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UNIT III SYNTAX ANALYSIS CS6660 Syllabus Need and Role of the Parser-Context Free Grammars -Top Down Parsing -General Strategies-Recursive Descent Parser Predictive Parser-LL(1) Parser-Shift Reduce Parser-LR Parser-LR (0)Item-Construction of SLR Parsing Table -Introduction to LALR Parser – Error Handling and Recovery in Syntax Analyzer-YACC-Design of a syntax Analyzer for a Sample Language . UNIT IV SYNTAX DIRECTED TRANSLATION & RUN TIME ENVIRONMENT Compiler Design Syllabus Syntax directed Definitions-Construction of Syntax Tree-Bottom-up Evaluation of S-Attribute Definitions- Design of predictive translator – Type Systems-Specification of a simple type checker-Equivalence of Type Expressions-Type Conversions. RUN-TIME ENVIRONMENT: Source Language Issues-Storage Organization-Storage Allocation-Parameter Passing-Symbol Tables-Dynamic Storage Allocation-Storage Allocation in FORTAN. UNIT V CODE OPTIMIZATION AND CODE GENERATION Compiler Design Syllabus Principal Sources of Optimization-DAG- Optimization of Basic Blocks-Global Data Flow Analysis-Efficient Data Flow Algorithms-Issues in Design of a Code Generator – A Simple Code Generator Algorithm. Subject Name Compiler Design Subject code CS6660 Regulation 2013 CS6660 Syllabus click here to download Compiler Design Notes Compiler Design Important questions CS6660 Question bank The purpose of this course is to learn how to transform programs written in common user-level programming languages into code that can be executed by the processor. We will cover all the stages of a compiler, from processing program text into an internal representation, through optimization and program improvement, to the generation of assembly code. By the end of this class, you will know how to: write lexers and parsers for any programming language, processing program text into an internal compiler representation use lex and yacc to automatically generate lexers and parsers based on a grammar implement type checking as a pass over the tree representation of program code translate the internal representation of program code into executable assembly analyze and transform programs to improve their time and memory efficiency Prerequisites The prerequisites for this class are CS 301 (Languages and Automata), CS 251 (Data Structures), and CS 261 (Machine Organization). I will assume that you know how to program in C, and have some familiarity with regular expressions, grammars, and assembly language. Communication The class discussion board on Piazza is the best place to post questions about the course material, assignments, course policies, exams, and anything else. Remember, if you have a question, someone else probably does too! You can ask and answer anonymously to the rest of the class (though the instructors will be able to see your name), and you can also use it to send messages to the instructors (we check it more often than email). There will be a small amount of extra credit available for being a good citizen on Piazza - asking questions, answering questions, and generally being helpful. Evaluation Grades are curved based on an aggregate course score. There are separate curves for graduate and undergraduate students. This means that the course score cut-offs for an A, B, C, etc. are not defined ahead of time: these will be set after the end of the course. The course grade weighting is: Task % of total grade Assignments 30 Midterms (2) 40 Final 30 Students taking the class for 4 credits will have additional problems to solve on written assignments. Attendance and Participation Class attendance is not mandatory; however, research indicates that students who attend class are more likely to be successful. You are strongly encouraged to attend every class. Lectures are recorded, and will be made available on Blackboard, but any in-class work or student discussions will not be recorded. A small amount of extra credit will be available for active participation in class or on Piazza. Textbook The main textbook will be Modern Compiler Implementation in C, by Andrew W. Appel. We may also occasionally use readings from other textbooks. One copy of the textbook is on reserve at the library. Assignments There will be two kinds of assignments in this class: programming assigments and written assignments, both drawn from the textbook. Feel free to post questions on Piazza. Assignments will be submitted via Gradescope. Homework Late Policy Assignments will be accepted up to 2 days after their due date. Late submissions will receive a 20% penalty. Assignments emailed to the instructor more than 2 days after the due date may be marked up and returned, but you will