CS2303 AutoGrader

A Major Qualifying Project Report submitted to the faculty of

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by:

Jonathan Morse (Computer Science)

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Professor Hugh C. Lauer, WPI Advisor

Abstract

The number of undergraduate computer science students at Worcester Polytechnic Institute has increased in recent years. Due to the increase, strain has been put on teaching assistants for grading programming assignments. In order to lessen this strain we developed a python-based autograder for the programming assignments in CS2303. These auto graders semi-automate the grading process which allows teaching assistants to spend more time helping students in office hours and less time grading.

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1 Introduction

In recent years, the number of students in each new class of undergraduate students at WPI is continuously setting the record for largest class in history. This increase in students is putting a significant strain on the computer science department. With the influx of students, grading the programming assignments of introductory computer science courses is becoming a time consuming task. More teaching assistants than ever before are required, and even with that increase, less time is actually being spent helping students learn. Teaching assistants grade quizzes, tests, and assignments with professors to allow grades to be returned in a timely manner for large classes. They also host office hours were a student can come and ask a teaching assistant any question about the course. Recently, teaching assistants are spending significantly more hours grading work than hosting office hours. Ideally, most of a teaching assistant's time would be spent in office hours working with students one on one, to ensure students grasp the concepts of the introductory courses. The goal of this project is to research and develop a way to decrease the number of hours a teaching assistant needs to spend grading in CS2303: Introduction to Systems Programming. This introductory class is usually taken by a student during C-Term of freshman year. It is most likely taken after a student has completed two previous programming classes. It introduces the C and C++ programming languages, which are harder to understand than the languages used in previous classes.

The best way we thought of accomplishing this goal was by automating as much grading of programming assignments as possible. We had to research and develop an autograder, or a program that grades another program. We researched autograders that were available and used in general and at the university level. To find general purpose autograders we searched the internet, and to find autograders used at other universities we emailed professors directly. We were hoping to find an

autograder with three characteristics, namely to integrate well with existing programming assignments, to be simple to maintain and, to work reliably.

In response to professors we got valuable input from Professor Armando Fox [1] a computer science professor at the University of California at Berkeley. He had previously created an autograder from scratch for one of his classes, so he had experience. What he mentioned was, if we were unable to find an existing autograder that fit our needs and had to make one from scratch, to aim to autograde 80% of each assignment. In his experience it was much easier to make an autograder that graded 80% of an assignment, than one that grades 100% of each assignment. Since the autograders are going to be used by teaching assistants and they have the ability to grade programming assignments along with the autograders, we thought 60% to 80% automation would accomplish the goals of the project. We specifically focused on automating redundant task like organizing files and compiling code, because those are tasks machines do more efficiently than humans.

After we conducted research, the best autograder we found to suite the goals of the project was *AutoLab* [2]. AutoLab is under active developed by a team at Carnegie Mellon University led by Professor David O'Hallaron [3]. It is a system that facilitates in autograding programming assignments. After attempting to use AutoLab and working with it to create our autograders, we determined it was not suited well to the goals of the project. The suite of features that AutoLab provided were mostly unnecessary, for the scope of this project. Also, we believe that AutoLab would not be simple and reliable when being used by the teaching assistants.

We then transitioned to creating an autograder from scratch. This allowed us to create an autograder that was specifically designed for CS2303's assignments and to have a complete understanding of how the system works. We were able to develop a series of programs written in the Python programming language, to partially grade some of the programming assignments in CS2303.

We first started by creating a basic user interface that was simple to use, then began developing functions to unzip directories and compile student code. Lastly, we were able to create functions that could test the output of student's code for correctness.

2 Initial Research

We divided the research portion of the project into two phases, first we conducted Internet research to investigate autograder use in general. Then, we emailed college professors directly to determine autograder use at the university level.

2.1 Autograders in General

Our initial research started on the Internet, in our searches we were able to find two particularly useful links. One was from researchgate.com [4] and the other was from stackexchange.com [5]. Both links were from reputable websites, and the commenters seemed to be either computer science students or computer science professors. Information in those links introduced us to two useful topics related to autograders.

First was *MOOCs*, which stands for Massive Open Online Courses. MOOCs are taken by thousands or millions of people online, and those students are taught through recorded presentations, interactive labs and programming assignments. Due to the size of these courses, feedback for labs and assignments needs to be provided without human intervention. Therefore, they make extensive use of autograders.

One website that offers MOOCs is *Stepik.com* [6]. Stepik provides premade course but also allows users to develop their own courses that can be public or private. Most of the teaching is done by explaining a topic in a few paragraphs of text, then having a student develop one or two lines of code at a time, this step-by-step process slowly turns those chunks of code into a program. The programming assignments for CS2303 are open-ended. Students produce entire programs from

scratch before submitting for grading. For this reason, research or websites that focus on MOOCs were avoided for the remainder of the project.

Second, we learned about four autograders from our internet searches. Those were *Junit [7], Web-Cat [8], Mooshak [9] and AutoGradr [10].*

- Junit is a framework for testing functions written in the Java programming language. It was originally developed by researchers out of the University of Calgary. Junit is very popular and is one of the most widely used external libraries in Java [11].
- Web-Cat is a system that determines grades based on the test cases the students make, not those made by the professor or teaching assistant. According to web-cat.org, it is a web application with a plug-in-style architecture.
- Mooshak is a code testing system originally used for keeping score of programming competitions. Due to its popularity it was then turned into a product for classroom use. The main developer is Professor José Paulo Leal out of the University of Porto [9].
- AutoGradr is a website were users can create courses, consisting of labs and projects. Once a course is created, AutoGradr provides tools to autograde the labs and projects within a web browser. According to AutoGradr.com, it "handles collecting student code, compiling and running them against test cases, providing instant feedback to students".

The only product that we determined could be used for this project was AutoGradr. All the other products either did not support C and C++ or were old and not under active development.

2.2 Autograders at the University Level

To get information on autograders used at other universities we emailed the computer science department heads of twenty-five of the highest ranking undergraduate computer science programs in the nation. Of the twenty-five schools, we got no response from sixteen. Four out of

the remaining nine schools either made their own autograder or did not use one. Of the remaining five schools, the recommended autograders were ZyBooks [12], EdX [13], GradeScope [14] and AutoLab [2].

- ZyBooks is a learning platform for programming languages that are accessible via a web browser.
- EdX is a collaboration between many high ranking universities including MIT and Harvard to create a collection of free, college-level MOOCs in many subjects.
- GradeScope is a web site used to speed up the grading of exams and quizzes that have repeatable answers, which also has an autograding tool for programming assignments. GradeScope was initially developed by Professor Peter Abbeel [15] of the University of California at Berkeley.
- AutoLab is an open source application that is being developed by a team at Carnegie Mellon University led by Professor David O'Hallaron. It provides a web interface to submit work, and view grades, which compliments a back-end auto grader written in Python, it also has a supplemental website that provides information on how to interact with the application.

AutoLab and GradeScope appeared to suit our needs so we investigated them further online. Grade Scope unfortunately charges a fee to use the website and is not open source. We wanted something that was free and open source to avoid having to secure funds for this project and so that we could make changes to the product if it was in our own best interest. AutoLab appeared to be similar to GradeScope but was free and open source, so we decided to give it a try.

2.3 AutoLab

AutoLab is being actively developed by a team of undergraduate and graduate students at Carnegie Mellon University. Currently, a local version of AutoLab can be downloaded from autolabproject.com, this local version is used at CMU by over twelve hundred students each

semester. However, the AutoLab team is working on a cloud-based system that would allow anybody in the world to use AutoLab via the web.

