UNIVERSITY OF WESTERN ONTARIO

DEPARTMENT OF COMPUTER SCIENCE

CS4470Y: SOFTWARE MAINTENANCE AND CONFIGURATION

FINAL PROJECT REPORT

Faulty: Fault Localization as a Service

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April 10, 2018

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Abstract

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Introduction *(1.5 pages max)*

Concepts, Terms, Definitions, Equations *(1 page max)*

RSF

An RSF is a map of relationships betweens tokens within a codebase, where a token is a keyword in the codebase such as a method. It is generated using preprocessing scripts, and the result allows us to verify tokens inside of bug reports.

Bug Report

A database entry for each bug report used for the analysis. Each bug report contains a String field containing what a user wrote inside their bug report.

Token Expansion

Tokens extracted from the bug report are expanded to find other similar tokens. Token expansion includes tokens that are referenced by the original token set.

Clique

A collection of tokens that are referenced the most within the expanded set of tokens

Cluster

A group of relationships that are closely related to each other
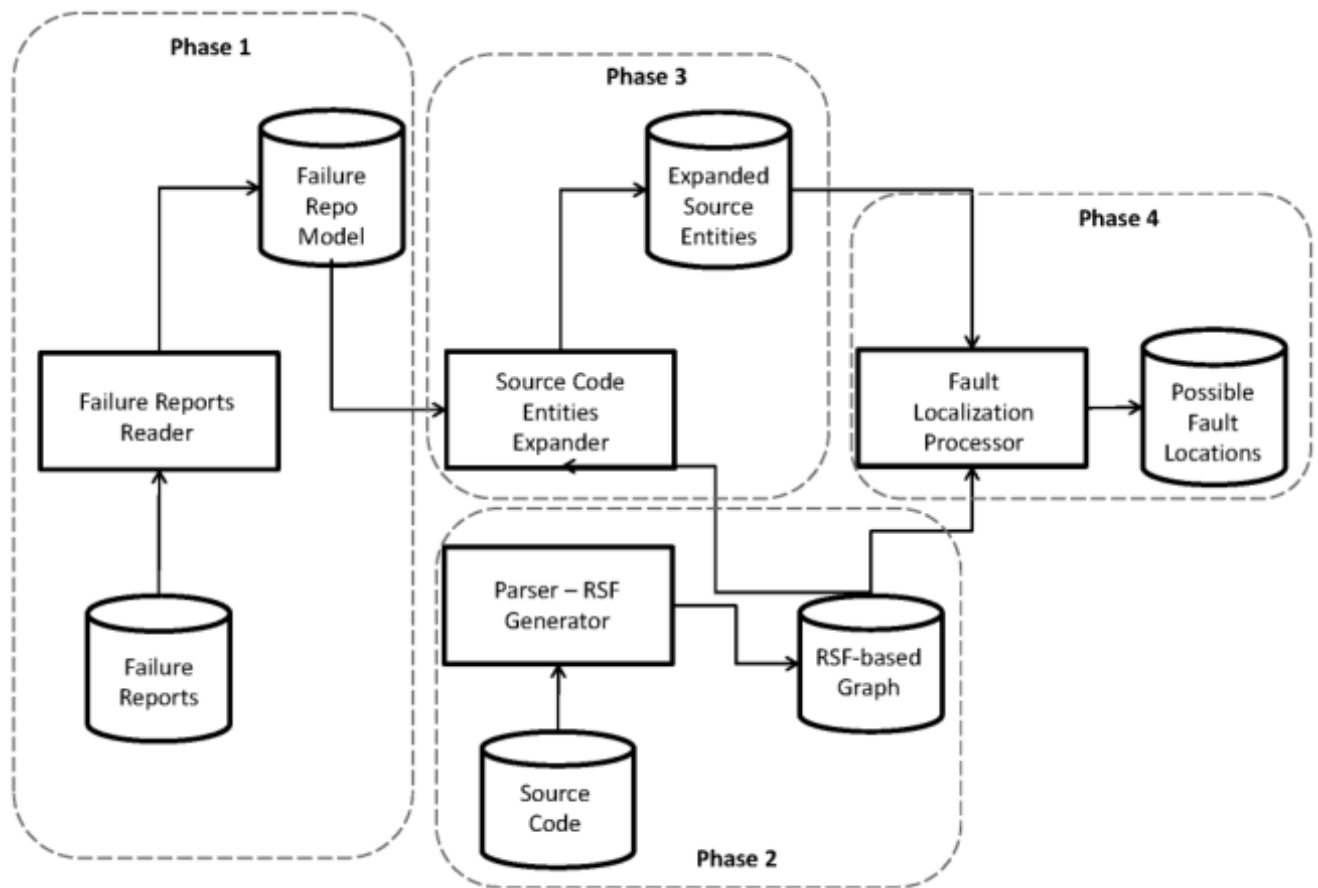
Background and Related Work

The main purpose of this project is to assist in locating faults so developers can isolate errors quicker. There are three main categories of fault localization: static-analysis/test-case based approach, machine learning based approach, and a type based approach. The method that we are expanding upon falls into the first category with an approach that heavily relies on preforming static analysis on the code and bug texts.

