1.6.2 C++ Class *Thread* for Pthreads

Listing 1.7 shows C++ classes *Runnable* and *Thread* for Pthreads.

- Method `run()` can return a value.
- A call to `T.join()` blocks the caller until thread T’s `run()` method completes. Method `join()` returns the value that was returned by `run()`.
- Class *Runnable* simulates Java’s *Runnable* interface.
- C++ *Threads* can be created on the heap or on the stack. (Java *Thread* objects, like other Java objects, are never created on the stack.)
- Java has a built-in `join()` operation that is useful in Java when one thread needs to make sure that other threads have completed before, say, accessing their results.
  
  Java’s `run()` method cannot return a value so results must be obtained some other way.

Listing 1.7 shows C++ classes *Runnable* and *Thread* for Pthreads.

The program in Listing 1.6 illustrates the use of C++ classes *Thread* and *Runnable*. It is designed to look like the Java programs in Listings 1-1 and 1-2.
class Runnable {
public:
    virtual void* run() = 0;
    virtual ~Runnable() = 0;
};
Runnable::~Runnable() {} // a function body is required for pure virtual destructors

class Thread {
public:
    Thread(auto_ptr<Runnable> runnable_, bool isDetached = false);
    Thread(bool isDetached = false);
    virtual ~Thread();
    void start(); void* join();
private:
    pthread_t PthreadThreadID; // thread ID
    bool detached; // true if thread created in detached state; false otherwise
    pthread_attr_t threadAttribute;
    auto_ptr<Runnable> runnable;
    Thread(const Thread&);
    const Thread& operator=(const Thread&);
    void setCompleted();
    void* result; // stores return value of run()
    virtual void* run() {} // a function body is required for pure virtual functions
    static void* startThreadRunnable(void* pVoid);
    static void* startThread(void* pVoid);
    void PrintError(char* msg, int status, char* fileName, int lineNumber);
};

Listing 1.7 C++/Pthreads classes Runnable and Thread.
class simpleRunnable: public Runnable {
public:
    simpleRunnable(int ID) : myID(ID) {}  
    virtual void* run() {
        std::cout << "Thread " << myID << " is running" << std::endl;
        return reinterpret_cast<void*>(myID);
    }
private:
    int myID;
};

class simpleThread: public Thread {
public:
    simpleThread (int ID) : myID(ID) {}  
    virtual void* run() {
        std::cout << "Thread " << myID << " is running" << std::endl;
        return reinterpret_cast<void*>(myID);
    }
private:
    int myID;
};

int main() {
    std::auto_ptr<Runnable> r(new simpleRunnable(1));
    std::auto_ptr<Thread> thread1(new Thread(r));
    thread1->start();
    std::auto_ptr<simpleThread> thread2(new simpleThread(2));
    thread2->start();
    simpleThread thread3(3);
    thread3.start();
    // thread1 and thread2 are created on the heap; thread3 is created on the stack

    int result1 = reinterpret_cast<int>(thread1->join()); // wait for the threads to finish
    int result2 = reinterpret_cast<int>(thread2->join());
    int result3 = reinterpret_cast<int>(thread3.join());

    std::cout << result1 << ' ' << result2 << ' ' << result3 << std::endl;
    return 0;
    // the destructors for thread1 and thread2 will automatically delete the
    // pointed-at thread objects
}

Listing 1.6 Using C++ classes Runnable and Thread.
Thread::Thread(auto_ptr<Runnable> runnable_, bool isDetached) :
  runnable(runnable_), detached(isDetached)
  if (runnable.get() == NULL) {
    std::cout << "Thread::Thread(auto_ptr<Runnable> runnable_,
      bool isDetached) failed at " " " << __FILE__ " " << __LINE__ " " << " runnable is NULL " << std::endl; exit(-1);
  }
}