2.3.1 Installation

We installed the local version of AutoLab. The AutoLab website provides installation instructions and what the website calls the "one-click install" option. This option only worked on the Ubuntu operating system [16] so we created an Ubuntu virtual machine using VirtualBox [17]. This option makes use of GitHub.com [18], a website that allows users to host source code that uses the Git [19] version control system to manage and to track the changes made to files. All we had to do was clone the required files from GitHub and run a shell script within the Ubuntu virtual machine. This simple installation process is possible because the shell script installs containers [20].

Containers allow a software application to be installed with all files and other dependencies it needs to run correctly, with no work from the end user. The developers at CMU used Docker [21] to create these containers, Docker is an application that provides an API to create and work with containers. The shell script installed three separate containers. The first container contained all the code needed to run the web interface, the second was a SQL database that stored all the information and data being shown on the web interface, lastly, the third container was called Tango and contains all the code that allows the system to autograde files. Even though the installation of AutoLab is supposed to be simple, we did receive errors during installation and had to reinstall multiple times.

2.3.2 Configuration

We were able to create a course and an assignment within AutoLab once we got it running. We initially used the sample assignment that the AutoLab developers created called Hello Lab. We downloaded the hello.tar file from AutoLab's GitHub [22] page and were able to install that file into AutoLab using the web interface. The way the web interface works is, each student, teaching assistant, and professor has an account for AutoLab, which provides different levels of access and

responsibility. A student for example can login in, select a specific course and submit a file to a specific assignment within the course, submitting files is the only action student accounts are allowed to do. This file would be saved by AutoLab into a specific folder and could be downloaded by the teaching assistant or professor. Unfortunately, the first time we attempted to submit a file to the Hello Lab assignment we got an error message. The error message was vague, all it stated was that the autograder was unable to grade the file, with no mention as two why. This was unusual because we made no changes to AutoLab and the lab that was used was made by the developers.

Next we attempted to create our own assignment and not use the hello.tar file assuming that was causing the problem. The web interface of AutoLab is nicely organized and visually appealing, we used the web interface to create our custom assignment, which was a simple process. However, we also had to write code that could interact with the web interface to autograde student submissions, AutoLab does this using JSON objects [23]. JSON stands for JavaScript Object Notation, and it allows for easy translation of data between a software application and a web server.

We were able to create a very simple program that returned JSON objects, but ran into serious difficulty integrating the program with AutoLab. This process involves creating a series of directories and makefiles and installing them within AutoLab. Specifics about all the makefiles and directories can be found at https://autolab.github.io/docs/lab/. Even though the website provides detailed information on what needs to be in the makefiles and directories, when we attempted to this it did not work properly. It was difficult to figure out what exactly was going wrong, and what we needed to fix. AutoLab provided no error or warnings messages that could give us hints into the cause of our problems.

We also struggled with Tango, another part of AutoLab. Tango is the application that interacts with user created programs using JSON objects. We developed our program based on information from the AutoLab website, and ensured that our program properly returned JSON

object. However, we still could not get AutoLab to grade any file we submitted. Unfortunately, the information about Tango on the AutoLab website is only useful if Tango is installed as a standalone application. When using the one click install, Tango should work without any setup. So, when we had trouble with Tango we were unsure what we had to do correct things, and what we were doing wrong.

2.3.3 Concerns

The main issue we had with AutoLab was determining the reason AutoLab would not grade a file we submitted. We could not determine if the problems were stemming from a misconfiguration of Tango, improper use of JSON objects in our program, or missing directories and makefiles. This did not allow us to properly investigate AutoLab, and determine its effectiveness at accomplishing the goals of the project.

Another problem with AutoLab is it requires a web server and user accounts. When we were testing out AutoLab we installed the "local" version. This version provides a dummy account and is used to just learn how works. If we wanted to deploy AutoLab for class room use we would need to install the "deployment" version. This version needs the ability to be accessed via a web address, which would require us to create and maintain a web server. Also the deployment version of AutoLab requires an email server. The email server is used to create and maintain user accounts. If students ever had difficultly accessing their account or resetting a password, it would cost teaching assistants a few hours of work each term. Due to one of our design goals being simplicity, the need for all these additional systems was a major negative. Although, we learned many valuable things from this experience we decided to no longer use AutoLab due to the many problems described above we decided no longer use AutoLab. The point of this project was to decrease time the teaching assistants have to spend on grading. The best way we believe that could be accomplished is by creating a simple to use autograder that is reliable. AutoLab is a complex piece of software that

has many points of failure and involves many systems working together correctly. We decided to develop our own autograder with a focus on simplicity. We wanted a solution that did not require user accounts, web servers, or emails.

3 Custom Built CS2303 AutoGrader

The point of this project was to decrease time the teaching assistants have to spend on grading. The best way we believe that could be accomplished is by creating a simple to use autograder that is reliable. AutoLab is a complex piece of software that has many points of failure and involves many systems working together correctly. We decided to develop our own autograder so we could have understanding of how the entire system works and to make the focus on simplicity,

3.1 Overview

(See Appendix C for information on downloading and using CS2303_Autograder)

Our autograder is a command-line application written in Python and is invoked using the operating system's shell. Below is a high-level step-by-step process of how the system works:

Step 1: User inserts zip file into Insert_Zip_File_Here directory (see section 4.1.1.1 for more information)

- This zip file should contain individual student projects, which should also be zip files.

Step 2: User invokes CS2303 Autograder from command line

Step 3: User answers the questions that the autograder asks which include first name, last name and the programming assignment user would like graded

Step 4: Autograder unzips zip file and creates a list of each student who's project is in the zip file, then unzips each individual student's zip file

Step 5: Autograder moves a student's folder into the specified programming assignment folder

Step 6: Autograder invokes specified programming assignment's grading file, that file grades project, outputs a rubric and then deletes the project from the directory

Step 7: Steps 5 and 6 are repeated until each student's project is graded

3.2 Getting Started

Before we started to build our autograder we wanted to understand what needs to be graded, to do this we completed the first programming assignment for CS2303. The first assignment is to design a program that accepts specific year as input and outputs the twelve month calendar of that year. The main difficulty of the program is accounting for leap years. A leap year occurs every four years, except every one-hundred years, except every four-hundred years. So the year 2000 was a leap year but the 1900 was not, for example. After finishing the first assignment we believed that an autograder would need to do many string manipulations and interact with the shell a large amount. We had experience coding in the Python programming language, and believe Python has functions that allow easy interaction with the shell and simple string manipulation. Python is also a readable language, which would be beneficial if the autograder needs to be changed or built upon in the future.

3.3 Programming Assignment One

Our first iteration of the autograder for Programming Assignment One was monolithic, the only custom made function was the main function and was hard to follow. It was obvious to us that changes needed to be made. The aspects of the program that would most likely be reused when writing the autograder for the other assignments were compiling the code and printing a rubric. That is when we created autograder_core.py, this file was meant to contain all custom-built functions for

all grader files so that each individual file could pull from the core file and use the same function. This made the grader files look significantly neater and made it is easier to make changes to the code. With this system, if we wanted to make a change, we could change the function in the core file and it would change it for every grader file. We found that debugging the code and understanding the entire scope of the autograder was much simpler with this system.

We first built functions for compiling code and creating a rubric, we then took what we did in the grader file for the first assignment and turned those actions into a series of functions. The first grader was broken up into four functions, were one function built off the previous function. We believed this would make it easier to reuse functions later.

We realized when developing the first grader that it was easiest to grade the output of a program. For the first three programming assignments no function names are mandatory, and no function stubs or pre-written program shells are given to students. The student starts with a blank file and must create the entire program from scratch. The professor that teaches this class believes this is the most effective way for students to learn how to code in C, so we believed it was best to work around this design constraint. So what we thought we would do is standardize the output (see Appendix D for details on the standardized outputs of the first three programming assignments).

