Qt Concurrency

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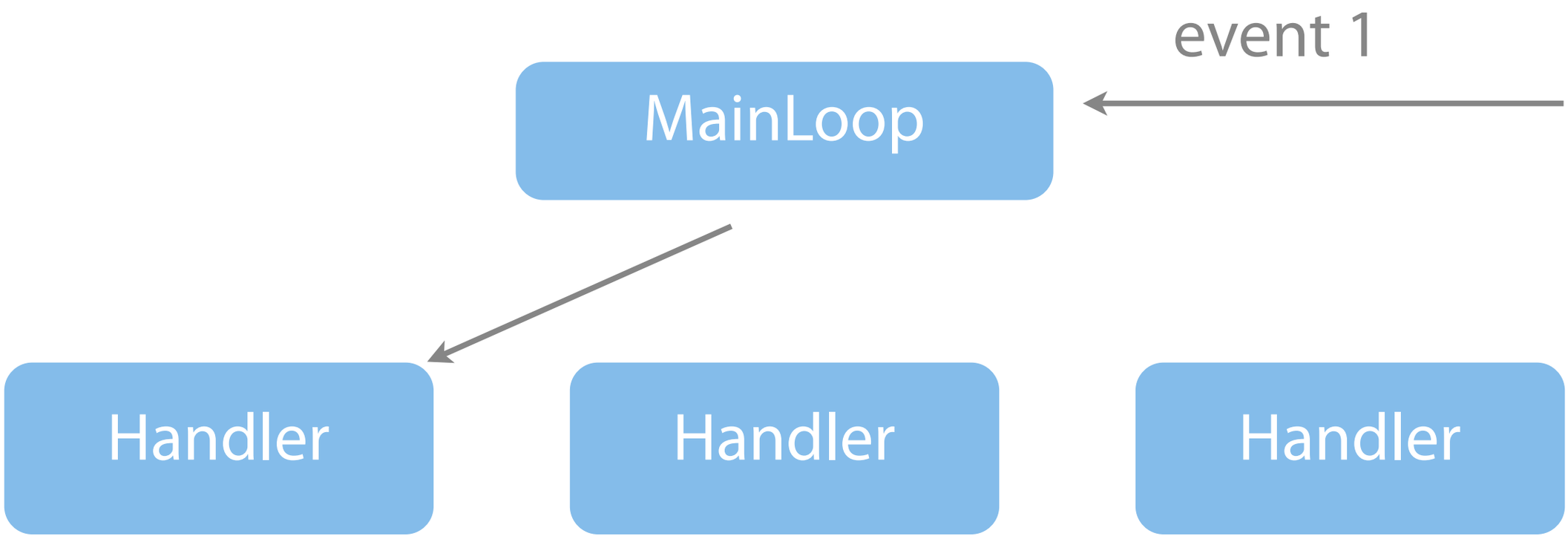
Agenda

- Doing things simultaneously
- Using the event loop
- Using threads
- Using QtConcurrent algorithms

The Event Loop



You're Already Doing It

- Network code runs in parallel
- Timers

Unfortunately …

- DB queries block
- Disk operations block
- CPU operations block

Latency Is The Enemy

What We Need

- Run something “in the background”
  - A single task
  - A worker thread
  - A full algorithm
  - Another application

Single Task

QThread
QThreadPool
QRunnable
Thread Synchronization

Threads Theory

- Define tasks by extending `QRunnable`
- Use `QThreadsPool` to run them

Demo Runnable

```
class MyTask : public QRunnable
{
    virtual void run()
    {
        for ( int i=0; i < 10; i++ )
        {
            qDebug() << "[" <<
                        QThread::currentThreadId() <<
                        "]" <<
                        " " <<
                        i;
        }
    }
};
```

Using The Thread Pool

```
QCoreApplication a(argc, argv);
MyTask *t1 = new MyTask;

QThreadPool p;
p.start(t1);

p.waitForDone();
```

Thread Pool Notes

- `start()` takes ownership of the runnable. It will be deleted when done
- Number of threads matches number of CPU cores
- `waitForDone()` stops the event loop. Be careful with that one