Thread::Thread(bool isDetached) : runnable(NULL), detached(isDetached) {} void* Thread::startThreadRunnable(void* pVoid) {
  // thread start function when a Runnable is involved
  Thread* runnableThread = static_cast<Thread*> (pVoid);
  assert(runnableThread);
  runnableThread->result = runnableThread->runnable->run();
  runnableThread->setCompleted();
  return runnableThread->result;
}

void* Thread::startThread(void* pVoid) {
  // thread start function when no Runnable is involved
  Thread* aThread = static_cast<Thread*> (pVoid);
  assert(aThread);
  aThread->result = aThread->run(); aThread->setCompleted();
  return aThread->result;
}

Thread::~Thread() {}

void Thread::join() {
  int status = pthread_join(PthreadThreadID,NULL);
  // result was already saved by thread start functions
  if (status != 0) { PrintError(...); exit(status); }
}

void Thread::setCompleted() /* completion was handled by pthread_join() */

void Thread::PrintError(char* msg, int status, char* fileName, int lineNumber) { /*see Listing 1.4*/

Listing 1.7 (cont.) C++/Pthreads classes Runnable and Thread.
void Thread::start() {
    int status = pthread_attr_init(&threadAttribute); // initialize attribute object
    if (status != 0) { PrintError(…); exit(status); }
    status = pthread_attr_setscope(&threadAttribute, PTHREAD_SCOPE_SYSTEM);
    if (status != 0) { PrintError(…); exit(status); }
    if (!detached) {
        if (runnable.get() == NULL) {
            int status = pthread_create(&PthreadThreadID,&threadAttribute,
            Thread::startThread,(void*) this);
            if (status != 0) { PrintError(…); exit(status); }
        } else {
            int status = pthread_create(&PthreadThreadID,&threadAttribute,
            Thread::startThreadRunnable, (void*)this);
            if (status != 0) {PrintError(…); exit(status); }
        }
    } else {
        // set the detachstate attribute to detached
        status = pthread_attr_setdetachstate(&threadAttribute,
        PTHREAD_CREATE_DETACHED);
        if (status != 0) {
            PrintError(…);exit(status);
        }
        if (runnable.get() == NULL) {
            status = pthread_create(&PthreadThreadID,&threadAttribute,
            Thread::startThread,(void*) this);
            if (status != 0) {PrintError(…);exit(status); }
        }
        else {
            status = pthread_create(&PthreadThreadID,&threadAttribute,
            Thread::startThreadRunnable, (void*) this);
            if (status != 0) {PrintError(…); exit(status); }
        }
    }
    status = pthread_attr_destroy(&threadAttribute);
    if (status != 0) { PrintError(…); exit(status); }
}

Listing 1.7 (cont.) C++/Pthreads classes Runnable and Thread.
When method start() is called, function pthread_create() is called with the following arguments:

- &PthreadThreadID: the address of the memory location that will receive an identifier assigned to the thread if creation is successful.
- &threadAttribute: This address of the thread attribute variable
- The third argument is either Thread::startThread() or Thread::startThreadRunnable(). Method startThread() is the startup method for threads created by inheriting from class Thread. Method startThreadRunnable() is the startup method for threads created from Runnable objects.
- (void*) this: The fourth argument is a pointer to this Thread object, which is passed through to method startThread() or startThreadRunnable(). Thus, all threads execute one of the startup methods, but the startup methods receive a different Thread pointer each time they are executed.

Method startThread() casts its void* pointer parameter to Thread* and then calls the run() method of its Thread* parameter.

- When the run() method returns, startThread() calls setCompleted() to set the thread’s status to completed and to notify any threads waiting in join() that the thread has completed.
- The return value of the run() method is saved so that it can be retrieved in method join().

Static method startThreadRunnable() performs similar steps when threads are created from Runnable objects. Method startThreadRunnable() calls the run() method of the Runnable object held by its Thread* parameter and then calls setCompleted().

In Listing 1.6, we use auto_ptr<> objects to manage the destruction of two of the threads and the Runnable object r.
- When `auto_ptr<>` objects `thread1` and `thread2` are automatically destroyed at the end of the program, their destructors will automatically invoke delete on the pointers with which they were initialized.
- This is true no matter whether the `main` function exits normally or by means of an exception.

Note that startup functions `startThreadRunnable()` and `startThread()` are static member functions.

Note also that calls to method `join()` are simply passed through to method `pthread_join().`