We also attempted to create autograders that allowed teaching assistants to never have the need to compile and run the program. We believed that computers more efficiently compile, run and test code than humans can. However, teaching assistants can do a far superior job when it comes to checking a programs style and checking aspects of a program that cannot be tested based on the output. We did not attempt to autograde any style aspect of a program but did try to ensure that everything that involved compiling or running a student's program was autograded.

Every programming assignment has a certain number of tasks that a student must accomplish to earn full points on the assignment. These tasks are how the professor and teaching

assistants can measure how well a student implemented the design goals of a programming assignment. For the first programming assignment there are seven tasks, the autograder is able to grade the first four tasks

- Task 1: Correct compilation without warnings
    - This task is autograded using the `compile_test` function (see Appendix A.2). This function is able to run the command used to compile the project. It checks if the compile was successful then returns the points the student earned and the reason the student earned that score.
- Task 2: Correct execution with graders' test cases
    - This task is autograded using the `check_year` function (see Appendix A.8). This function compares the output of the student's code for a specific year to a pre-written project that to our knowledge is always correct. It then returns 0 if the outputs were different or 1 if outputs were the same. The result of the function is then used to determine the students score and reason for score.
- Task 3: Correct usage of scanf() to get inputs from user
    - This task is autograded using the `search_words` function (see Appendix A.6). This function ensures that the first month of the year and the inputted year is printed in the output in the correct spot. This shows that scanf() was implemented correctly because year that was inputted by the user was printed out in the output, showing the program successfully accepts user input.
- Task 4: Correct usage of print() to print the various lines of the calendar
    - This task is autograded using the `check_month` function (see Appendix A.7). This function ensures that the student properly lined up the dates in a certain month with the days of the week, with correct formatting.

- Task 5: Correct usage of conditional and loop statements
    - This task is autograded using the `check_year` function again (see Appendix A.8). It checks to ensure the year 2000 prints out correctly. We used this year because it requires that all the leap year calculations are correct, making it one of the hardest years to correctly print out.

The remaining tasks we were not able to autograde. They involve manual inspection, and the correctness cannot be determined by the output of the student's code. To combat this problem we expanded on the task descriptions within the programming assignment description to give teaching assistants a better understanding of what to look for. We believe this will reduce the time it takes to grade these tasks significantly. Two aspects of grading that take time is for a teaching assistant to determine what exact to look for in students code, and to answer students emails or questions asking why she received a certain score on a task. With specific instructions on what to look for, teaching assistants will not need to think as much when grading, and will be able to be transparent as well as direct with students, which will reduce follow up questions and in person meetings. The remaining three tasks should be graded as follows.

- Task 6: Satisfactory README file – 2 Points
    - Explanation of how a student's program works - .5 Points
    - Explanation of how to run program - .5 Points
    - Includes information about use of outside sources – 1 Point
        - If a student did use an outside source, source must be cited with at least a one sentence explanation per source.
- Task 7: Loop invariant for each loop in comments in the code and also in the README document

- One or two sentences explaining each loop invariant in the comments of the source code. – 2 Points
- One or two sentences explaining each loop invariant in the README document – 2 Points
- First line of each loop invariant explanation in README document includes the line in source code document related to the specific loop invariant – 1 Point

3.4 User Interface

Next, while running the first autograder many times, we realized it would be annoying for a teaching assistant to have to find the specific grader file she wants to use. To combat this problem we created a file called `CS2303_autograder.py` (see Appendix B), which when ran displays a simple to use menu within the command linel. Then the program asks for the teaching assistants first and last name, as well as the programming assignment she would like graded. Figure One below shows what the autograder interface displays.

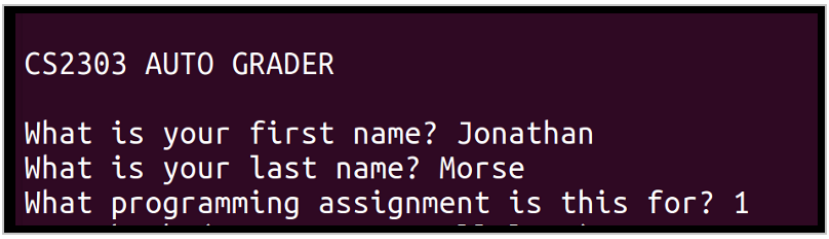

Figure One: Autograder interface

This interface allows the teaching assistant to see visually that the autograder is running and to use the same command to grade any assignment.

Once we finished the interface we were worried about how the teaching assistant would give the autograder the file or folder she needs graded. Our solution was to create a simple to understand

structure so everything was organized and have a folder that was called "Insert_Zip_File_Here" (see section 4.1.1.1), within that structure. A teaching assistant would insert the zip file that contained all of the student's code into that folder. Then we created a function called `unzip_organize` (see section A.1) that is used within CS2303_Autograder.py, this function that's unzips each zip file and the records the WPI username of the student based on the file name. Then CS2303_Autograder.py moves student folders one at a time into whatever programming assignment directory the teaching assistant chose (see section 4 for information on files and directories)

Upon further testing, another problem occurred when student's code did not properly compile. When that occurred, it would cause the autograder to return an error because no file was available. Also in the program description it states that students lose points if their code does not properly compile. So we created a function called `compile_test` (see Appendix A.2) that would produce a list of student names whose code did not compile. This list allows the program to continue running and grade other student's code as well as gives the teaching assistants a list of students with incorrect code, so they simply can email the students, inform them of the points lost and ask them to resubmit the project.

3.5 Programming Assignment Two

We believed we had worked out the initial problems with the first autograder enough to begin completing the next assignment. The major difference between this assignment and the first assignment from our perspective was the use of the "make" command and student submissions containing multiple files. We combatted these problems by developing a function that tested if a student has a functioning makefile, and if a student's program properly compiles using the "make" command. Also, we created a function that ensured that a student ran the "make clean" function before submitting the project, which was something that needed to be done according to the program assignment description.

In Programming Assignment Two a student must create a program that implements the Game of Life. The Game of Life was created in the early 1970s by John Conway, a detailed description of the game can be found at http://web.stanford.edu/~cdebs/GameOfLife/. This assignment has ten tasks, each worth four points for a total of forty points. The autograder we developed was able to grade eight out of the ten tasks.

- Task 1: Correct makefile to build program and individual components and to clean up
    - We created a function called `make_all_files_test` (see Appendix A.9) that is able create a list of all the ".c" files a student created then attempt to compile each of those individual files, once it does that it attempts to compile the entire project and then clean the entire project. Using the results of the function we were able to assign a student a score and a reason for that score.
- Task 2: Correct compilation without warnings (using –Wall)
    - We used the `compile_test` (see Appendix A.2) function again to grade this task. It runs the "make" command then returns a score and a reason for that score.
- Task 3: Correctly reading the initial configuration and centering it in the array
    - We created a function called `array_compare` (see Appendix A.11) that allowed us to compare a correct output of the Game of Life to the students output. We were able to test if a student correctly centered and configured the array using this function.
- Task 4: Correct allocation of arrays at run time – 4 Points
    - We used the `array_compare` (see Appendix A.11) function to test for this task. We ensured that the students code could produce arrays of different sizes, which ensures that arrays are created at run time
- Task 5: Correct use of two-dimensional arrays – 4 Points

    - We also used the `array_compare` (see Appendix A.11) function for this task. If the students code was able to create multiple arrays that ensures that the student used the correct technique in creating two-dimensional arrays.

- Task 6: Correct implementation of game function
    - Using the `array_compare` (see Appendix A.11) function again, we were able to check if a student properly determined if an occupied cell survived or died and if an unoccupied cell gave birth.
- Task 7: Correct test for termination
    - We created a function called `termination_condition` (see Appendix A.12) that was able to ensure that a student properly ended the game when one of the four termination conditions were met.
- Task 9: Correct execution with graders' test cases
    - Using `array_compare` (see Appendix A.11) we checked if the output from student's code was correct based on our test cases.

