C++ Multithreading

Spring 2015

CSC 462

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lecture:	CDM 222, Monday 5:45-9:00pm
Desired to Learn (D2L):	d2l.depaul.edu (Grades, Viewing lectures, Announcements)
Version Control:	perforce: ***140.192.39.61:1666***

Description

Software architecture of applied C++ concurrency and multithreading fundamentals. Basics threading concepts: process model, threads, stacks, fibers, mutexes, semaphores, atomics and events. Leveraging advanced C++ language features relating to the memory model and the threading support in large multithreaded architectures. Architecting lock-based and lock-free concurrent data structures in applications. Designing a threaded management system to control the access and reuse of threads in applications. Designing multithread architecture for real-time performance.

Prerequisites

- GAM 471 - Optimized C++ or CSC 461 Optimized C++
  - Implies CSC 403 & CSC 407

Reference Material

- **C++ Concurrency in Action: Practical Multithreading**, 2012 by Athony Williams
- **Windows System Programming** (4th Edition), 2010, Johnson Hart, ISBN: 978-0321657749
- **The C++ Programming Language, 4th Edition** - Bjarne Stroustrup

Learning Objectives

- Students will be able to demonstrate basic thread knowledge (threads, mutexes, semaphores, atomics, events)
- Students will be able to optimally design applications to minimize stalls due to thread waits and dependencies.
- Students will be able to design a thread management system to control the access and lifecycles of threads in an application.
- Students will design multithreaded applications to improve its run-time performance and resource usage.

Grading

- 20 % - Simplified Threading program
  - Program using basic multithreading primitives
    - Several fixed threads, Mutexes, Callbacks, Critical Sections
- 30 % - Conversion problem
  - Puzzle program or something similar
    - Converting a single thread system into multiple threaded solution
- 30% - Managing multiple thread in pools
  - Creating a threading pool system.
    - Manage and control thread execution and priorities.
  - Spawning multithreaded program
    - Creating a dynamically spawning application of autonomous agents
    - Design and implemented using the thread pool system
- 10% - Research paper on Multithreading 3-5 page ACM formatted research paper
  - Several citations on multithreading.
  - Topics on specific types of multithreading such as:
    - Multiple sequence,
    - fine-grain MT (FGMT),
    - coarse-grain MT (CGMT),
    - implicit MT (IMT)
    - dynamic MT (DMT)
- 10 % - Final Exam

Software

- ***Microsoft Visual Studio 2012 (ultimate edition - Recommended)***
  - DePaul MSDNAA link Microsoft_Visual_Studio_Ultimate_2012
  - C# and C++ install (future classes)
  - Microsoft Visual Studio 2013 is not used in this class.
- Perforce - Visual Client (p4v)
  - www.perforce.com
- Download and configuration instructions will be provided in class
  - Server address: ***140.192.39.61:1666***

Research Paper – 10%

- Read the material from the class reference books and external materials
  - journals, white papers, technology specifications
- Write a 3-5 page ACM formatted researchpaper
  - Several citations on multithreading.
  - Topics on specific types of multithreading such as:
    - Multiple sequence,
    - fine-grain MT (FGMT),
    - coarse-grain MT (CGMT),
    - implicit MT (IMT)
    - dynamic MT (DMT)

Topics:

Understanding the multi-threading primitives / basic concepts

- Managing Threads
- Sharing Data between Threads
- Synchronizing concurrent operations
- C++ Memory Model
- Lock-based current data structures
- Lock Free concurrent data structures

Design Software

- Dividing work between threads
- Thread Management
- Debugging
- Testing
- C++ 11 Language Features

Primitives

- Threads
- Fibers
- Atomics
- Mutexes
- Semaphores
- Events

Phase 1 : Basics

- ***Programming Assignment***
  - (20%) PA1: **Simplified Threading program**
    - Program using basic multithreading primitives
      - Several fixed threads, Mutexes, Callbacks, Critical Sections
  - Book Demos
    - Sample code from book: Submitted to Perforce with commentary
- Week 1
  - Introduction to Concurrency
  - Launching a thread
  - Waiting for a thread to complete
  - Passing arguments to a thread
  - Transferring ownership of a thread
- Week 2
  - Sharing Data between thread
  - Race conditions
  - Protecting shared data with mutexes
  - Deadlocks
  - Flexible locking (C++ specifics)
  - Transferring mutex ownership
  - Recursive locking

