CS 721 Real-Time and Embedded Systems

University of Nevada, Las Vegas

Instructor:

Name:
Email:
Office address:
Office hours:

Course Description:

Graduate Bulletin Description:

Operating system design for real-time and embedded systems. Focus on scheduling, synchronization, communication, and process and memory management for time-critical and resource-constrained applications.

Section-Specific Description:

Real-time embedded systems have become an integral component in daily human activities such as transportation, communication, entertainment, and medicine. As an example, consider an actual implementation of an avionic control system of a helicopter: the computer control system must periodically sample the pilot's commands, perform required computation, and make mechanical adjustments every 1/40 of a second. If an adjustment, computation, or command does not complete within the approximately 25 millisecond interval, the flight control response of the helicopter will degrade (and, in the worst-case the failure will result in a crash). In such a real-time system, each computation has associated temporal constraints (e.g., each command computation must successfully complete execution on the system by a hard deadline every 25 milliseconds). Along with restrictive temporal constraints, many embedded systems operate in settings with limited available physical space and power. These physical limits severely constrain the processing speed, memory space, and other resources available to applications executing upon an embedded system and present difficult system design challenges.

In this course, we will study issues relevant to operating system design and analysis for real-time and embedded systems. We will focus on scheduling, synchronization, communication, and process and memory management for time-critical and resource- constrained applications. After the course, you should understand basic and fundamental concepts in analysis and operating system design for real-time and embedded systems and have a foundation to understand and critique current research in real-time and embedded systems.

Credit Hours:

3 credit hours (Lecture)

Prerequisites:

CS 370 Operating Systems or equivalent. A basic background in undergraduate discrete math, algorithm analysis, and data structures is required.

It will be helpful to take CS 677 Analysis of Algorithms, but it is not a formal prerequisite. Any material needed from CS 677 will be reviewed during class, if needed. Please note that the instructor does not intend to zealously enforce the prerequisites. Anyone with a decent background in operating systems and algorithms should be able to handle the material.

Required Reading:

Hard Real-Time Computing Systems: Predictable Scheduling Algorithms and Applications, Giorgio C. Buttazzo, Springer, Third Edition, 2011.

Research papers will be assigned throughout the semester and posted on WebCampus. Check the course WebCampus site for details and a reading schedule. It is expected that students read the assigned material prior to lecture and will be prepared to discuss the material.

Optional Textbooks:

- Real-Time Systems, Jane Liu, Prentice Hall, 2000.
- Real-Time Systems, C.M. Krishna and K.G. Shin, McGraw Hill, 1997.
- High-Embedded Computing: Architectures, Applications, and Methodologies. Wayne Wolf, Morgan-Kaufman, 2007.

Course Learning Objectives:

The purpose of this course is to provide students an in depth understanding of real-time operating systems, and embedded systems. After the successful completion, students should be able to

1. Identify the major differences and design challenges for real-time systems compared to traditional performance-based computing systems.
2. Perform schedulability analysis for standard real-time task/scheduling models, accounting for various system complexities (e.g., resource-sharing, non-preemptivity, etc).
3. Evaluate, compare, and contrast different scheduling algorithms and real-time and embedded kernel designs.
4. Summarize and critique the major contributions of recent research publications in the real-time and embedded systems area.
5. Apply knowledge of real-time and embedded system concepts to address an open research question in real-time and embedded systems and related fields.

Course contents: (Tentative List of Topics):

Real-time task models and specifications; scheduling algorithms; clock-driven scheduling; priority-driven scheduling; non-preemptivity; timing analysis; schedulability analysis; resource-sharing; mixed real-time and non-real-time scheduling; distributed and multiprocessor systems; real-time kernel design and overview; real- time application considerations; embedded system considerations; real-time verification and logic.

A tentative schedule of topics and reading assignments is given in the table below. An updated schedule (with a one-to-two week notice) may be found on the WebCampus course website. Please check this site often for any changes to the schedule or announcements.