The remaining tasks we were not able to autograde and just like the first assignment, we expanded on the task descriptions within the programming assignment description to give teaching assistants a better understanding of what to look for. The remaining two tasks should be graded as follows:

- Task 8: Satisfactory test cases – 4 Points
    - Output of each test case is contained within submission – 1 Point
    - Explanation of each test case is in README document – 1 Point
    - Test case(s) are non-trivial and show that the student's program properly implemented the Game of Life – 2 Points
- Task 10: Satisfactory README file, including loop invariants – 4 Points

- Explanation of how a student's program works - .5 Points
- Explanation of how to run program and any problems student had - .5 Points
- Includes information about use of outside sources – 1 Point
  - If a student did use an outside source, source must be cited with at least a one sentence explanation per source.
- One or two sentences explaining each loop invariant – 1 Point
- First line of each loop invariant explanation includes the file name and line number related to the specific loop invariant – 1 Point

3.6 Programming Assignment Three

For the third assignment students must create a program that scans one or more input text files. Then use a binary tree to record all of the words in the file, then output a text file, that lists all the unique words and the number of times they occurred. The assignment is graded based on eight tasks that are all worth five points each, and has a ten point extra credit task. The autograder we developed was able to grade six out of the eight tasks.

- Task 1: Correctly build from the makefile without warnings (with –Wall switch)
  - We used the `compile_test` (see Appendix A.2) function again to grade this task. It runs the "make" command then returns a score and a reason for that score.
- Task 2: Organization of program into at least three modules
  - We created a function called `counting_modules` (see Appendix A.13) that ensures that the students program is made up of at least three or more ".c" files, then returns the score and the reason for the score.
- Task 3: Correct construction of binary tree and insertion of nodes

    - We created a function called `total_word_scan` (see Appendix A.15) that ensures the output file properly lists the number of unique words and the total number of words.

- Task 4: Correct traversal of binary tree and output of information according to specified format
    - We created a function called `individual_word_scan` (see Appendix A.16) that ensures that the format of the output file is correct, contains the proper number of words, and proper count of those words.
- Task 5: Correct use of malloc() and correctly freeing all malloc'ed data – 5 Points
    - We used the function `individual_word_scan` (see Appendix A.16) to ensure that the code did not produce a segmentation fault, to ensure malloc() was used correctly.
- Task 7: Correct execution with graders' test cases
    - We combined `total_word_scan` (see Appendix A.15) and `individual_word_scan` (see Appendix A.16) to ensure the output file is correct for our test cases.

The remaining tasks we were not able to autograde, we expanded on the task descriptions within the programming assignment description to give teaching assistants a better understanding of what to look for. The remaining two tasks should be graded as follows:

- Task 6: Proper destruction of tree and all of its objects before exiting – 5 Points
    - Using the free() command to deconstruct each object – 2.5 Points
    - Using the free() command to deconstruct tree – 2.5 Points
- Task 8: Satisfactory README file, including output of two non-trivial test cases – 5 Points

- Explanation of how a student's program works - .5 Points
- Explanation of how to run program and any problems student had - .5 Points
- Includes information about use of outside sources – 1 Point
  - If a student did use an outside source, source must be cited with at least a one sentence explanation per source.
- One or two sentences explaining each loop invariant with first line of each loop invariant explanation including the file name and line number related to the specific loop invariant – 1 Point
- At least two test cases, with the output in the submission and an explanation of each test case in the README document – 2 Points

4 Description of Directories and Files

For the below subsections, all files or directories that are within the same section level (ex. Section 4.1 and Section 4.2 are on the same level) are within the same directory level. With each subsection is one level lower than its parent section in the directory structure.

4.1 CS2303_AutoGrader

4.1.1 src

4.1.1.1 Insert_Zip_File_Here

This directory is where the user will input the zip file that contains each individual student's project, each student project should also be a zip file.

4.1.1.2 Output_Files

4.1.1.2.1 Rubrics

This directory is where the rubrics for each student will be after the autograder is run.

4.1.1.2.2 not_clean.txt

This file will contain the name of any student who did not run the "make clean" command before submitting the project. The students who are on this list will lose points on the project. This file is deleted when running the autograder for programming assignment one because it is not needed.

4.1.1.2.3 did_not_compile.txt

This file will contain the name of any student whose code failed to compile. This list can be used by the teaching assistants to email those specific students to resubmit working code.

4.1.1.3 PA1

4.1.1.3.1 PA1_autograder.py

This file uses functions from autograder_core.py and calls to the shell to compile, grade and create a rubric for the first programming assignment.

4.1.1.3.2 PA1_Test.c

This file is a correctly implemented program for the first assignment. This file is used in the check_year function found in autograder_core.py. It is used to test the output of a student's program to the correct output. In our testing we have found no problems in this file.

4.1.1.4 PA2

4.1.1.4.1 PA2_autograder.py

This file uses functions from autograder_core.py and calls to the shell to compile, grade and create a rubric for the second programming assignment.

4.1.1.4.2 task_*_test_*_answer.txt

These files are used in the array_compare and termination_condition functions found in autograder_core.py. These functions compare this text file to the output of a student's program.

4.1.1.4.3 task_*_test_*_input.txt

These files are used in the array_compare and termination_condition functions found in autograder_core.py. These text files are needed to run programming assignment two.

4.1.1.5 PA3

4.1.1.5.1 PA3_autograder.py

This file uses functions from autograder_core.py and calls to the shell to compile, grade and create a rubric for the third programming assignment.

4.1.1.5.2 individual_word_test_answer.txt

Used as one of the arguments in individual_word_scan function in PA3_autograder.py. Contains all the individual words that should be found in the input files.

4.1.1.5.3 program_test_input_one.txt

Used as one of the arguments in both the individual_word_scan and total_word_scan functions in PA3_autograder.py. It is a text file of the Martin Luther King Jr. speech.

4.1.1.5.4 program_test_input_two.txt

Used as one of the arguments in both the individual_word_scan and total_word_scan functions in PA3_autograder.py. It is a text file of a Roosevelt speech.

4.1.1.5.5 total_word_test_answer.txt

Used as one of the arguments in total_word_scan function in PA3_autograder.py. Contains information about total number of words.

4.1.1.6 PA4

4.1.1.6.1 PA4_autograder.py

This file is a template for the programming assignment four autograder. It uses functions from autograder_core.py to print the rubric for programming assignment four.

4.1.1.7 PA5

4.1.1.7.1 PA5_autograder.py

This file is a template for the programming assignment five autograder. It uses functions from autograder_core.py to print the rubric for programming assignment five.

4.1.1.8 PA6

4.1.1.8.1 PA6_autograder.py

This file is a template for the programming assignment four autograder. It uses functions from autograder_core.py to print the rubric for programming assignment four.

4.1.1.9 autograder_core.py

This file contains all custom made functions used to unzip files, compile code, grade projects and create rubrics.

4.1.1.10 CS2303_autograder.py

This file provides an interface for the user, then unzips student projects using the unzip_organize function in autograder_core.py. Then it moves student projects to the specified autograder and invokes the autograder.

4.1.2 README.txt

This file provides information about the autograder. It contains general information, instructions on how to run the autograder, a description of files and directories and information about each argument for each custom made function in autograder_core.py.

5 Future Work

Currently, we believe that our system makes it unnecessary for teaching assistants to compile and run student code for the first three programming assignments. In our opinion, two more crucial steps are needed to make our system complete.