This project was conceived from research that Professor Kontogainnis had completed with past students regarding the task of determining faults in a large codebase using only past bug reports. Past students had experimented with multiple algorithms for processing large amounts of bug reports in order to come up with an index of files that are most likely to have a new bug within them.

The project operated in many phases. Each one containing one very specific task. The first phase involved extracting bug reports from a repository and parsing them through a reader into an object model that allowed easier processing. The second phase handled pulling the source code of the project and generating tokens. Tokens can be entities in the codebase but for our specific use they are method names that are later lifted up to filenames. A map of these tokens is created and then using the results from phase 1 and 2, the next piece of software is ready to make a connection between these two datasets. In phase 3 each of the tokens extracted from the bug report are verified and expanded to generate a set of tokens that include all relatives to each token. A token's relative is defined as a token that makes a call to or from the original token.

The first three phases mostly involved preprocessing different datasets into a form that would be ideal for making a conclusion. At this point we have a large set of entities that we suspect are vaguely related to the bug report we want to process. Phase 4 is where we begin making conclusions on the data. The software chooses between two algorithms for determining the score that will indicate the faulty files. If the amount of files associated with the bug are less than 15% of the total system files, we choose the simpler algorithm and find the score by determining which files have the most outward connections to the codebase. If the bug effects more than 15% of total files, we generate clusters of related entities using our relationship map produced in phase 2 and then for each cluster we check how connected it is to the most important files related to our bug. The cluster that is most connected has the highest chance of containing the bug.

The original system consisted of a collection of scripts written in Java, Python and Shell. The scripts were fairly distributed and had very little documentation. Most of the work was done in intermediate steps and did not fit well together as a system because too much user intervention was required between steps.

Diagram

Phase 1

Failure Repo Model

Failure Reports Reader

Failure Reports

Phase 3

Expanded Source Entities

Source Code Entities Expander

Phase 4

Fault Localization Processor

Possible Fault Locations

Phase 2

Parser – RSF Generator

Source Code

RSF-based Graph

Development Objectives *(0.75 page max)*

Develop a complete system (O1)

Since they are so many individual parts to the system required to run the system, we wanted to combine scripts and Java code into an easy to access complete system. Considering there were still some Python scripts we did not get access to by the end of the project, it would be very beneficial to have a complete system that is able to handle new codebases and improve with new bug reports.

Be able to integrate with a GitHub based workflow (O2)

We saw a great opportunity to integrate this system into GitHub's system. Initially, the system was set up to read reports from BugZilla, but we wanted to add the ability to integrate the system with GitHib's issue tracker. This would entail fetching new issues as they are created in a repo and processing them, pushing results back to the issue page so the developers can get a head start, and allowing users to authenticate using GitHub.

Operate as a standalone service with a UI (O3)

The system initially was just run through a terminal, and because there aren't too many options needed from the user, it would be beneficial to create a system that can work independantly with an easy to use interface. This would Work in a similar fashion to other CI tools, such as Travis. We would also plan to give users the control to hook into any of their repositories.

System Requirements *(2 pages max)*

Section A : Data Processing

- **Feature 1:** Able to generate entity relationship rsf from codebase
    - FR 1: Pass code through cdif2rsf to generate rsf
    - FR 2: Clean up incorrect entity and relationships
    - FR 3: Store in accessible data storage for next step to use

- **Feature 2:** Able to generate set of keywords from bug description
    - FR 1: Compare each token to codebase to find valid functions
    - FR 2: Expand initial token set by a factor of 3
    - FR 3: Use NLP to determine question context

- **Feature 3:** Able to combine keywords and rsf into ranked outcomes
    - FR 1: Run LSI on each token and generate search space for each
    - FR 2: Expand the search space for each result in FR 1
    - FR 3: Find similarities between the initial token expansion and the final set of tokens
    - FR 4: Apply ranking equation from research paper to come up with final outcome

Section B : Front-End User Interface

- **Feature 4:** User is able to scan and mark a new repository for processing
    - FR 1: Scan user's Github repos using Github's API
    - FR 2: Allow the user to select ones they wish to run processing on
    - FR 3: Remember which ones the user selected by storing on backend

- **Feature 5:** User is able to view the results of a new bug report's processing
    - FR 1: Monitor output from backend endpoints showing new results for user's repos
    - FR 2: When a new bug report is created, and the processing finishes, show the output of that processing on a separate page
    - FR 3: Allow the user to rerun processing on a specific bug report by sending a request to backend