- Week 3
  - Synchronization concurrent operations
  - Building a thread-safe queue
  - Waiting for an event or other condition
  - Waiting for one-off events with futures
  - Return from background tasks, promise - future
  - Waiting with a time limit
  - Clocks, Timepoints
- Week 4
  - C++ memory model
  - Atomic Types in C++
  - Synchronizing operations and enforcing ordering using Atomics
  - Fences

Phase 2: Refactoring existing solutions

- ***Programming Assignment***
  - (30%) PA2: Conversion problem
    - Converting a single thread system into multiple threaded solution
      - Example problems:
        - NxN sliding puzzle
        - Maze program
  - Book Demos
    - Sample code from book: Submitted to Perforce with commentary
- Week 5
  - Lock-based concurrent data structures
  - A thread-safe stack using locks
  - A thread-safe queue using locks and condition variables
  - A thread-safe queue using fine-grained locks and condition variable
  - Writing a thread-safe list using locks
- Week 6
  - Designing lock-free concurrent data structures
  - Non blocking data structures
  - Lock-free data structures
  - Writing a thread-safe stack without locks
  - ABA problem
- Week 7
  - Designing concurrent code
  - dividing work between threads
  - Dividing work by task
  - performance of concurrent code
  - Oversubscription and excessive task switching
  - Hiding latency with multiple threads
  - Improving responsiveness with concurrency

Phase 3: Threading system / management

- ***Programming Assignment***
  - (30%) PA3: Managing multiple thread in pools
    - Creating a threading pool system.
      - Manage and control thread execution and priorities.
    - Spawning multithreaded program
      - Creating a dynamically spawning application of autonomous agents
      - Design and implemented using the thread pool system
    - Examples:
      - **Interactive spawning / dispatch / threading system**
        - Genetic bug spawn / growth / death - Gui application
        - or Desktop Tower Defense
  - Book Demos
    - Sample code from book: Submitted to Perforce with commentary
- Week 8
  - Advanced thread management
  - Thread pools
  - Interrupting threads
  - Launching and interrupting another thread
  - Detecting that a thread has been interrupted
  - Interrupting other blocking calls
- Week 9
  - Debugging multithreaded applications
  - Types of concurrency-related bugs
  - Race conditions
  - Unwanted blocking
  - Locating concurrency-related bugs by testing
- Week 10
  - Performance tuning
  - Contest

Final Exam (10%)

Final exam covering the concepts and the material of the class

- In class exam
- Multithreading concepts
- Diagramming communication between threads
- Applied problems

Perforce Submissions

- Everyone is expected to submit at least 10 submissions a week to perforce.
- The biggest reason students get into trouble with software design:
    - Not working on the material frequently enough
    - Taking too large of a bite of the design
- Both are fixed with this *Perforce RULE*
- Even my simplest programs take 10-20 submissions.
    - For these project assignments my average is 40-400 submissions, so 10 will be no problem.
- Detailed perforce changelist comments are expected

Piazza Discussion forum

- Statistics show: students who participate more and help other students do better!
    - The correlation is ridiculous!
        - Poor understanding / poor participation.
        - Great understanding / Great participation
    - As you master the material, help others learn!
        - You're in the master's program so master it!
- Everyone is ***expected*** and encouraged to participate on the Piazza discussion forum. All class-related discussion here this term.
- The quicker you begin asking questions on Piazza (rather than via emails), the quicker you'll benefit from the collective knowledge of your classmates and instructors. I encourage you to ask questions when you're struggling to understand a concept.
- All correspondence that is not personal in nature should be vectored through Piazza
- Sensitive material, use Piazza private note, not email.
- Keep the forum professional and positive, help each other out.
    - Karma really pays off here.
    - Help each other whenever you can.
        - There will be a section where you'll need help (trust me).