First, an autograder needs to be developed for the last three programming assignments. We believe that custom functions should be developed to grade these assignments, because we have not found any autograders that would be as effective as custom built function. The most efficient way of accomplishing this, in our opinion, is to start with the stub files we have created for the last three programming assignment. Then combine custom built functions with our `compile_test, compile_check and clean_check` functions. That should be enough to grade 60% to 80% of all three assignments. Second, the autograders need to be tested in the real world. This could be completed the next time CS2303 is offered, by possible having half the teaching assistants use CS2303 autograder and half perform manual grading. Using surveys, observation and interviews gather data on the time requirement, reliability and simplicity of CS2303 autograders compared to manual grading to determine the usefulness of the system.

6 Conclusion

CS2303 AutoGrader provides teaching assistants with a simple, and reliable way of automatically grading most aspects of the first three programming assignments in CS2303. This allows teaching assistants to grade programming assignments much faster than can be accomplished through manual grading, creating more opportunity for teaching assistants to host office hours and help students learn.

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8 Appendices

A. autograder_core.py

We divided up the file into subsections by function, each subsection contains a screenshot of the source code of the function and a description of each of the arguments of the function.

A.1 unzip_organize:

```
14      # Goes into the "Insert_Zip_output_Here" directory and records the
15      # name of the zip file that contains each student's project. Unzips
16      # the file and records the name of each file within. Then, unzips
17      # each student's file and returns a list of each student's WPI
18      # username and the name of the first zip file.
19  def unzip_organize():
20
21      zip_output_name = os.listdir("./Insert_Zip_File_Here")[0]
22      # removes .zip from name
23      output_name = zip_output_name.split('.')[0]
24      # unzips file
25      subprocess.run("cd ./Insert_Zip_File_Here; unzip %s"
26          % (output_name),
27                     shell=True,
28                     stdout=subprocess.PIPE,
29                     stderr=subprocess.PIPE
30                     )
31
```

```
50
51      # Unzips every students file and changes the folder name to just
52      # the student's WPI username
53      for x in range(0,number_student_zip_outputs):
54          subprocess.run("cd ./Insert_Zip_File_Here/%s; unzip %s; mv %s %s"
55              % (output_name,
56                 list_student_outputs[x],
57                 list_student_outputs[x],
58                 list_students[x]),
59                         shell=True,
60                         stdout=subprocess.PIPE,
61                         stderr=subprocess.PIPE
62                         )
63
64      return list_students, output_name
```

```
32      list_student_zip_output = os.listdir("./Insert_Zip_File_Here/%s"
33          % (output_name))
34
35      number_student_zip_outputs = len(list_student_zip_output)
36
37      # Initializes list that will contain the name of each student's project
38      list_student_outputs = []
39
40      # Removes the ".zip" from every students file name
41      for x in range(0,number_student_zip_outputs):
42          list_student_outputs.append(list_student_zip_output[x].split('.')[0])
43
44      # Initializes list that will contain every students WPI user name
45      list_students = []
46
47      # Removes the "_PA<some number>" from every students file name
48      for x in range(0,number_student_zip_outputs):
49          list_students.append(list_student_outputs[x].split('_')[0])
```

A.2 compile_test:

```
66      # Runs provided command and checks if the return code is zero.
67      # If return code is zero then function returns grade_possible
68      # and a string saying the compile was successful. If return
69      # code is not zero then the compile failed due to error or
70      # warning, so the functions returns zero for the grade, and
71      # that the compile failed for the reason_for_score. If the
72      # return code is zero that means the function was successful
73  def compile_test(command, grade_possible):
74
75      compile_test_one = subprocess.run(command,
76                                        shell=True,
77                                        stdout=subprocess.PIPE,
78                                        stderr=subprocess.PIPE)
79
80      if compile_test_one.returncode == 0:
81          grade_earned = grade_possible
82          reason_for_score_for_score = "Compile was successful, no warnings or errors"
83      else:
84          grade_earned = 0
85          reason_for_score_for_score = "Compile failed, program had error(s) or warning(s)"
86
87      return grade_earned, reason_for_score_for_score;
```

command: a string, the command used to compile the project (ex. "make")
grade_possible: an int, the number of possible points that could be earned for the task

A.3 compile_check:

```
89      # Checks the grade earned from the compile test. If it
90      # is not equal to the highest possible grade then the code
91      # did not compile. So the function adds the student's name
92      # to the did_not_compile.txt output.
93  def compile_check(grade_earned, grade_possible, student_name):
94
95      if grade_earned != grade_possible:
96          compile_doc = open("../Output_Files/did_not_compile.txt", "w")
97          compile_doc.write("\n%s" % (student_name))
98      else:
99          return
100
101     return
```

grade_earned: an int, compile_check should be run after compile_test, and this argument should be set to the grade_earned that was returned in compile_test
grade_possible: an int, the number of possible points that could be earned for the task
student_name: a string, the name of the student who's code is being graded.

A.4 clean_check:

```
103     # Counts the number of files in the students folder then
104     # runs "make clean", then recounts the number of files.
105     # If the initial count is greater then adds the students
106     # name to the not_clean.txt file.
107  def clean_check(student_name):
108
109     initial_dir_size = len(os.listdir("./%s" % (student_name)))
110
111     clean_command = subprocess.run("make clean",
112                                    shell=True,
113                                    stdout=subprocess.PIPE,
114                                    stderr=subprocess.PIPE)
115
116     cleaned_dir_size = len(os.listdir("./%s" % (student_name)))
117
118     if initial_dir_size > cleaned_dir_size:
119         clean_doc = open("../Output_Files/not_clean.txt", "w")
120         clean_doc.write("\n%s" % (student_name))
121     else:
122         return
123
124     return
```

student_name: a string, the name of the student who's code is being graded.

A.5 test_case:

```
130     # Creates a pipe and runs given command. Then inserts program_input
131     # into the pipe and records stdout. Stdout is then decode from bytes
132     # to a string. Then the string is turned into a list of strings,
133     # split at every new line character ("\n").
134 def test_case(command, program_input):
135 
136     run_command = Popen(command, stdin=PIPE, stdout=PIPE)
137 
138     output_bytes = run_command.communicate(input=b'%d' % (program_input))[0]
139 
140     output_list = output_bytes.decode("utf8"). splitlines()
141 
142     return output_list;
```

command: a string, should be the command used to run the program
program_input: an int, the number that is entered into the program while it is running. This function was designed specifically for programming assignment one.

A.6 search_word:

```
145     # Runs the test_case function then checks to see if the two inputted
146     # words are in any line of the output. Then returns the grade_earned
147     # and the reason_for_score for that grade.
148 def search_word(command,
149                 program_input,
150                 word_one,
151                 word_two,
152                 grade_possible):
153 
154     output = test_case(command,
155                        program_input)
156 
157     for x in range(0, len(output)):
158 
159         if word_one in output[x] and word_two in output[x]:
160             grade_earned = grade_possible
161             reason_for_score_for_score = "\n\tThe number '%d' was entered as user " \
162                 % (program_input) \
163                                 + "input, code successfully scanned user " \
164                                 + "input and printed it on screen, scanf()" \
165                                 + " implemented correctly"
166             break
```

```
167         else:
168             grade_earned = 0
169             reason_for_score_for_score = "\n\tThe number '%d' was entered as user" \
170                 % (program_input) \
171                                 + " input, code unsuccessfully scanned user " \
172                                 + "input, scanf() was not implemented " \
173                                 + "correctly"
174 
175             continue
176 
177     return grade_earned, reason_for_score_for_score;
```

command: a string, should be the command used to run the program
program_input: an int, the number that is entered into the program while it is running. This function was designed specifically for programming assignment one.
word_one: a string, should be a month of the year (ex. "June")
word_two: a string, should be the string form of program_input. (ex. if program_input = 20, then word_two = "20")
grade_possible: an int, the number of possible points that could be earned for the task