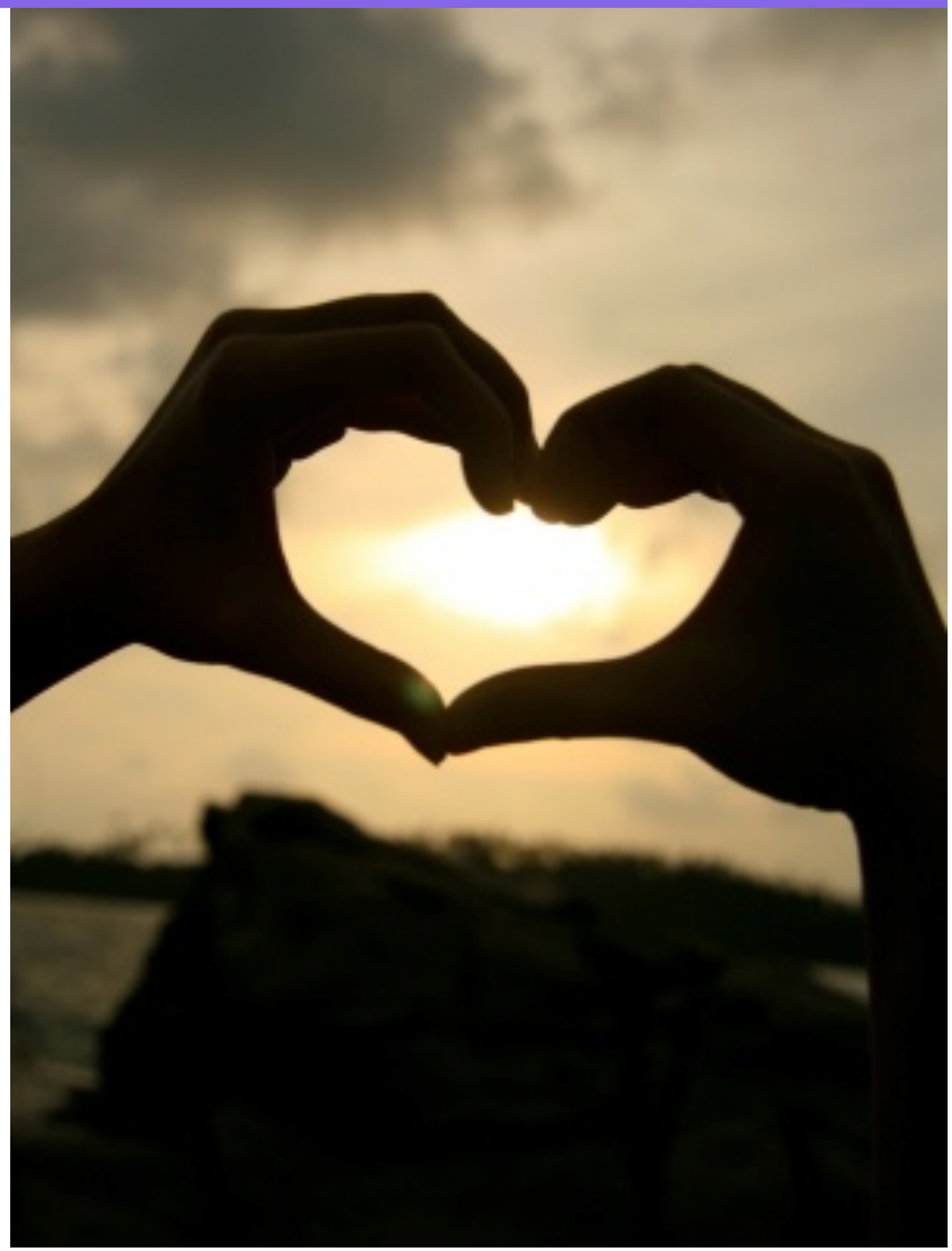
Yielding

- If you feel your thread has worked hard enough, rest with:

```
QThread::yieldCurrentThread();
```

Sharing

- Cool in real life
- Uncool for threads



Sharing Problems

- Shared resources can be manipulated from other threads
- Even when you're in the middle

Sharing Problems

Can you use the code below from multiple threads ?