Date	Topic	Reading	Assignment
Aug 23rd	Course Overview	Chapter 1: A General Review J. Stankovic, Misconceptions about real-time computing: A serious problem for next-generation systems, IEEE Computer 1990	
Aug 25th	Real-Time Scheduling Concepts	Chapter 2: Basic Concepts	
Aug 30th	Real-Time Scheduling Concepts		
Sep 1st	Online and Offline Real-Time Scheduling	Chapter 3: Aperiodic Task Scheduling	Assignment #1 out
Sep 6th	Online and Offline Real-time Scheduling	Chapter 4: Periodic Task Scheduling T. Baker and A. Shaw, The cyclic executive model and ada. Real-Time Systems Symposium, 1988	
Sep 8th	Online and Offline Rel-Time Scheduling		
Sep 13th	Online and Offline Real-Time Scheduling		
Sep 15th	Periodic Task Scheduling	Chapter 4: Periodic Task Scheduling	
Sep 20th	Periodic Task Scheduling		
Sep 22nd	Periodic Task Scheduling		Assignment #1 Due
Sep 27th	Periodic Task Scheduling		
Sep 29th	Periodic Task Scheduling		Assignment #2 out
Oct 4th	Periodic Task Scheduling Non-preemptive Scheduling	K. Jeffay, D.F. Stanat, and C.U. Martel, On non-preemptive scheduling of periodic and sporadic tasks, Real-Time Systems Symposium 1991	Paper Presentation list Due
Oct 6th	Non-preemptive Scheduling	Chapter 8: Limited Preemptive Scheduling	
Oct 11th	Resource Access Protocols	Chapter 7: Resource Access Protocols	
Oct 13th	Resource Access Protocols		
Oct 18th	Resource Access Protocols		
Oct 20th	Student Presentations		
Oct 25th	Student Presentations		Assignment #2 Due
Oct 27th	Student Presentations		
Nov 1st	Handling Overload Conditions	Chapter 9: Handling Overload Conditions	Assignment #3 out

Date	Topic	Reading	Assignment
Nov 3rd	Handling Overload Conditions		
Nov 8th	Handling Overload Conditions		
Nov 10th	Handling Overload Conditions		
Nov 15th	Worst-case Execution Timing Analysis Real-Time Operating Systems overview	Handout: Excerpt from Krishna & Shin textbook on Timing Analysis (Real-Time Systems, pg. 25 - 37) Optional Reading Chapter 10: Kernel Design Issues Chapter 12: Real-Time Operating Systems and Standards	
Nov 17th	Final project Presentations		
Nov 22nd	Final project Presentations		
Nov 24th	Final project Presentations		Assignment #3 Due

Assessment:

Attendance & Class Participation: 5%
Assignments: 15%
Paper Presentation & Discussion: 20%
Project Presentation: 30%
Project Report: 30%

Grading Scale:

85 – 100% A
70 – 84% B
60 – 69% C
0 – 59% F

Assignments:

There will be three homework assignments in the course. Homework assignments will be given roughly once a month. Assignments 1 and 3 will involve implementing schedulers, operating system concepts, and/or experimental analysis on POSIX threads. Assignment 2 will involve formal verification of real-time guarantees. All homework assignments must be completed individually. It is not acceptable to discuss possible approaches for solving the assigned problems unless the instructor explicitly gives permission. Any collaboration on homework assignments will be considered cheating. A student caught cheating will receive a grade of "F" for the assignment (and potentially the course) and face charges as determined by the office of student conduct. For more details, see Academic Dishonesty section below.

Assignments are due before the beginning of the class on the given due date. Late Assignments will not be accepted.

Exams:

There will be no exams for this course.

Class Participation:

Attendance is mandatory for this course. Although excused absences are occasionally necessary, students should inform the instructor about an absence prior to the missed lecture by email.

A course in which students actively participate in the discussion of ideas is always much more enjoyable and stimulating. In fact, 5% of your grade is determined by participation in the class discussions. Students who routinely participate in the class will receive full points for this portion of the grade. However, the instructor also reserves the right to deduct points for those who routinely do not participate in the discussion, come to class late, use their phone/tablets/laptop for non-course-related activities, text, or sleep in class, etc.

Reading Presentation:

Each student will be required to present at least one research paper from a real-time and/or embedded systems conference or journal. A list of potential papers will be made available early in the semester; each student will choose a paper from the list or suggest a paper (approved by me). A sign-up sheet will also be circulated early in the semester. Each presentation will be evaluated on quality of summary, student's grasp of topic, ability to handle questions, and presentation style.

Class Project:

A significant portion of the course grade is the required class project. In this course, you will be responsible for designing your own project. Your project can be either experimental investigation or a research project on an open topic in real-time systems. The project must be a fairly significant piece of work. It is acceptable to use research from a current GRA or research position as the basis for your class project. However, your project may not be based on work from another course without the permission of me and the instructor for the other course (permission will be granted only if the total work involved is commensurate with the amount of effort expected in both courses combined). Two-person projects may be permitted, provided the total work involved is about twice that of the typical single-person project.

The components of the class project that will be graded are a class presentation and a technical report describing the project. The class presentation will occur during the course's scheduled final exam time. Officially, the technical report of the project will be due on the last day of class. In addition, each student will be required to submit an initial informal project proposal early in the semester, and a more detailed project proposal later. Details on class projects will be discussed in greater detail during the second or third week of class.