A.7 check_month:

```
179     # Checks to ensure that a month starts on the proper day. It does
180     # this by finding the line with specific month on it, then appending
181     # the lines two and three lines down. The line two down should equal
182     # "Sun Mon Tue Wed Thu Fri Sat" and the line three down should be
183     # something like "  1  2  3  4  5  6  7". Then the functions checks
184     # if two specific characters match up. For example if the "t" in "Sat"
185     # matches up with "7" on the line below.
186 def check_month(command, program_input, char1,
187                 char2, month, grade_possible):
188 
189     output = test_case(command,program_input)
190 
191     # Initializes a list that will contain all strings of a particular month
192     month_list = []
193 
194     for x in range(0,len(output)):
195 
196         if month in output[x]:
197             month_list.append(output[x+2])
198             month_list.append(output[x+3])
199             break
200         else:
201             result = 0
202             continue
203 
```

```
204     # Error handling
205     if char1 in month_list[0] and char2 in month_list[1]:
206 
207         if month_list[0].index(char1) == month_list[1].index(char2):
208             grade_earned = grade_possible
209             reason_for_score_for_score = "\n\tCorrectly printed first week of" \
210                                 + " calendar for year %d, printf()" \
211                                 % (program_input) \
212                                 + " implemented correctly"
213         else:
214             grade_earned = 0
215             reason_for_score = "\n\tIncorrectly printed first week of" \
216                                 + " calendar for year %d, printf()" \
217                                 % (program_input) \
218                                 + " not implemented correctly"
219 
220     else:
221         grade_earned = 0
222         reason_for_score = "\n\tCorrectly printed first week of" \
223                            + " calendar for year %d, printf()" \
224                            % (program_input) \
225                            + " implemented correctly"
226 
227     return grade_earned, reason_for_score
```

command: a string, should be the command used to run the program
program_input: an int, the number that is entered into the program while it is running. This function was designed specifically for programming assignment one.
char_one: a char, should be the last letter of one of abbreviated days of the week. (ex. The abbreviation for Wednesday is Wed so char_one should equal 'd')
char_two: a char, should be a number anywhere from 1 to 7 in string form. (ex. '4')
month: a string, should be the name of a month (ex. "June")
grade_possible: an int, the number of possible points that could be earned for the task

A.8 check_year:

```
229     # Runs PA1_Test for user inputted year to get the correct
230     # characters to insert into check_month, then runs the
231     # check_month function for each month of the year.
232 def check_year(command, program_input):
233     # A list of strings from test program
234     test_output = test_case("./PA1_Test",program_input)
235 
236     first_week = []
237 
238     result = 0
239 
```

```
240     # A list of all the months
241     all_months = ["January",
242                   "February",
243                   "March",
244                   "April",
245                   "May",
246                   "June",
247                   "July",
248                   "August",
249                   "September",
250                   "October",
251                   "November",
252                   "December"]
253
254     for x in range(0,len(all_months)):
255
256         for y in range(0,len(test_output)):
257
258             if all_months[x] in test_output[y]:
259                 first_week.append(test_output[y+2])
260                 first_week.append(test_output[y+3])
261                 char_one = first_week[0][32]
262                 char_two = first_week[1][32]
263                 month_check = check_month(command,
264                                           program_input,
265                                           char_one,
266                                           char_two,
267                                           all_months[x],
268                                           1)[0]
269                 result = month_check + result
270                 first_week.clear()
271
272     if result == 12:
273         final_result = 1
274     else:
275         final_result = 0
276
277     return final_result
```

command: a string, should be the command used to run the program
program_input: an int, the number that is entered into the program while it is running. This function was designed specifically for programming assignment one.

A.9 make_all_files_test:

```
283         # This function test to see if each individual ".c" file
284         # compiles, and also test to see if "make" and "make clean"
285         # were implemented correctly
286     def make_all_files_test(grade_possible, student_name):
287         # Creating a list of all file names in student's folder
288         list_of_files = os.listdir("./%s" % (student_name))
289         # Number of files in student's folder
290         num_of_files = len(list_of_files)
291         # Inializing a list that will contain the name of
292         # all ".c" files in folder
293         code_files = []
294         # Finding all the ".c" files
295         for x in range(0,num_of_files):
296             if ".c" in list_of_files[x]:
297                 # If a file ends in ".c" the ".c" is removed and
298                 # ".o" is added then the string is added to the code_files list
299                 code_files.append(list_of_files[x].split('.')[0] + ".o")
300         # Number of source code files
301         num_of_code_files = len(code_files)
302         # Variables used to calculate if all compile test worked
303         total = 0
304         # Set to 2 to account for "make" and "make_clean" tests
305         tests_run = 2
306         reason_for_score = ""
```

```
307     # Goes into the folder and runs make
308     # for each individual ".o" file
309     for x in range(0,num_of_code_files):
310         output_make_test = compile_test("cd ./%s; make %s"
311             % (student_name, code_files[x]), 1)
312         total = total + output_make_test[0]
313         reason_for_score = reason_for_score \
314                 + "\n\t" \
315                 + output_make_test[1] \
316                 + " when running command: make %s" % (code_files[x])
317         tests_run = tests_run + 1
318     # Runs make on the entire project
319     make_test = compile_test("cd ./%s; make" % (student_name), 1)
320     total = total + make_test[0]
321     reason_for_score = reason_for_score \
322                     + "\n\t" \
323                     + make_test[1] \
324                     + " when running command: make "
325     # Test to make sure "make clean" works correctly
326     make_clean_test = compile_test("cd ./%s; make clean"
327         % (student_name), 1)
328     total = total + make_clean_test[0]
329     reason_for_score = reason_for_score \
330             + "\n\t" \
331             + make_clean_test[1] \
332             + " when running command: make clean"
333
334     if total == tests_run:
335         grade_earned = grade_possible
336         return grade_earned, reason_for_score
337     else:
338         grade_earned = 0
339         return grade_earned, reason_for_score
```

grade_possible: an int, the number of possible points that could be earned for the task
student_name: a string, the name of the student who's code is being graded.

A.10 test_case_two:

```
341     # Runs a command that does not need inputs when running,
342     # unlike test_case and returns stdout as a list of strings.
343 def test_case_two(command):
344 
345     output = subprocess.run(command,
346                                 shell=True,
347                                 stdout=subprocess.PIPE,
348                                 stderr=subprocess.PIPE)
349 
350     output_list = output.stdout.decode("utf8").splitlines()
351 
352     return output_list
```

command: a string, should be the command used to run the program

A.11 array_compare:

```
354     # Test to ensure that the expected array that is created
355     # when running Programming Assignment Two is what is
356     # actually created. Does this by reading a file that
357     # contains the correct array and comparing that to the
358     # array created by the student
359 def array_compare(command, answer_output, num_of_lines):
360 
361     student_output = test_case_two(command)
362 
363     # Turn a output into a list line by line
364     output = open(answer_output,"r")
365     read_output = output.read().splitlines()
366 
367     counter = 0
368 
369     for x in range(0,num_of_lines):
370         if read_output[x] == student_output[x]:
371             counter = counter + 1
372         else:
373             continue
374 
375     if counter == num_of_lines:
376         result = 1
377     else:
378         result = 0
379 
380     return result
```

command: a string, should be the command used to run the program
answer_output: a string, this should be the name of the file that contains the array that should be produced.
num_of_lines: an int, the number of lines that should be recorded of the student program's output so that only the array will be recorded.