not receive credit for them. Academic Integrity Consulting with your classmates on assignments is encouraged, except where noted. However, submissions are individual, and copying code from your classmates is considered plagiarism. For example, given the question “how did you do X?”, a great response would be “I used function Y, with W as the second argument. I tried Z first, but it doesn’t work.” An inappropriate response would be “here is my code, look for yourself.” If you ask for help from sources outside the course, you must clearly state that you’re asking for help on homework for a class. To avoid suspicion of plagiarism, you must specify your sources together with all submitted in materials. List classmates you discussed your homework with and webpages from which you got inspiration or copied (short) code snippets. All students are expected to understand and be able to explain their submitted materials. Plagiarism and cheating, as in copying the work of others, paying others to do your work, etc, is prohibited, is grounds for failing the course, and will be reported. Religious Holidays The UIC Senate Policy on religious holidays is as follows: “The faculty of the University of Illinois at Chicago shall make every effort to avoid scheduling examinations or requiring that student projects be turned in or completed on religious holidays. Students who wish to observe their religious holidays shall notify the faculty member by the tenth day of the semester of the date when they will be absent unless the religious holiday is observed on or before the tenth day of the semester. In such cases, the students shall notify the faculty member at least five days in advance of the date when they will be absent. The faculty member shall make every reasonable effort to honor the request, not penalize the student for missing the class, and if an examination or project is due during the absence, give the student an exam or assignment equivalent to the one completed by those students in attendance. If the student feels aggrieved, they may request remedy through the campus grievance procedure. Grievance Procedures UIC is committed to the most fundamental principles of academic freedom, equality of opportunity, and human dignity involving students and employees. Freedom from discrimination is a foundation for all decision making at UIC. Students are encouraged to study the University’s Nondiscrimination Statement. Students are also urged to read the document Public Formal Grievance Procedures. Information on these policies and procedures is available on the University web pages of the Office of Access and Equality. Course Reference Number: CS-322-001, Winter 2006: CRN 40839 When and Where: Tuesday & Thursday, 2:00PM - 3:50PM PCAT, Room 138 First Class: Tuesday, January 10, 2006 Holidays: None Quiz #1: Thursday, February 9 (Tentative) Quiz #2: Thursday, March 2 (Tentative) Final Exam: Monday, March 20, 10:15AM-12:05PM The final will be comprehensive. It will be closed book and closed notes. Instructor: Prof. Harry Porter E-Mail: harry@cs.pdx.edu Web Page: www.cs.pdx.edu/~harry Office space at PSU: 115-06 (Fourth Ave Bldg) Office hours: Directly after class meetings and by arrangement. Grader: Aaron Kryger E-Mail: akryger@cs.pdx.edu Office: 115-??? (Fourth Ave Bldg) Office Hours: ??? Misc. Material - CS-322 Checklist for FIRST meeting: (pdf, 1 page) My Java Summary: html or (pdf, 62 pages) Coding Style For Java Programs: pdf, 8 pages PCAT Reference Manual: pdf, 11 pages SPARC Overview: pdf file SPARC Demo Programs: pdf file ASCII Byte Encoding Chart: pdf file Misc Useful Programs: directory Study Guide / Terminology: pdf file or html Grades for CS-322: PDF file of point spreadsheet or PDF file of bar chart Homeworks - CS-322 Homework 1: pdf file Homework 2: pdf file Homework 3: pdf file Homework 4: pdf file Homework 5: pdf file Homework 6: pdf file Homework 7: pdf file Projects - CS-322 Project 7 Files: ~harry/public_html/compilers/p7/ (SPARC Assembler) Project 7a Files: ~harry/public_html/compilers/p7a/ (PrettyPrint) Project 8 Files: ~harry/public_html/compilers/p8/ (IR Code Generation 1) Project 9 Files: ~harry/public_html/compilers/p9/ (IR Code Generation 2) Project 10 Files: ~harry/public_html/compilers/p10/ (IR Code Generation 3) Project 11 Files: ~harry/public_html/compilers/p11/ (Final Code Generation) Lecture Notes - CS-322 Packet-19 (Intro to CS322): pdf Packet-20 (SPARC Architecture - part 1): pdf Packet-21 (SPARC Architecture - part 2): pdf Packet-22 (SPARC Architecture - part 3): pdf Packet-23 (Code Generation-Part 1): pdf Packet-24 (Project-8): pdf Packet-25 (Tolmach's AST): pdf Packet-26 (Project-9): pdf Packet-27 (Code Generation-Part 