An Exploratory Study on the Information Seeking Behavior of Developers on Stack Overflow

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Project Description

Developers use Stack Overflow daily to find answers to questions they might have while coding or debugging software. The Stack Overflow website is an essential and a growing resource among developers. Software developers use it to post questions and answers related to programming and software engineering problems they need to solve. Questions such as seeking input on some efficient and time-saving methods of coding a particular program, getting help on solving various bottlenecks in coding are commonly seen. There is a lot of data on Stack Overflow. To date, it includes over 12 million questions, 19 million answers and 47 million comments all freely available for developers to query from.

Given the availability and size of the dataset many researchers in the software engineering field are looking into ways to use the Stack Overflow dataset to determine or predict some aspect of the data such as finding the causes of unanswered questions [1] or finding the gender of Stack Overflow users [2]. In contrast, we are interested in a long term goal of helping developers while they work by automatically formulate queries to help them with their daily work. However, in order to build such an automated system that formulates queries for developers, we first need to understand how developers work. We need to study a set of developers to understand patterns of information seeking behavior or information foraging in order to develop better theories. Since Stack Overflow is used ubiquitously by a majority of developers, we chose to focus on it. Our methods can be extended to other types of information stores as well.

In order to understand the behavior, we will conduct an exploratory study using a state-of-the-art eye tracker and screen logging software to study how developers go about solving software tasks such as fixing a bug, or summarizing an unknown method API element. Thus, *our goal for this project* is to learn via an eye-tracking study how developers find information on Stack Overflow based on the task they are given to solve. The information we seek to find includes the types of queries they use [3], what results they read and what parts of the posts they focus on the most. The eye tracker gives us fine-grained data on the latter two items. In addition, we are also interested in how developers navigate through the results.

Eye Tracking Overview

Given any type of text, image or video the eye-tracker will show where the users look and for how long. The eye-tracking device can collect information such as eye fixations and saccades. Scanpaths are a set of fixations in order. See Figure 1 for an example of fixations, saccades, and scanpaths. The circles indicate fixations, the radius of the circle represents the duration of the fixation, and the lines between fixations are saccades. The numbers shown in the circles are the fixation number. A sequence of fixations and saccades is a scanpath.

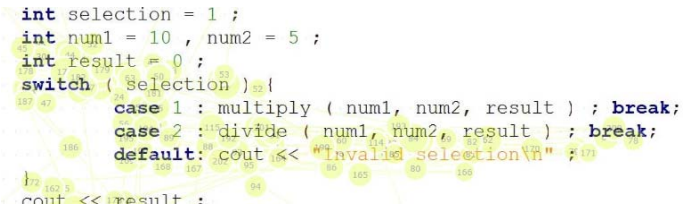

Figure 1: Scan path of an expert reading a C++ program.

Eye tracking has only recently been used in the field of software engineering to study how developers work [4-6]. Although it is new to software engineering [7], eye tracking has been used to study cognitive processes involved in the comprehension of visual material for over thirty years [8]. The main premise is that mental processes are triggered when people focus on certain things [9]. This focus is referred to as visual attention.

In our project, the tasks are related to software engineering artifacts such as source code and Stack Overflow questions/answers. In particular, the task will be to fix a bug and summarize an API element (not known to the user). The participant will also be instructed that they can use Stack Overflow to look for solutions. PI Sharif and her team have developed an Eclipse plugin namely iTrace [10-12], that automatically maps eye gazes on semantic elements even in the presence of scrolling and file switches. This makes it extremely versatile to conduct a study that involves large code bases, and Stack Overflow documents. Our tool is able to seamlessly switch between different artifacts and still capture fine grained line level and sub-line level gaze information.

Eye trackers generate a huge amount of data per session per user. An eye tracker running at 300 Hz will generate 300 samples per second. This can easily add up to a lot of data during a session that typically lasts anywhere between 20 minutes to 60 minutes. This data is very rich in thought processes, strategies, techniques that a user utilizes while they are working on a task. Fixations and saccades are the two most widely used eye movement measures. We will also focus on pupil dilation and the saccadic amplitude to determine trends in developer cognitive overload.

Our main goal this year is to use eye movement data of developers to determine how they forage for information on Stack Overflow. The main benefits of this work are to build heuristics to help automated query formulation based on the results of this study. For example, if based on eye movement data we recognize that a developer is having trouble understanding a parameter in a method call, we can help them by querying Stack Overflow and prompt them with a list of choices that might help them with parameter selection. This is one example of how we would use the results of this study. In order to find more heuristics, it is imperative to first understand how developers look for information and help automate the process in the long run. Secondary benefits include a deeper knowledge of how developers use Stack Overflow. To date, we are not aware of any eye tracking study on Stack Overflow documents. Our project seeks to change that.