University Policies

Public Health Directives

Face coverings are currently mandatory for all faculty and students in the classroom. Students must follow all active UNLV public health directives while enrolled in this class. UNLV public health directives are found at Health Requirements for Returning to Campus, https://www.unlv.edu/coronavirus/health-requirements. Students who do not comply with these directives may be asked to leave the classroom. Refusal to follow the guidelines may result in further disciplinary action according to the UNLV Student Conduct Code, https://www.unlv.edu/sites/default/files/page_files/27/StudentConduct-Code.pdf, including being administratively withdrawn from the course.

Academic Misconduct

Academic integrity is a legitimate concern for every member of the University community. We all share in upholding the fundamental values of honesty, trust, respect, fairness, responsibility, and professionalism. By choosing to join the UNLV community, students accept the expectations of the Student Academic Misconduct Policy, and are encouraged to always take the ethical path whenever faced with choices. Students enrolling at UNLV assume the obligation to conduct themselves in a manner compatible with UNLV's educational mission. An example of academic misconduct is plagiarism. Plagiarism is using the words or ideas of another person, from the Internet or any other source without proper citation of the source(s). See the Student Conduct Code, https://www.unlv.edu/studentconduct/student-conduct.

Auditing a Course

Auditing a course allows a student to continue attending the lectures and/or laboratories and discussion sessions associated with the course, but the student will not earn a grade for any component of the course. Students who audit a course receive the same educational experience as students taking the course for a grade, but will be excused from exams, assessments, and other evaluative measures that serve the primary purpose of assigning a grade.

Classroom Conduct

Students have a responsibility to conduct themselves in class and in the libraries in ways that do not interfere with the rights of other students to learn, or of instructors to teach. Use of devices such as cellular phones and pagers, or other potentially disruptive activities are only permitted with the prior explicit consent of the instructor. Students are specifically prohibited to record classes without instructor authorization, including online/remote classes (either audio only, or video and audio). The instructor may rescind permission at any time during the class. If a student does not comply with established requirements or obstructs the functioning of the class, the instructor may initiate an administrative withdrawal of the student from the course.

Since the COVID-19 pandemic forced some instruction to be delivered remotely starting in Spring 2020, numerous students have asked instructors to record their synchronous classes, so that they can access them at their convenience. Instructors who agree to record their classes (audio only, or video and audio) should inform students in advance. Recorded lectures may not be broadly released to anyone, but made available exclusively to those students enrolled in the class during the particular academic term. Recorded lectures must be stored securely, and are subject to the Nevada System of Higher Education's Records Retention Policy, meaning that the recordings can only be deleted 120 days after the end of class (i.e., after grades are posted). Once

this requirement is met, the recordings should be deleted. Class recordings are protected from disclosure, as they are deemed part of an educational record under the Family Educational Rights and Privacy Act (FERPA).

Copyright

The University requires all members of the University Community to familiarize themselves with, and to follow copyright and fair use requirements. You are individually and solely responsible for violations of copyright and fair use laws. The University will neither protect nor defend you, nor assume any responsibility for student or employee violations of fair use laws. Violations of copyright laws could subject you to federal and state civil penalties and criminal liability, as well as disciplinary action under University policies. Additional copyright policy information is available at https://www.unlv.edu/provost/copyright.

Disability Resource Center (DRC)

The UNLV Disability Resource Center (Student Services Complex, SSC-A, Room 143, https://www.unlv.edu/drc, telephone 702-895-0866) provides resources for students with disabilities. Students who believe that they may need academic accommodations due to a permanent disability, temporary or permanent medical need, or academic support due to pregnancy are encouraged to contact the DRC as early as possible in the academic term. A Disabilities Specialist will discuss what options may be available to you. Students who are already registered with the DRC should request their accommodations online each semester, and make an appointment to discuss their accommodations with their instructors.

Final Examinations

The University requires that final exams given at the end of a course occur on the date and at the time specified in the Final Exam schedule. The Final Exam schedule is typically available at the start of the semester, and the classroom locations are available approximately one month before the end of the semester. See the Final Exam Schedule, https://www.unlv.edu/registrar/calendars.

Identity Verification in Online Courses

All UNLV students must use their Campus-issued ACE ID and password to log in to WebCampus-Canvas.

UNLV students enrolled in online or hybrid courses are expected to read and adhere to the Student Academic Misconduct Policy, https://www.unlv.edu/studentconduct/misconduct/policy, which states that "acting or attempting to act as a substitute for another, or using or attempting to use a substitute, in any academic evaluation or assignment" is a form of academic misconduct. Intentionally sharing ACE login credentials with another person may be considered an attempt to use a substitute, and could result in investigation and sanctions, as outlined in the Student Academic Misconduct Policy.