2): pdf Packet-28 (Parameter Passing): pdf Packet-29 (Code Generation-Part 3): pdf Packet-30 (Project 10): pdf Packet-31 (Target Gen-Part 1): pdf Packet-32 (Target Gen-Part 2): pdf Packet-33 (Register Allocation): pdf Packet-34 (Tiling): pdf Packet-35 (Project 11): pdf Packet-36 (Optimization, Part 1): pdf Packet-37 (DAG-Based Optimization): pdf Packet-38 (Data Flow Analysis): pdf Packet-39 (Loop Optimizations): pdf Packet-40 (The SPANK Project): pdf Each programming project will have a due date and you should plan on submitting your project before that date. If you submit something late, there is a penalty. The late policy is: Up to 48 hours late - No points off Up to 7 days late - 5 points off Later than 1 week - 5 points off for every additional week, or part thereof The last assignment will be due approx. 1 week before the final. Every project must be received before the final exam, with absolutely no exceptions. Furthermore, you must complete project 8 before you begin working on project 9, and you must complete project 9 before you begin working on project 10. By complete, I mean you must sucessfully pass all tests. You need not finish project 7 before you begin working on 8, nor must you complete project 10 before you begin working on project 11. This policy effectively recognizes that events like illness or funerals will occassionally come up, so projects cannot always be handed in on time. You are effectively allowed to fall behind. Although there is a small point loss if things are late, it is not large. I decided to take off a few points to prevent students from holding on to project submissions longer than necessary, then handing in everything at the time of the final, which would overwhelm the grader. If you fall behind, it is your responsibility to find the time in the remainder of the term to catch up. If you fall behind by more than a week, it will hurt you on other projects later in the term, since you may run out of time before the final hard deadline, and be unable to complete the last project. I strongly encourage you to keep up and hand in projects before the due date, and not fall behind. Experience has shown that students who allow themselves to fall behind, often have great difficulty catching up later. If projects are handed in within 48 hours of the due date, they will be graded immediately and returned with the others. When projects are later than that, their grading will be delayed, possibly by a couple of weeks. Week 1 - SPARC Assembly Code Tuesday (Jan 10) Thursday (Jan 12) Week 2 - SPARC Assembly Code Tuesday (Jan 17) Reading: Complete "Overview of SPARC Architecture" before class Thursday (Jan 19) Reading: Begin reading ch. 7 HW #1 due Week 3 - Generating Intermediate Code, Runtime Environment Tuesday (Jan 24) Reading: Read ch. 7, through page 373 Project P7 due ("SPARC Assembly Language") Thursday (Jan 26) HW #2 due Week 4 - Execution Stack, Function Activations, Parameter Passing Tuesday (Jan 31) Reading: Complete ch. 7 before class Project P8 due ("Generate Intermediate Code, part 1") Thursday (Feb 2) HW #3 due Week 5 - Records, Arrays, Switch Statement Tuesday (Feb 7) Reading: Read ch. 8, through page 428, before class Thursday (Feb 9) Quiz # 1 Week 6 - Target Code Generation Tuesday (Feb 14) Reading: Read ch. 8, through page 467, before class Project P9 due ("Generate Intermediate Code, part 2") Thursday (Feb 16) HW #4 due Week 7 - Register Allocation Tuesday (Feb 21) Project P10 due ("Generate Intermediate Code, part 3") Thursday (Feb 23) HW #5 due Week 8 - Code Generation via Tiling Tuesday (Feb 28) Reading: Complete ch. 8 before class Thursday (Mar 2) Quiz #2 Week 9 - Introduction to Code Optimization Tuesday (Mar 7) Thursday (Mar 9) HW #6 due Week 10 - Data Flow Analysis, Loop Optimizations Tuesday (Mar 14) Project P11 due ("Generate Target Code") Thursday (Mar 16) HW #7 due Finals Week Monday (Mar 20) Exam 10:15 AM (2 hours) Misc. Material - CS-321 Checklist for FIRST meeting: (pdf, 1 page) Hello-World Assignment: (pdf, 1 page) My Java Summary: html or (pdf, 62 pages) Coding Style For Java Programs: pdf, 8 pages PCAT Sample Programs: directory Terminology / Study Guide for Exams: pdf file or html Grades for CS-321: PDF file of point spreadsheet or PDF file of bar chart Homeworks - CS-321 Homework 1: pdf file Homework 2: pdf file Homework 3: pdf file Homework 4: pdf file Homework 5: pdf file Homework 6: pdf file Projects - CS-321 Project 0 Files: ~harry/public_html/compilers/p0/ (Tree) Project 1 Files: ~harry/public_html/compilers/p1/ (E Language) Project 2 Files: ~harry/public_html/compilers/p2/ (Lexer) Project 3 Files: ~harry/public_html/compilers/p3/ (Parser 1) Project 4 