A.12 termination_condition:

```
382     # This function first ensures that the proper array is produced
383     # using array compare, then ensures the program stopped due to
384     # the correct termination condition.
385 def termination_condition(command, answer_output, num_of_lines, condition):
386     # Tests to see if proper array is produced
387     counter = array_compare(command, answer_output, num_of_lines)
388     # Records entire output of command
389     command_output = test_case_two(command)
390 
391     for x in range(0,len(command_output)):
392         if condition in command_output[x]:
393             counter = counter + 1
394         else:
395             continue
396 
397     if counter == 2:
398         result = 1
399     else:
400         result = 0
401 
402     return result
```

command: a string, should be the command used to run the program
answer_output: a string, this should be the name of the file that contains the array that should be produced.
num_of_lines: an int, the number of lines that should be recorded of the student program's output so that only the array will be recorded.
condition: a string, the reason why the students program is being terminated

A.13 counting_modules:

```
406     # Counts the number of ".c" files in a folder. Then
407     # returns a grade and a reason for that grade based
408     # on the number of ".c" files.
409  def counting_modules(grade_possible,student_name):
410     # Creating a list with all files in student's folder
411     list_of_files = os.listdir("./%s" % (student_name))
```

```
412
413         num_of_files = len(list_of_files)
414         # Creating a list of all ".c" files
415         list_of_c_files = []
416         # Creating output counter
417         num_of_c_files = 0
418         # Finding all the ".c" outputs
419         for x in range(0,num_of_files):
420             if ".c" in list_of_files[x]:
421                 num_of_c_files = num_of_c_files + 1
422             else:
423                 continue
424
425         if num_of_c_files >= 3:
426             grade_earned = grade_possible
427             reason_for_score = "Project has three or more modules"
428         else:
429             grade_earned = 0
430             reason_for_score = "Project has less than three modules"
431
432         return grade_earned, reason_for_score
```

grade_possible: an int, the number of possible points that could be earned for the task
student_name: a string, the name of the student who's code is being graded.

A.14 word_scan:

```
434         # Runs a command, and then scans the output file that is
435         # produced. It then divides the output file at the line that
436         # starts with "---" which in Programming Assignment Three
437         # divides the individual word section from the total word section.
438         # Lastly it returns three lists of strings, the first is all the
439         # lines in the output file, the second is the individual word section
440         # of the output file and the last is the total word section of the
441         # output files.
442     def word_scan(command, output_name):
443         command_output = test_case_two(command)
444         output = open(output_name,"r")
445         word_output = output.read().splitlines()
446         total_word_output = []
447         individual_word_output = []
448
```

```
448
449     for x in range(0,len(word_output)):
450         if "---" in word_output[x]:
451             total_word_output.append(word_output[x+1])
452             total_word_output.append(word_output[x+2])
453             for y in range(0,(x-1)):
454                 individual_word_output.append(word_output[y])
455         else:
456             continue
457
458     return word_output, total_word_output, individual_word_output
```

command: a string, should be the command used to run the program
output_name: a string, the name of the file that the students program outputs.

A.15 total_word_scan:

```
460     # Checks to see if the command properly counts the
461     # total number of unique words and total number
462     # of words overall in the input files(s)
463 def total_word_scan(command, output_name, test_name, grade_possible, comment):
464     total_word_output = word_scan(command, output_name)[1]
465     test_output = open(test_name,"r")
466     test_output_list = test_output.read().splitlines()
467
468     if test_output_list[0] in total_word_output[0] \
469         and test_output_list[1] in total_word_output[1]:
470
471         grade_earned = grade_possible
472         reason_for_score_for_score = comment + " was successful"
473     else:
474         grade_earned = 0
475         reason_for_score_for_score = comment + " was unsuccessful"
476
477     return grade_earned, reason_for_score_for_score
```

command: a string, should be the command used to run the program
output_name: a string, the name of the file that the students program outputs.
test_name: a string, the name of the file that contains the output that will be compared to the students output (ex. "task_four_test_answer.txt")
grade_possible: an int, the number of possible points that could be earned for the task
comment: a string, used to set the reason_for_score variable.

A.16 individual_word_scan:

```
479     # Checks to see if the command properly counts the total
480     # number of each individual word in the input files(s)
481 def individual_word_scan(command, output_name, test_name,
482                          grade_possible, comment):
483     individual_word_output = word_scan(command, output_name)[2]
484     test_output = open(test_name,"r")
485     test_output_output = test_output.read().splitlines()
486 
487     total_counter = 0
488     correct_counter = 0
489 
490     for x in range(0,len(individual_word_output)):
491         total_counter = total_counter + 1
492         if test_output_output[x] == total_word_output[x]:
493             correct_counter = correct_counter + 1
494         else:
495             continue
496 
497     if total_counter == correct_counter:
498         grade_earned = grade_possible
499         reason_for_score_for_score = comment + " was successful"
500     else:
501         grade_earned = 0
502         reason_for_score_for_score = comment + " was unsuccessful"
503 
504     return grade_earned, reason_for_score_for_score
```

command: a string, should be the command used to run the program
output_name: a string, the name of the file that the students program outputs.
test_name: a string, the name of the file that contains the output that will be compared to the students output (ex. "task_four_test_answer.txt")
grade_possible: an int, the number of possible points that could be earned for the task
comment: a string, used to set the reason_for_score variable.

A.17 header:

```
508     # Creates the header for a rubric text file.
509 def header(assignment_number, student_name, grader_first_name,
510             grader_last_name, point_total):
511 
512     # Centers the title in a space of 100 total characters
513     title = "PROGRAMMING ASSIGNMENT %s RUBRIC" \
514         % (assignment_number)
515 
516     # WPI username of student completing assignment
517     student_name = "Student WPI username: %s" \
518         % (student_name)
519 
520     # Full name of grader
521     grader_name = "Assignment graded by: %s %s" \
522         % (grader_first_name,
523            grader_last_name)
524 
525     # Total points for the programming assignment
526     point_statement = "This programming assignment is worth: %s points" \
527         % (point_total)
528 
529     # Formatting
530     header = "%s\n\n%s\n\n%s\n\n%s" \
531         % (title,
532            student_name,
533            grader_name,
534            point_statement)
535 
536     return header;
```

assignment_number: an string, a string form of a number in all caps. (ex. "TWO")
student_name: a string, the name of the student who's code is being graded.
grader_first_name: a string, first name of the grader (ex. "Jonathan")
grader_last_name: a string, last name of the grader (ex. "Morse")
point_total: an int, total number of points for the assignment, (ex. "Forty points(40)")

A.18 task_create:

```
538     # Creates a task description for the rubric text file.
539 def task_create(task_number, task_description, points_possible,
540                 points_earned, reason_for_score):
541 
542     task_statement = "Task %s: %s" \
543         % (task_number,
544            task_description)
545 
546     points_possible_statement = "Maximum Points: %d" \
547         % (points_possible)
548 
549     points_earned_statement = "Earned Points: %d" \
550         % (points_earned)
551 
552     reason_for_score_statement = "reason for score: %s" \
553         % (reason_for_score)
554 
555     # Formatting
556     task = "\n\n%s\n\n\t%s\n\n\t%s\n\n\t%s" \
557         %  (task_statement,
558             points_possible_statement,
559             points_earned_statement,
560             reason_for_score_statement)
561 
562     return task;
```

task_number: a string, a number in string form (ex. "one")
task_description: a string, a sentence describing what the task is testing for
points_possible: an int, the possible amount of points that could be earned for the task
points_earned: an int, the amount of points a student earned on the task
reason_for_score: a string, the reason a student earned a particular grade on the task