UNLV students enrolled in online courses are also expected to read and adhere to the Acceptable Use of Computing and Information Technology Resources Policy, https://www.it.unlv.edu/policies/acceptable-use-computing-and-information-technology-resources-policy, which prohibits sharing university accounts with other persons without authorization.

To the greatest extent possible, all graded assignments and assessments in UNLV online courses should be hosted in WebCampus-Canvas or another UNLV-managed platform that requires ACE login credentials for access.

Incomplete Grades

The grade of "I" (Incomplete) may be granted when a student has satisfactorily completed three-fourths of course work for that semester/session, but cannot complete the last part of the course for reason(s) beyond the student's control and acceptable to the instructor, and the instructor believes that the student can finish the course without repeating it. For undergraduate courses, the incomplete work must be made up before the end of the following regular semester. Graduate students receiving "I" grades in 500-, 600-, or 700-level courses have up to one calendar year to complete the work, at the discretion of the instructor. If course requirements are not completed within the period indicated, a grade of "F" will be recorded, and the student's GPA will be adjusted accordingly. Students who are fulfilling an Incomplete grade do not register for the course, but make individual arrangements with the instructor who assigned the "I" grade.

Library Resources

Librarians are available to consult with students on research needs, including developing research topics, finding information, and evaluating sources. To make an appointment with a subject expert for this class, please visit the Libraries' Research Consultation website, https://guides.library.unlv.edu/appointments/librarian. You can also ask the library staff questions via chat and text message at https://ask.library.unlv.edu/.

Missed Classwork

Any student missing class, quizzes, examinations, or any other class or laboratory work because of observance of religious holidays will be given an opportunity during that semester to make up the missed work. The make-up opportunity will apply to the religious holiday absence only. It is the responsibility of the student to notify the instructor within the first 14 calendar days of the course for Fall and Spring courses (except for modular courses), or within the first 7 calendar days of the course for Summer and modular courses, of their intention to participate in religious holidays which do not fall on state holidays or periods of class recess. For additional information, please visit the Missed Classwork policy, under Registration Policies, on the Academic Policies webpage.

In accordance with the policy approved by the Faculty Senate regarding missed class time and assignments, students who represent UNLV in any official extracurricular activity will also have the opportunity to make up assignments, provided that the student submits official written notification to the instructor no less than one week prior to the missed class(es).

The spirit and intent of the policy for missed classwork is to offer fair and equitable assessment opportunities to all students, including those representing the University in extracurricular activities. Instructors should consider, for example, that in courses which offer a "Drop one" option for the lowest assignment, quiz, or exam, assigning the student a grade of zero for an excused absence for extracurricular activity is both contrary to the intent of the Faculty Senate's policy, and an infringement on the student's right to complete all work for the course.

This policy will not apply in the event that completing the assignment or administering the examination at an alternate time would impose an undue hardship on the instructor or the University that could be reasonably avoided. There should be a good faith effort by both the instructor and the student to agree to a reasonable resolution. When disagreements regarding this policy arise, decisions can be appealed to the Department Chair/School Director, College/School Dean, and/or the Faculty Senate Academic Standards Committee.

For purposes of definition, extracurricular activities may include, but are not limited to academic recruitment activities, competitive intercollegiate athletics, fine arts activities, liberal arts competitions, science and engineering competitions, and any other event or activity sanctioned by a College/School Dean, and/or by the Executive Vice President and Provost.

Rebelmail

Rebelmail is UNLV's official email system for students and by University policy, instructors and staff should only send emails to students' Rebelmail accounts. Rebelmail is one of the primary ways in which students receive official University communications, information about deadlines, major Campus events, and announcements. All UNLV students receive a Rebelmail account after they have been admitted to the University. Sending emails within WebCampus-Canvas is also acceptable.

Tutoring and Coaching

The Academic Success Center (ASC), at the Claude I. Howard Building, provides tutoring, academic success coaching, and other academic assistance for all UNLV undergraduate students. For information regarding tutoring subjects, tutoring times, and other ASC programs and services, please visit the ASC website, https://www.unlv.edu/asc, or call 702-895-3177. The ASC is located across from the Student Services Complex (SSC). Academic success coaching is located on the second floor of SSC A, Room 254. Drop-in tutoring is located on the second floor of the Lied Library, and on the second floor of the College of Engineering building (TBE A 207).

UNLV Writing Center

One-on-one or small group assistance with writing is available free of charge to UNLV students at the Writing Center, https://writingcenter.unlv.edu/, located in the Central Desert Complex, Building 3, Room 301 (CDC 3–301). Walk-in consultations are sometimes available, but students with appointments receive priority assistance. Students may make appointments in person or by calling the Center, telephone 702-895-3908. Students are requested to bring to their appointments their Rebel ID Card, a copy of the instructions for their assignment, and two copies of any writing they have completed on their assignment.