Why ?

```
class Counter
{
public:
    Counter() { n = 0; }

    void increment() { ++n; }
    void decrement() { --n; }
    int value() const { return n; }

private:
    int n;
};
```

Sharing Problems

- Most Qt and C++ code is re-entrant
- It means you can’t access same instance from different threads at the same time

Quiz

- Assume m_text is a QStringList
- Can you use the code from multiple threads ? Why ?

```
virtual void run()
{
    m_text.append(m_a);
    for ( int i=0; i < 100; i++ )
    {
        if ( m_text.last() == m_a )
        {
            m_text.append(m_b);
        }
        else
        {
            m_text.append(m_a);
        }
    }
}
```

Thread Safety

- Code is marked thread-safe if it's ok to use it from multiple threads, on the same instance.
- Thread-safe code manages data access

Other Considerations

- When locking threads, you lose concurrency
- Previous example was better written by:
  - Separating the problem to sections
  - Solving each section in a thread

Locking Options

- QMutex
- QSemaphore
- QReadWriteLock
- QWaitCondition

QMutex

- Only one thread can “hold” a mutex
- Others wait till done
- Like the java’s `synchronized` keyword

QMutex Demo

- Consider the two methods on the right
- If called from multiple threads, they'll break

```
int number = 6;

void method1()
{
    number *= 5;
    number /= 4;
}

void method2()
{
    number *= 3;
    number /= 2;
}
```

QMutex Demo

- But the mutex changes everything
- Now method2 has to wait for method1 to finish

```
QMutex mutex;
int number = 6;

void method1()
{
    mutex.lock();
    number *= 5;
    number /= 4;
    mutex.unlock();
}

void method2()
{
    mutex.lock();
    number *= 3;
    number /= 2;
    mutex.unlock();
}
```

Deadlocks

- Forgetting to unlock a mutex creates deadlocks
- Unlocking in a wrong order creates deadlocks

QMutexLocker

With QMutexLocker, you'll never forget to unlock your mutex

```
virtual void run()
{
    QMutexLocker l(&mutex);
    num = 6;
    m1();
    m2();
    qDebug() << QThread::currentThreadId() << ") n = " << num;
}
```

Q & A

Lab

- Modify Counter code so it is thread safe

QReadWriteLock

- Multiple reads, single write
- Prevents starvation

Demo

- Write a QRunnable class to run the following code
- Did you segfault ? Good, now fix it

```
virtual void run()
{
    if ( m_writer )
    {
        m_list << QString::number(qrand());
    }
    else
    {
        qDebug() << m_list;
    }
}
```

QReadWriteLock vs. QMutex

- Use QReadWriteLock when you have many readers and few writers
- For other cases, mutex is sufficient

QSemaphore

- Producer-Consumer problem
- One producer, multiple consumers

QSemaphore

- A general counting semaphore
- Methods:
  - acquire(n)
  - release(n)