B. CS2303_autograder.py

```python
# File Name: CS2303_autograder.py
# Author: Jonathan Morse

# Used to access command line arguments
import sys
sys.path.insert(0, './')
from autograder_core import *
# Allows shell commands
import subprocess
# Allows access to file system
import os

def UI():
    print("\nCS2303 AUTO GRADER\n")
    TA_first_name = input("What is your first name? ")
    TA_last_name = input("What is your last name? ")
    AG_of_choice = input("What programming assignment is this for? ")

    compile_doc = open("./Output_Files/did_not_compile.txt", "w")
    clean_doc = open("./Output_Files/not_clean.txt", "w")

    # Unzips all student files
    unzip_file = unzip_organize()

    # Name of zip file containing all students code
    zip_file_name = unzip_file[1]

    # Creates a list of all student's names
    list_of_students = unzip_file[0]

    # Number of students being graded
    num_of_students = len(list_of_students)

    if AG_of_choice is "1":
        # Deletes the not_clean.txt file because it is not needed for PA1
        clean_doc.close()
        subprocess.run("rm ./Output_Files/not_clean.txt", shell=True)

        for x in range(0,num_of_students):
            # Moves student files into autograder folder
            subprocess.run("mv ./Insert_Zip_File_Here/%s/%s ./PA1/" \
                % (zip_file_name,list_of_students[x]),
                            shell=True)
            # Runs autograder for each student project
            subprocess.run("cd ./PA1/; python3 PA1_autograder.py %s %s %s;"
                % (TA_first_name,TA_last_name,list_of_students[x]),
                            shell=True)
```

```
48      elif AG_of_choice is "2":
49          for x in range(0,num_of_students):
50              subprocess.run("mv ./Insert_Zip_File_Here/%s/%s ./PA2/"
51                  % (zip_file_name,list_of_students[x]),
52                              shell=True)
53              subprocess.run("cd ./PA2/; python3 PA2_autograder.py %s %s %s;"
54                  % (TA_first_name,TA_last_name,list_of_students[x]),
55                              shell=True)
56      elif AG_of_choice is "3":
57          for x in range(0,num_of_students):
58              subprocess.run("mv ./Insert_Zip_File_Here/%s/%s ./PA3/"
59                  % (zip_file_name,list_of_students[x]),
60                              shell=True)
61              subprocess.run("cd ./PA3/; python3 PA3_autograder.py %s %s %s;"
62                  % (TA_first_name,TA_last_name,list_of_students[x]),
63                              shell=True)
64      elif AG_of_choice is "4":
65          subprocess.run("cd ./PA4/; python3 PA4_auto_grader.py jhmorse;",
66                         shell=True)
67      elif AG_of_choice is "5":
68          subprocess.run("cd ../PA5/; python3 PA5_auto_grader.py;",
69                         shell=True)
70      elif AG_of_choice is "6":
71          subprocess.run("cd ../PA6/; python3 PA6_auto_grader.py;",
72                         shell=True)
73      else:
74          print("Invalid character entered, please enter a number " \
75                + "1-6 for autograder to work correctly")
76
77      subprocess.run("rm -r ./Insert_Zip_File_Here/%s" % (zip_file_name),
78                     shell=True,
79                     stdout=subprocess.PIPE,
80                     stderr=subprocess.PIPE)
81
82  UI()
```

C. User Guide

We developed the CS2303_AutoGrader in an Ubuntu 16.02 virtual machine, and we recommend you use CS2303_Autograder with Ubuntu 16+. We have not tried using Windows or MacOS. We also used the "root" user account within Ubuntu when using CS2303_AutoGrader, so we cannot guarantee the system works using a standard user account.

To download application:

Go to https://web.wpi.edu/E-project-db/E-project-search/search and toggle to "Author" under the "Fields" column and type "Jonathan Morse" under the "Fields" column in the same row. Then click on the project titled "CS2303_AutoGrader" and download the zip file called "CS2303_Autograder.zip".

To use:

Step 1: Unzip and open "CS2303_Autograder.zip"

Step 2: Type "cd src; cd Insert_Zip_Files_Here"

Step 3: Insert zip file of student's projects into this directory

Step 4: Type "cd ..; python3 CS2303_autograder.py"

Step 5: Fill in first name, last name and what programming assignment needs to be graded

Step 6: Once autograder finishes, type "cd Output_Files; cd Rubrics" to see student's text file rubrics.

D. Programming Assignment Output Specifications

As we mentioned previously, we designed the functions in this autograder to manipulate the output of student's programming assignments. In order to do that effectively the output of the programming assignments have to be standardized.

For Programming Assignment One:

Example Output:

```
January 2018

Sun  Mon  Tue  Wed  Thu  Fri  Sat
       1    2    3    4    5    6
  7    8    9   10   11   12   13
 14   15   16   17   18   19   20
 21   22   23   24   25   26   27
 28   29   30   31

February 2018

Sun  Mon  Tue  Wed  Thu  Fri  Sat
                      1    2    3
  4    5    6    7    8    9   10
 11   12   13   14   15   16   17
 18   19   20   21   22   23   24
 25   26   27   28

March 2018

Sun  Mon  Tue  Wed  Thu  Fri  Sat
                      1    2    3
  4    5    6    7    8    9   10
 11   12   13   14   15   16   17
 18   19   20   21   22   23   24
 25   26   27   28   29   30   31
```

Notes:

- Exactly one blank line is needed before and after the "<month> <year>" line, as seen in the example above
- Every line that has the month on it must also have the year on it (ex. "March 2018"

- No blank lines between "Sun Mon Tue Wed Thu Fri Sat" and " 1 2 3 4 5 6" lines

For Programming Assignment Two:

Example Output:

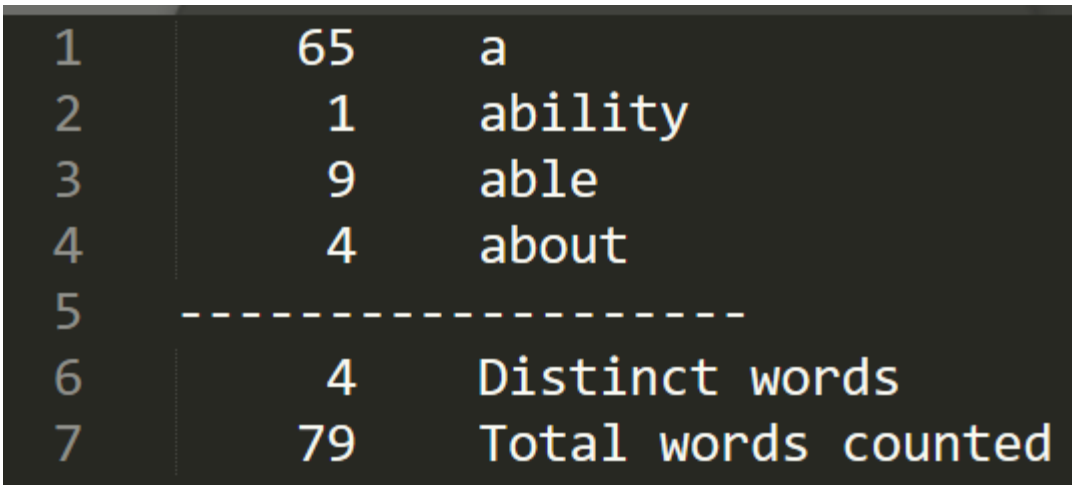
```
ooo
oXo
ooo

ooo
ooo
ooo

The Game of Life ran for 1 generations.
The Game ended because all of the cells are dead.
```

Notes:

- The first array must start on the first line of the output, as seen above.
- There should be exactly one blank line in between arrays
- The last line of the output must describe why the game ended. It must contain one of four possible phrases. Those phrases are "predefined", "dead", "steady state", and "oscillating".

For Programming Assignment Three:

Example Output:



Notes:

- First individual letter output must start on the first line of the file
- There must be at least three dashes ("---") separating the individual word counts and the total word counts
- There must be a tab in-between the number of occurrences and the words or sentences
- The field width of the number of occurrences of each word or total words should be at least six decimal digits