NOTE: Do ***NOT*** post until you have watched the entire lecture ***FIRST*** (in class or online)
This will prevent frustration on all sides (members asking or answering questions)

Collaborating together on programming assignments

- You are encourage to work together
  - Use the Piazza forums heavy
  - Even share your material with others in the common directory
- Everyone is 100% responsible for the work they do.
  - If you get help with a section of code,
  - Please refactor the code the ***snot out of it***
    - Comment and understand that material
    - Transform the code to ***make it yours***
  - Be able to answer ***any*** question regarding the code you commit
- System for Detecting Software Plagiarism
  - We will be using MOSS - Measure of Software Similarity (Standford University)
    - Indicates possible code infringements (plagiarism)
    - MOSS - will detect the similarity independent of naming convention, indentation style or formatting, it compares abstract syntax tree of your code.
- If you gain significant support / help from another student
  - Fully disclose the support / help you had in a Readme.txt file submitted with your assignments.
    - Disclosing the help, is ***not permission*** for copying the code.
    - Only there to clarify and acknowledge help you were given from a fellow student.
- Modifying any Unit Test to alter the outcome results is also an ***Academic Integrity Violation***
- If you are stuck and find yourself even tempted to plagiarize
  - Ask for help !!!!
    - Use on Piazza -> Visit during offices hours, make an appointment
  - ***Don't ever compromise your integrity!***

Schedule:

Week	Lecture	Work
1	Overview C++ 11 Review Thread Creation	Chapter 1-2 PA1 - assignment
2	Sharing Data Deadlocks Mutex	Chapter 3
3	Synchronization Waiting for Events Clocks	Chapter 4
4	C++ Memory Model Atomic Types Fences	Chapter 5
5	Lock-Base concurrent structures Thread-safe Queues **PA1 - due before class**	Chapter6 PA2 - assignment
6	Lock-Free concurrent structures Non-Blocking ABA problem	Chapter 7
7	Dividing work between threads Oversubscription excessive switching Improving responsiveness	Chapter 8
8	Thread Pools Interrupting Threads Blocking calls **PA2 - due before class**	Chapter 9 PA3 - assignment
9	Debugging multithreading Race conditions Unwanted blocking	Chapter 10
10	Performance tuning Contest	
11	**Final Exam** **PA3 - due before exam** **Research Paper - due before exam**	

April 3, 2015	Last day to add classes to SQ2015 schedule
April 10, 2015	Last day to drop classes with no penalty, Last day to select pass/fail option
April 11, 2015	Grades of "W" assigned for SQ2015 classes dropped on or after this day
April 18, 2015	Last day to select auditor status
May 15, 2015	Last day to withdraw from SQ2015 classes

Course Policies

Changes to Syllabus

This syllabus is subject to change as necessary during the quarter. If a change occurs, it will be thoroughly addressed during class, posted under Announcements in D2L and sent via email.

Online Course Evaluations

Evaluations are a way for students to provide valuable feedback regarding their instructor and the course. Detailed feedback will enable the instructor to continuously tailor teaching methods and course content to meet the learning goals of the course and the academic needs of the students. They are a requirement of the course and are key to continue to provide you with the highest quality of teaching. The evaluations are anonymous; the instructor and administration do not track who entered what responses. A program is used to check if the student completed the evaluations, but the evaluation is completely separate from the student's identity. Since 100% participation is our goal, students are sent periodic reminders over three weeks. Students do not receive reminders once they complete the evaluation. Students complete the evaluation online in CampusConnect.

Academic Integrity and Plagiarism

This course will be subject to the university's academic integrity policy. More information can be found at http://academicintegrity.depaul.edu/. If you have any questions be sure to consult with your professor.

Academic Policies

All students are required to manage their class schedules each term in accordance with the deadlines for enrolling and withdrawing as indicated in the University Academic Calendar. Information on enrollment, withdrawal, grading and incompletes can be found at: cdm.depaul.edu/enrollment.

Students with Disabilities

Students who feel they may need an accommodation based on the impact of a disability should contact the instructor privately to discuss their specific needs. All discussions will remain confidential.
To ensure that you receive the most appropriate accommodation based on your needs, contact the instructor as early as possible in the quarter (preferably within the first week of class), and make sure that you have contacted the Center for Students with Disabilities (CSD) at: csd@depaul.edu.

Lewis Center 1420, 25 East Jackson Blvd.
Phone number: (312)362-8002
Fax: (312)362-6544
TTY: (773)325.7296

Retroactive withdrawal

This policy exists to assist students for whom extenuating circumstances prevented them from meeting the withdrawal deadline. During their college career students may be allowed one medical/personal administrative withdrawal and one college office administrative withdrawal, each for one or more courses in a single term. Repeated requests will not be considered. Submitting an appeal for retroactive withdrawal does not guarantee approval. Information on enrollment, withdrawal, grading and incompletes can be found at: http://www.cdm.depaul.edu/Enrollment-Policies.aspx