Files: ~harry/public_html/compilers/p4/ (Parser 2-Build AST) Project 5 Files: ~harry/public_html/compilers/p5/ (Checker 1) Project 6 Files: ~harry/public_html/compilers/p6/ (Checker 2) Lecture Notes - CS-321 Packet-1 (Course Introduction): pdf Packet-2 (Introduction to Java - optional, not covered in class): pdf Packet-3 (The Tree Assignment): pdf Packet-4 (Intro-part 1): pdf Packet-5 (Intro-part 2): pdf Packet-6 (Lexical-part 1): pdf Packet-7 (Lexical-part 2): pdf Packet-8 (Lexical-part 3): pdf Packet-9 (Lexical-part 4): pdf Packet-10 (Project 3-Parser): pdf Packet-11 (Syntax-Part 1): pdf Packet-12 (Project 4-Abstract Syntax Tree): pdf Packet-13 (Syntax-Part 2): pdf Packet-14 (Syntax-Part 3): pdf Packet-15 (Project 5): pdf Packet-16 (Semantics-Part 1): pdf Packet-17 (Project 6): pdf Packet-18 (Semantics-Part2): pdf Bonus Question Answers to the bonus question Week 1 - Overview of Compiling Tuesday (Sept 27) Thursday (Sept 29) Complete HelloWorld Assignment Week 2 - Lexical Analysis and Scanning Tuesday (Oct 4) Reading: Complete ch. 1 before class Project P0 due ("Working with trees") Thursday (Oct 6) HW #1 due Week 3 - Lexical Analysis and Scanning Tuesday (Oct 11) Reading: Complete ch. 2 before class Project P1 due ("The E Language") Thursday (Oct 13) HW #2 due Week 4 - Context Free Grammars Tuesday (Oct 18) Reading: Complete ch. 3 before class Project P2 due ("Build a lexical scanner") Thursday (Oct 20) HW #3 due Week 5 - Top-Down Parsing Tuesday (Oct 25) Reading: Complete ch. 4 before class Project P3 due ("Build a parser") Thursday (Oct 27) Quiz # 1 Week 6 - Top-Down Parsing Tuesday (Nov 1) Reading: Begin reading ch. 5 Project P4 due ("Build the Abstract Syntax Tree") Thursday (Nov 3) HW #4 due Week 7 - Bottom-Up Parsing Tuesday (Nov 8) Reading: Complete ch. 5 before class Thursday (Nov 10) HW #5 due Week 8 - Bottom-Up Parsing Tuesday (Nov 15) Reading: Begin reading ch. 6 Project P5 due ("Semantic Analysis-part 1") Thursday (Nov 17) Quiz #2 Week 9 - Attribute Grammars and Semantic Analysis Tuesday (Nov 22) Reading: Complete ch. 6 before class Thursday (Nov 24) Thanksgiving Holiday - no class Week 10 - Attribute Grammars and Semantic Analysis Tuesday (Nov 29) Project P6 due ("Semantic Analysis-part 2") Thursday (Dec 1) HW #6 due Finals Week Monday (Dec 5) Exam 10:15 AM (2 hours) This course studies the principles of programming languages with an emphasis on programming language implementation and compiler design. This includes various techniques for describing and defining a language, as well as techniques for implementing compilers. The course is centered on a large programming project-the construction of a complete compiler for a small programming language-which will be completed over the two term sequence CS 321 and CS 322. Topics to be covered over the two terms include: lexical analysis, syntactic analysis, recursive descent parsing, LR parsing, syntax-directed translation, type checking, run-time environments, code generation, code optimization, and various language design issues. This is a two term sequence. Students are strongly encouraged to take CS 321 and CS 322 in consecutive quarters from the same instructor. Required: Compiler Construction: Principles and Practice, Kenneth C. Louden, PWS Publishing, 1997, ISBN 0-534-93972-4. This is our primary textbook and will be available through the PSU Bookstore. Required: You will definitely need a book on Java, but the choice is yours. Here are two recommended books on Java: The Java Programming Language, 3rd Edition, Ken Arnold, James Gosling, and David Holmes, Addison-Wesley, 2000. ISBN 0-201-70433-1. Thinking in Java, 2nd Edition, Bruce Eckel, Prentice-Hall, 2000. This book is also available free on the web at www.mindview.net/Books/TIJ Related Websites Harry Porter's Java Summary: html or (pdf, 62 pages) Java Web Site: java.sun.com/j2se/1.4/docs/index.html Java Class Documentation (Frames): java.sun.com/j2se/1.4/docs/api/index.html Java Class Documentation (No Frames): java.sun.com/j2se/1.4/docs/api/overview-summary.html The official prerequisites are: CS 202 (Programming Systems) CS 300 (Software Engineering) CS 311 (Computational Structures) Students will work on a large programming project; as such, they will need the previous experience in writing and debugging large programs provided in classes like CS 202 and CS 300. Java will be used as the implementation language for the compiler project, but no previous experience with Java is required. This course will look at regular languages, finite-state automata, and context-free languages in some depth; CS 311 will have provided the student's first exposure to these topics. The prerequistes for the second term (CS-322) also include having passed the first term (CS-321). In the second term (CS-322), you will learn a new machine architecture, the SPARC architecture. We will assume you are familiar with the concepts of machine language and that you have written assembly language programs before, but we will not assume any familiarity with the SPARC architecture. It is the student's ressponsibility to ensure that he/she has the appropriate background before attempting this class. Over the course of two terms, students will work on a single large programming project, which is the implementation of a compiler for the "PCAT" language. This project will be implemented in Java. There will be approximately 6 programming projects during the first term, taking about 2 weeks each. All but the first project are part of the overall compiler project. Since later programs will make use of earlier programs, it is critical that students complete all projects on time. You may develop your code on any machine and operating system you like, as long as it supports Java (SDK version 1.2 or later, corresponding to "Java 2"). However, the code you submit will be tested and graded on the CS department's Sparc machines, using SDK version 1.4. It is your responsibility to make sure that your code works properly on this system; since Java is highly portable, this should not be a significant difficulty. Students must not work together: All programs must be designed and coded independently. You must compose and type in every line code you submit, with the exception of code I distribute to the class. Any form of code sharing will be considered cheating. Grading will be based on style, organization, and aesthetics; submissions will also be tested for correctness. Late programming submissions will not be accepted without prior approval. For CS-322: There will be approximately 5 programming projects during the second term, taking approximately 1-2 weeks each. Later programs will make use of earlier programs, so it is critical that students complete all projects. In CS-321, it is assumed that you wrote a lexical analyser, parser, and type-checker for the PCAT language. It is assumed that you are familiar with PCAT from CS-321. In CS-322, we will complete the compiler. In outline, the projects will be: A SPARC assembly language program (not part of the compiler) (p7) Generate intermediate code from abstract syntax tree (p8, p9, p10) Generate SPARC assembly code from intermediate code (p11) The compiler projects in this term will make use of the code written last term, in my section of CS-321 If you did not take CS-321 from me last term, I will provide .jar files that can be linked with the code you write this term. In other words, I will provide the lexer, parser, and type-checker and, during CS-322, you will create the back-end to give a full, working compiler. (There are subtle differences in the PCAT language used in other sections of this course which make it impractical to use a front-end implemented in another instructor's section of CS-321.) There will be approximately 5 homework assignments per term, generally weekly and due at the beginning of class. Late homeworks will not be accepted without prior approval. A "MailMan" e-mailing list will be maintained for this class. Students must subscribe to this list. From time to time I will post notices about the class and hints/comments about assignments. Students are encouraged to send mail to the list, too. However, please be careful to send your completed project code to the proper address, and not to the mailing list! To subscribe, go to the following web page and enter your email address and a password and click "subscribe". webmail.cecs.pdx.edu/mailman/listinfo.cgi/cs321-001 The MailMan program will email you a confirmation message. You must reply, but you can simply hit your email "reply" button. After being adding to the mailing list you will get a "welcome" message from me. To post a message to all the list members, send email to: cs321-001@cs.pdx.edu For additional documentation, see ckolar/mailman/mailman-userguide-0.1.pdf (pdf, 8 pages) (By the way, if Internet Explorer does not work with MailMan on the Mac, use the "Safari" web browser instead.) You may wish to use an "ftp" program to transfer class files from my directory (the "remote") to your computer (the "local"). If you want to use the standard UNIX ftp program, type the following command: ftp anonymous@ftp.cs.pdx.edu Then, change to my directory. For example, to get to the directory containing the files for project 1, at the "ftp>" prompt type: cd /pub/users/harry/compilers/p1 To list all the files in the remote directory, type: ls To copy all files from the remote directory into the current directory on your local machine, type mget * To suppress verbose interaction, answer "a" to the "mget filename [anpqy?]