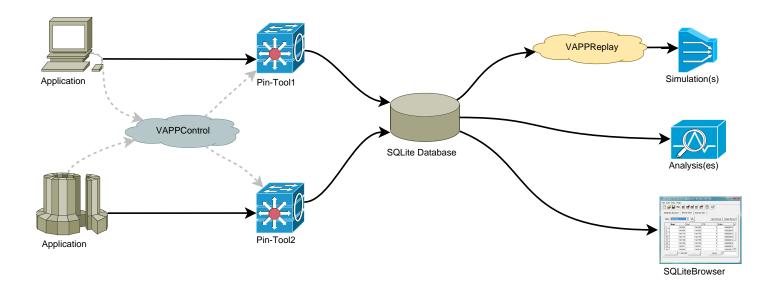
Goals

- Quickly simulate application execution over many architecture configurations
- Analyze and debug programs designed for parallel architecture
- Allow developers to view and query intermediate execution traces

Approach

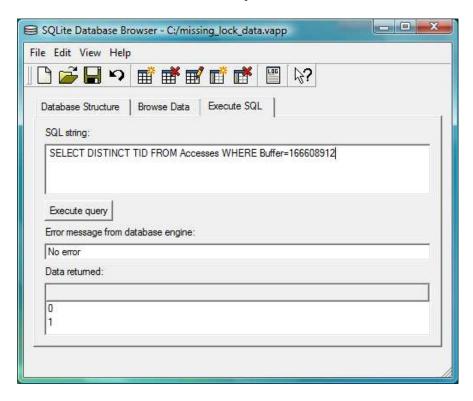
Software-based log-and-replay system

Design



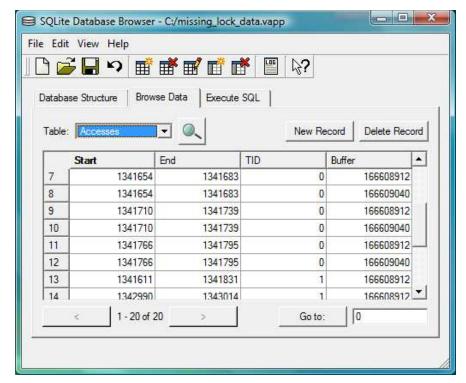
- Pin tools log memory accesses, function calls, image loads, locking, memory allocation, etc.
- SQLite database store execution trace
- Collection of replay and analysis programs take database as input
 - Replay execution on simulated hardware
 - Analyze memory access patterns
 - Lockset verification

SQLite Database



- Developer can easily examine all trace data
- SQLite Database Browser

Many types
 of custom
 analysis
 can be
 formulated
 using SQL



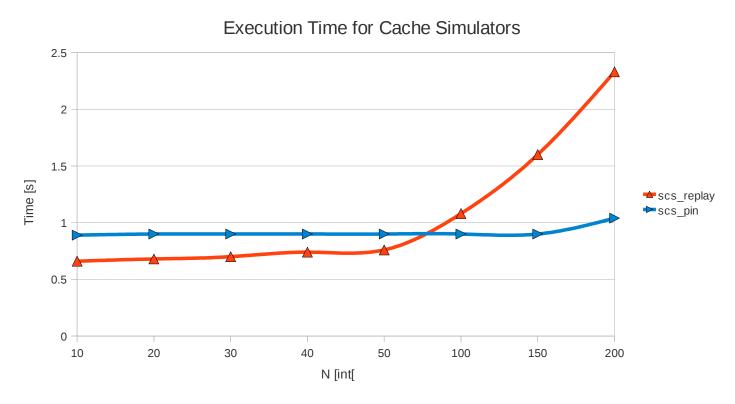
E.g. which threads access a particular memory buffer

Replay and Analysis

- Variety of analysis tools have been implemented on top of the database
- Cache simulator
 - Prototype of a complete memory hierarchy simulator
- Lockset algorithm
 - Detect which locks protect which memory buffers in a parallel program
 - Identify inconsistent locking patterns and unprotected accesses

Simulator Performance

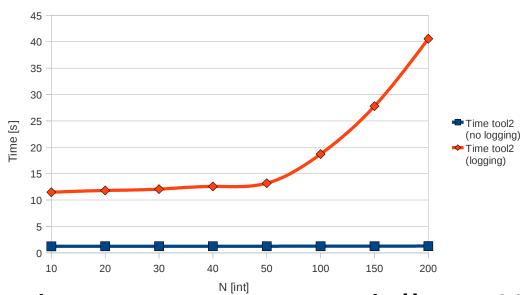
- Goal is to amortize cost of running instrumented code over many simulations
- Increase # loop iterations (N) in simple benchmark application



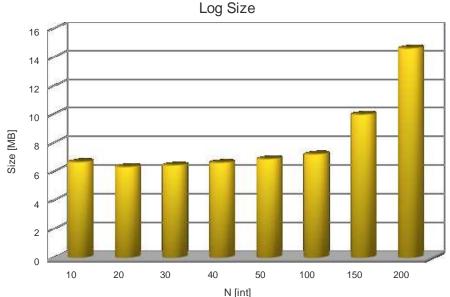
- In practice, prototype version is bogged down by I/O costs of database
- For large applications, running pure Pin versions is better (for now)

Logging Performance

 Writing logging information dominates execution time



 Log size grows exponentially as N increases



Allow application to dynamically enable/disable logging

Parallel Program Analysis

- Memory accesses in parallel programs tracked at buffer level
- Support pthreads and Open MP
- Discover unprotected accesses to shared memory
- Example:

```
int main(void)
                                                  int main(void)
  int *result = (int*)malloc(sizeof(int));
                                                    int *result = (int*)malloc(sizeof(int));
                                                    int value = 3;
  int value = 3;
                                                  #pragma omp parallel for
#pragma omp parallel for
                                                    for ( int i = 0 ; i < 100 ; i++ ) {</pre>
  for ( int i = 0 ; i < 100 ; i++ ) {</pre>
                                                      if ( i % value == 0) {
    if ( i % value == 0) {
                                                        #pragma omp critical
      if ( *result < i )
         *result = i;
                                                          if ( *result < i ) {
                                                             *result = i;
                                                   Thread 0 -> [11018256,11018288,11019872,11020080]>
                                                   Thread 0 -> [32243728,32243760,32245344,32245552]>
 Thread 1 -> [11018256,11018288,11019872]>
                                                   Thread 1 -> [32243728,32243760,32245344]>
 shared buffer 11018256
                                                   shared buffer 32243728
  t1 []
                                                     t1 [666]>
   t2 []
                                                     t2 [666]>
 shared buffer 11018288
                                                   shared buffer 32243760
  t1 []
                                                     t1 []
 shared buffer 11019872
                                                   shared buffer 32245344
   t1 []
                                                     t1 []
   t2 []
                                                     t2 []
```

result NOT protected

result **protected** by Internal Open MP lock

Future Work

- Implement trace compression
 - Will greatly reduce log size
 - Database I/O dominates execution time so performance will significantly improve
- Allow analysis of program behavior over multiple executions
- Track lock contention and feed information back to system
 - Recommend particular lock types
 - Pin memory that is used exclusively by one thread
- Use logged information to support deterministic replay