ECE 2400 Computer Systems Programming
Fall 2017

Topic 16: C++ Threads

School of Electrical and Computer Engineering
Cornell University

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Processing an Array

Sorting an Array

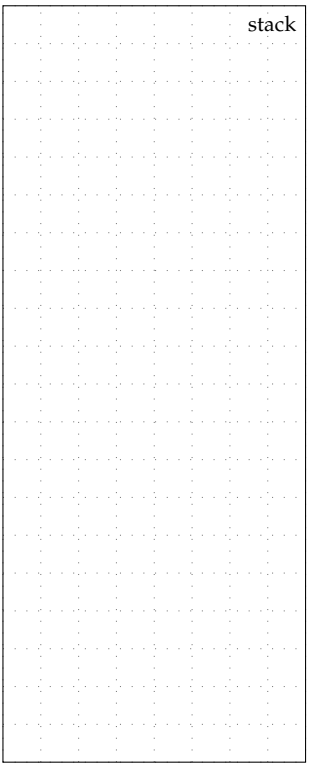
Graphical User Interface

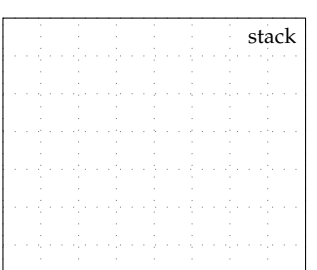
Database Transactions

1. Concurrency via Threads

```
1  #include <thread>
2
3  void avg( int* z_p, int x, int y )
4  {
5    int sum = x + y;
6    *z_p = sum / 2;
7  }
8
9  int main( void )
10 {
11   int a;
12   std::thread t( avg, &a, 5, 10 );
13
14   int b;
15   avg( &b, 10, 15 );
16
17   t.join();
18   return 0;
19 }
```

https://repl.it/@cbatten/4





Parallel Vector-Vector Add

```
#include <thread>

void vvadd( int dest[], int src0[], int src1[],
            size_t lo, size_t hi )
{
  for ( size_t i = lo; i < hi; i++ )
    dest[i] = src0[i] + src1[i];
}

int main( void )
{
  const int size = N;
  int src0[size] = { ... };
  int src1[size] = { ... };
  int dest[size];

  size_t middle = size/2;
  std::thread t( vvadd, dest, src0, src1, 0, middle );

  vvadd( dest, src0, src1, middle, size );

  t.join();
  return 0;
}
```

https://repl.it/@cbatten/3

Parallel Merge/Quick Sort

```
#include <thread>

int main( void )
{
  const int size = N;
  int arr[size] = { ... };

  size_t mid1 = 1*(size/4);
  size_t mid2 = 2*(size/4);
  size_t mid3 = 3*(size/4);

  // Sort each partition in parallel

  std::thread t0( qsort, arr, 0,    mid1 );
  std::thread t1( qsort, arr, mid1, mid2 );
  std::thread t2( qsort, arr, mid2, mid3 );

  qsort( arr, mid3, mid4 );

  t0.join(); t1.join(); t2.join();

  // Serial merge

  merge( arr, 0,    mid1, mid2 );
  merge( arr, mid2, mid3, size );
  merge( arr, 0,    mid2, size );
  return 0;
}
```

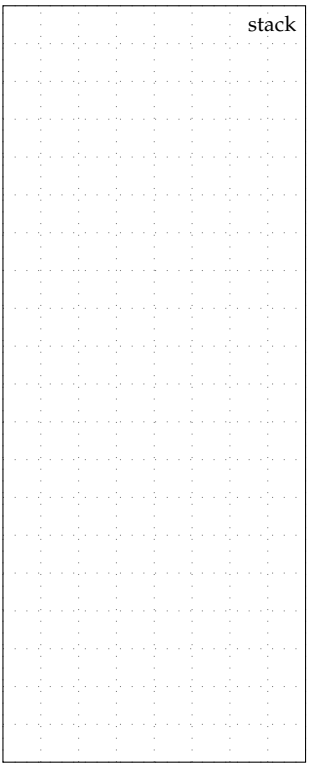
Complexity Analysis

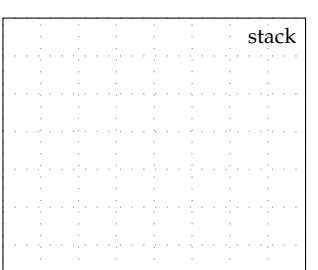
What is the execution time complexity as a function of N (size of array) and P (number of processors) using big-O notation?