Demo Code

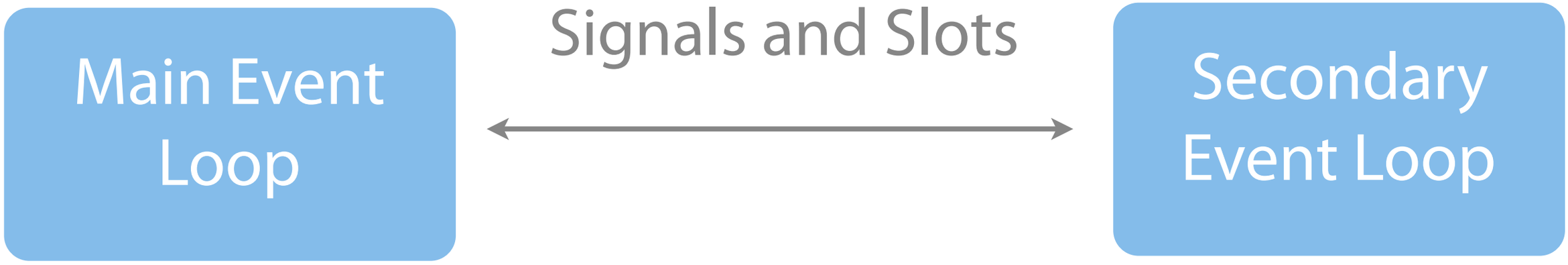
```
QSemaphore sem(5);          // sem.available() == 5

sem.acquire(3);             // sem.available() == 2
sem.acquire(2);             // sem.available() == 0
sem.release(5);             // sem.available() == 5
sem.release(5);             // sem.available() == 10

sem.tryAcquire(1);          // sem.available() == 9, returns true
sem.tryAcquire(250);        // sem.available() == 9, returns false
```

Locking Alternatives

- Locking mechanisms are used to sync with worker threads
- Some alternatives:
  - Using QtConcurrent algorithms

Q & A

Qt Style Worker Thread



The Code

- Create a worker thread as a normal QObject
- Move it to another thread
- Start the thread's event loop

```
MyWorker w;
QThread t;
w.moveToThread(&t);
t.start();
```

Why Is It Awesome

- Write code with normal signals and slots
- Make it multi-threaded when needed
- Almost no change

Under The Hood

- QObject::connect uses a message queue to call slots in other threads

Lab

- Write a GUI app that displays an image
- Use QFileDialog to choose image file
- Read image file from a worker thread

Concurrent Algorithms

Concurrent Algorithms

- Algorithms on collections can make use of concurrent primitives
- Qt provides:
  - map
  - filter
  - reduce

Let's Start With A Demo

```
int main(int argc, char *argv[])
{
    QCoreApplication a(argc, argv);
    QList<long> seq;
    QTime t1,t2;

    for (long i=2; i < 100000; i++ ) seq << i;

    t1.start();
    QtConcurrent::blockingFiltered(seq, isPrime);
    qDebug("Time elapsed (Multi): %d ms", t1.elapsed());

    t2.start();
    foreach ( long n, seq ) isPrime(n);
    qDebug("Time elapsed (Single): %d ms", t2.elapsed());


    return 0;
}
```

Results

```
Time elapsed (Multi):  1433 ms
Time elapsed (Single): 3408 ms
```

The Good Parts

- Easily implement algorithms on collections
- Avoid common mistakes
- No need to synchronize threads

Other Primitives

- map applies a function to each item in the collection, returning a list of the results
- mappedReduced does map and reduces the result

Other Primitives

- filter applies a function on each item in the collection, returning a list of the "true" ones
- filteredReduced does the same, and also reduces to a single result

Progress Indication

- Algorithms return QFuture object
- Use QFutureWatcher to add signals and slots

Demo Code

```
QFutureWatcher<long> w;
ProgressReporter p;

w.setFuture(QtConcurrent::filtered(seq, isPrime));

QObject::connect(&w, SIGNAL(progressRangeChanged(int,int)),
                 &p, SLOT(progressRangeChanged(int,int)));
QObject::connect(&w, SIGNAL(progressValueChanged(int)),
                 &p, SLOT(progressValueChanged(int)));
```

Progress Notes

- QFutureWatcher is templated to the type of the list
- Progressive filling is possible with:
  - `resultReadyAt(int)`
  - `resultsReadyAt(int,int)`
- Best gain: no latency

Q & A

Concurrency Takeaways

- Use worker threads for IO
- Use QtConcurrent for algorithms
- Latency is the enemy

Lab

- Move our prime number detection code to a GUI app
- User selects range, and the application prints all prime numbers in range
- Try with and without QtConcurrent

Online Resources

- http://qt-project.org/doc/qt-5.0/qtcore/thread-basics.html
- http://www.greenteapress.com/semaphores/
- http://qt-project.org/videos/watch/threaded_programming_with_qt

Thanks For Listening

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