?" prompt. You can also type "help" or "quit" to leave ftp. For further info, in UNIX type: man ftp The final exam may test on material covered only in class and on material covered only in the reading assignments. Your grade will be based approximately, as follows. These percentages are tentative; I may change them. Homeworks 10% Programs 29% Quizes 29% Final Exam 29% Attendance 3% I will compute your grade as follows. Each homework will be worth some number of points. For example, HW #2 might be worth 25 points. Each homework will also count for a certain percentage of your grade. For example, HW #2 might be worth 3% of your final grade. The actual number of points you make on an individual assignment will then be divided by the number of points earned by the high scorer for that assignment and the result will be multiplied by the percentage weight of the assignment to give a normalized number of points. (For example, if you got 18 points on HW #2 and the highest score on the assignment was 23 points, you would get 2.35 normalized points, i.e., (18/23) * 3%.) Likewise, for the programming projects and the final exam, I will compute your normalized points, based on the percentage weights for each of the programs and the final. Summing the normalized points from each of your homeworks, programs, and the final, you will then have a net score between 0 and 100. I will then sort everybody on net score and give people with more points better grades. Grading will be based on a curve; in other words, I will select the range for A's, B's, etc., after seeing how the net scores distribute. I will select the percentage weights of the individual homeworks and programs at the end of the term (keeping within the general percentages listed above), since some assignments may be harder than others and will deserve larger weights in the final score. Incompletes will not be given. Successful students will arrive on-time, relaxed and full of curiosity. Attendance in class is mandatory; it will be checked and will count for part of your grade. The programming project is not a group project. You must create the code on your own! I encourage students to discuss the material in this class. Feel free to discuss the programming projects amongst yourselves, but only at a higher-level than the code. Do not share code. Do not work together on any programming project in this class. Do not look at anyone else's code. Do not allow anyone to use your code. Every line of code you submit must be your own work, except of course the code I provide. You may discuss the assignments with other students, but only in general terms. You may not look at someone else's code or share Java code. It is NOT okay to look at someone else's code, even for the purposes of helping that person or for comparing your different approaches. Each student must do the coding alone. You must type in every line of code you submit. You must not copy another student's code. Do not look at some one else's code, then turn around and type that code in. It will be considered cheating to copy code. It will be considered cheating to decompile or look inside any .class or .jar file I provide. If you have questions about what these files do, just ask me! It will be considered cheating to send your project code to the class mailing list, even if it is an accident. I simply cannot allow students to send their completed solution code to the mailing list! Snow Closure: For inclement weather information, call the University switchboard, 725-3000, for a recorded message about university-wide class cancellation. Snow closure info is also available at: www.flashnews.net/pdx.html (click on "View Current Info"). Other Cancellations: If I should need to cancel class for any reason, I will email the mailing list. YAPP (Yet Another PCAT Parser) is an SLR generator written in PCAT. YAPP can read in a grammar and a sample string. It will build parsing tables according to the SLR algorithm and then use those tables to parse the sample string. YAPP can easily handle a grammar for the PCAT language and can parse a PCAT program. YAPP can even parse itself. YAPP is the largest known PCAT program in the universe, consisting of more than 2100 lines of PCAT code. Over the years that CS-321 has been taught, there have been many, many PCAT parsers produced. YAPP is not just another PCAT parser. Click here to see the YAPP source code. Click here to look at the system in more detail. Send email to: harry@cs.pdx.edu

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