- **Feature 6:** User is able to login using their Github credentials
    - FR 1: On first usage redirect user to Github's App authentication page
    - FR 2: Ask backend to associate bug reports and repositories with this user
    - FR 3: Redirect user to main UI

Section C : Back-End Runtime Processing

- **Feature 7:** Support front-end operations

    - FR 1: Allow registration using Github Auth
    - FR 2: Allow retrieval of processing results for each bug report
    - FR 3: Support re-running processing on a specific bug report
    - FR 4: Create a API where the UI can fetch everything from

- **Feature 8:** Manage the automation of Data Processing (F1, F2, and F3)

    - FR 1: Automate RSF generation when a new repository is linked
    - FR 2: Automate keyword generation when a new repository is linked
    - FR 3: Continuously improve and modify RSF and keywords as code/bugs change

- **Feature 9:** Handle processing and evaluation when a new bug report comes in

    - FR 1: Monitor marked repositories for each registered user and trigger when new issue is filed
    - FR 2: Run through automated ranking algorithm
    - FR 3: Store result for later retrieval
    - FR 4: Be able to connect to a repository and fetch an issue when it is posted

- **Feature 10:** Combine each element of data processing into the backend runtime

    - FR 1: Combine entity generation into token generation
    - FR 2: Combine FR1 with RSF processing all into one unit
    - FR 3: Move all functionality to an exposed part of the API
    - FR 4: Create all endpoints for data processing functionality

Development Strategy *(2 pages max)*

Since this project had a lot of the main functionality already implemented, we did not have many choices over what development tools and languages to use. The majority of the project was written in Java, with some separate Python scripts used for data manipulation at some of the stages in the system. Including the development tools previously mentioned, the following were also used in the system:

Technologies

- Kotlin
- Python
- Java
- Javalin
- MongoDB
- Github Webhooks

Tools

- Intellij Idea
- NeoVim
- Robo3T
- ngrok

Datasets

- BugZilla reports

Results *(10 pages max)*

BugLocalization Project

- Restructured and cleaned up codebase
- Reduced very large codebase to 10 files
- Documented and made more readable for easier integration

API

- Able to monitor a GitHub repo for events
- Detect new issues and add into a Mongo database
- Able to start and end deployments on Pull Requests

Discussion *(1.5 pages max)*

Threats to the validity of the results

Due to the large amount of bug reports and the possibility of having reports without enough details, the results are not guaranteed to find where the fault occurs. The ranking used in the system is useful in mitigating incorrect results, but does not gurantee that any of the results will be useful in determining the cause of fault in the software. A lot of other methods used to minimize the threats to validity were already implemented in the project, but it was mentioned that using different algorithms would allow us to compare the accuracy of different methods.

Implications of the results

One of the original goals of this project was to implement another algorithm for determining the cause of fault to then use to compare the validity of the results for both algorithms. The validity of the results is important for a system like this because of how flexible it is for testing on software projects. The system would be language agnostic and allow the user to be able to accurately detect specific points of faults in software projects that use multiple languages. This is much more useful than traditional tools used for detecting issues in software and would be applicable to any project, where those that have large projects and/or use multiple languages would benefit the most.

This system would save software engineers lots of time and effort wasted on debugging issues with software systems that don't provide enough information about where a fault in the program occurs.

Limitations of the results

The main limitation to this project is the complexity of being able to detect a fault based on reports alone. When developing, users have many methods of getting feedback through logs and error detection that are not available to our system. The best way to remove this limitation would be to get more details from failure reports, but unfortunately there are not many alternatives that offer nearly as many reports as BugZilla.

Conclusions *(1 page max)*

Unfortunately, for our project we had some communication problems for a large portion of the year. We ended up getting a late start to the project and had to re-purpose the project after the second milestone. Due to our late start and a couple missing scripts, we did not have access to all parts of the system needed to create a complete system and did not have enough time to create a standalone service with a UI. The implications of creating a complete system would mean that the computer running the system would have to be powerful enough to process all parts of the analysis within a reasonable amount of time in order to be of use to the programmer. Based on our testing with the components we had, we believe that this would be achievable if given access to the remaining parts of the program. We were able to refactor the code and greatly improve the structure and readability. The main method contained too much of the logic of the system, so modularizing the code and adding comments made it much easier to understand for others who will look at the code.

Completing O2 added the ability to connect to GitHub using their API and get issues from their tracker. Since the biggest change to the existing system is the report data used, the main structure of the system remains the same while allowing it to be used in another useful domain. Using this system in GitHub allows developers to easily discover faults in their applications. The system is set to be run whenever an issue was added by a user and would notify the repo owner.

Future Work and Lessons Learnt *(1 page max)*

Future work

- Develop software to process issues incrementally into the BugLocalization
- Integrate the BugLocalization project as part of the API and utilize its full power
- Make a web UI similar to Travis to display results

Lessons learnt

- Develop consistent communication plan with stakeholders