2. Synchronization

```
1  #include <thread>
2
3  void incr( int* x_p )
4  {
5    int y = *x_p;
6    int z = y + 1;
7    *x_p  = z;
8  }
9
10 int main( void )
11 {
12   int a;
13   std::thread t( incr, &a );
14
15   incr( &a );
16
17   t.join();
18   return 0;
19 }
```

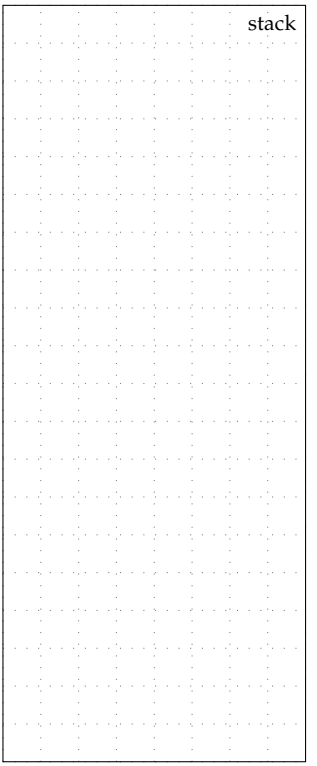
https://repl.it/@cbatten/6

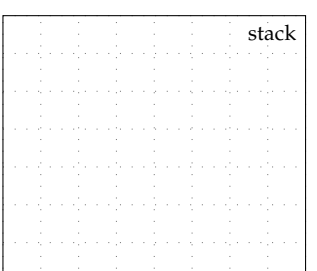




```
1  #include <thread>
2
3  void incr( int* x_p )
4  {
5    (*x_p)++;
6  }
7
8  int main( void )
9  {
10   int a;
11   std::thread t( incr, &a );
12
13   incr( &a );
14
15   t.join();
16   return 0;
17 }
```

https://godbolt.org/g/zXLFXE





Using atomic operations

```
#include <thread>
#include <atomic>

void incr( std::atomic<int>* x_p )
{
  (*x_p)++;
}

int main( void )
{
  std::atomic<int> a;
  std::thread t( incr, &a );

  incr( &a );

  t.join();
  return 0;
}
```

https://repl.it/@cbatten/9

https://godbolt.org/g/bBeRzh

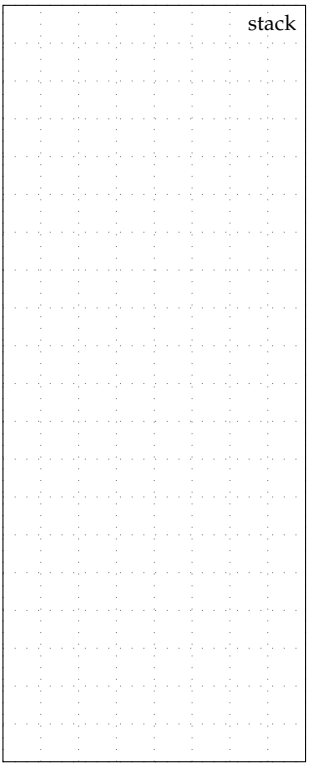
`std::atomic<T>` member functions

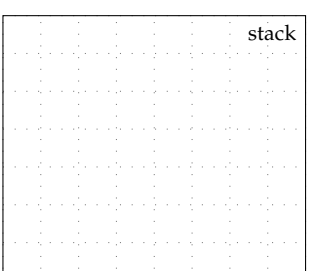
```
operator++
operator--
operator+=
operator-=
operator&=
operator|=
operator^=
```

```
fetch_add
fetch_sub
fetch_and
fetch_or
fetch_xor
```

```
1  void incr( int* x_p,
2             std::atomic<int>* y_p )
3  {
4    // acquire lock
5    while ( y_p->fetch_or(1) == 1 )
6    { }
7
8    *x_p = foo(*x_p);
9
10   // release lock
11   *y_p = 0;
12 }
13
14 int main( void )
15 {
16   int a = 0;
17   std::atomic<int> b;
18
19   std::thread t( incr, &a, &b );
20
21   incr( &a, &b );
22
23   t.join();
24   return 0;
25 }
```

https://repl.it/@cbatten/10





Encapsulate lock into a mutex

```
1  class Mutex
2  {
3   public:
4    Mutex() : m_lock(0) { }
5
6    void lock()
7    {
8      while ( m_lock.fetch_or(1) == 1 ) { }
9    }
10
11   void unlock() { m_lock = 0; }
12  private:
13   std::atomic<int> m_lock;
14 };
15
16 void incr( int* x_p, Mutex* m_p )
17 {
18   m_p->lock();
19   std::cout << "start ..." << std::endl;
20   *x_p = foo(*x_p);
21   std::cout << "stop ..." << std::endl;
22   m_p->unlock();
23 }
24
25 int main( void )
26 {
27   int a = 0;
28   Mutex m;
29   std::thread t( incr, &a, &m );
30   incr( &a, &m );
31   t.join();
32   return 0;
33 }
```

https://repl.it/@cbatten/11

RAII: Resource Acquisition is Initialization

- What if we forget to unlock mutex?
- What if there is an exception?
- RAII ties resources to object lifetime

```
1  class LockGuard
2  {
3    public:
4
5     LockGuard( Mutex* m )
6      : m_mutex_p(m)
7     {
8       m_mutex_p->lock();
9     }
10
11    ~LockGuard()
12    {
13      m_mutex_p->unlock();
14    }
15
16   private:
17    Mutex* m_mutex_p;
18 };
19
20 void incr( int* x_p, Mutex* m_p )
21 {
22   LockGuard guard(m_p);
23
24   std::cout << "start ..." << std::endl;
25   *x_p = foo(*x_p);
26   std::cout << "stop ..." << std::endl;
27 }
```

https://repl.it/@cbatten/12