Research Questions

For this project we will focus on the following research questions.

- What types of queries do developers formulate to find the answers to their questions on Stack Overflow?
- What parts of the Stack Overflow questions and answers do developers focus on the most?
- How do developers navigate between and within Stack Overflow posts and the code editor in order to finish working on their task?

Since this is an exploratory study, we do not form any hypotheses up front. Future studies will take results from this exploratory study and form hypotheses specific to the tasks they seek to focus on.

Methods

We will conduct an eye tracking study to determine how developers look for information on Stack Overflow to solve tasks. The most important part of a study is task selection. The student will be responsible to find a set of tasks that will best represent typical tasks a developer performs. For example, tasks could be bug fixes, refactoring or summarizing a method, class, or API element. The next important step is choosing an appropriate subject system to work with. It is important that domain knowledge exists in Stack Overflow as well. For example, Android has its own Stack Overflow space that developers can query for information. Care will be taken to make sure tasks and subject systems are chosen such that enough information is available to query from. The study will be conducted in our eye tracking lab at the Computer Science and Information Systems department. We will use the Tobii TX300 eye tracker to collect data. The eye tracker generates additional data such as pupil dilation, saccade durations, dwell time, fixation duration, to name a few. We will obtain IRB approval from YSU's IRB before we conduct the study. The student will also do the online training on how to deal with human subjects. The faculty mentors' online CITI training is current and valid.

A thorough background and literature survey will be conducted to learn about existing studies that might exist using Stack Overflow. The study we propose will take into account prior designs adapted towards the use of an eye tracker for data collection.

Performance Metrics

While writing up the experiment design, the team will come up with a set of dependent variables that we see to measure performance by. The eye tracker gives us fixation counts, fixation durations, pupil dilation, saccades and their amplitude. Other derived measures will also be introduced such as transition times between certain parts of the Stack Overflow posts and the source code. We will then run parametric or non-parametric tests where appropriate on each of these variables. Since this is an exploratory study, we will finalize these metrics during the experimental design phase.

Impact on the Goal of CREU

The goal of the CREU project is to encourage females and minorities to pursue graduate work and study in the field of Computer Science. This project will provide realistic research experience for our female undergraduates, by active involvement in the planning, execution and interpretation of scientific research. Well-developed research projects can significantly enrich the educational experience for undergraduate students. Working on this research project, the students will be able to enhance their computer and programming skills, apply those skills to investigate scientific problems, learn how to formulate questions and problems and to participate in the discovery of new knowledge. A good research experience can foster an enthusiasm for lifelong learning and a desire to continue education beyond the bachelor's degree. The students will be exposed to both sides of the scientific investigation: hypothesis testing and development of theoretical explanations of observations. No science education is complete without research related activities, technical writing and oral presentations.

Participant Names

Natalie Halavick is a senior pursuing a minor in Computer Science with a major in Mathematics. She is an honors student and is very interested in pursuing a research project in Computer Science. Her mathematical background will be ideal for this type of research project that involves many mathematical models for finding sequences of information seeking behavior. She is well versed with R and can help put her knowledge of R towards a real research problem. The experiential nature of this project will add to the science of teaching and learning in software development.

Even though Natalie is the only girl we have chosen for the CREU project, she will be interacting with Dr. Sharif's Software Engineering Research and Empirical Studies Lab (SERESL) group in the department of Computer Science and Information Systems at YSU. Currently, we have a total of 5 students actively working on research projects supported by PI Sharif. Natalie will meet with PI Sharif and co-PI Lazar along with the SERESL team weekly to work on CREU specific goals but also to learn how her findings will impact other projects (long term goal of query formulation) actively being undertaken in the lab. Since she will be using iTrace (github.com/YSUSeresl/iTrace) for her study, Natalie will need to interact with the SERESL team as they are the main developers for iTrace.

Natalie is a very motivated student with great CS and Math skills. She intends to present this project at next year's QUEST at Youngstown State University (a program highlighting student research). We will also write up our results to submit to the regional and/or national scientific meetings (Mining Software Repositories and International Conference on Program Comprehension) within the software engineering field. We will also participate in the YSU STEM Showcase that is held every year and open to all nearby schools. This will help get more students interested in Computer Science projects. We have had great success with this approach and our STEM stops have always been popular and in demand. Results generated by this project will be included in one or more future manuscripts, with participating students afforded full opportunity to share the responsibilities and rewards of authorship.

Student Activities and Responsibilities

Specific tasks for the student will include: literature search and review, review write-ups, reading, presenting, and discussing research articles, designing and implementing the experimental studies, data processing, data analysis and interpretation, running sequence mining algorithms, summarizing and preparing results for presentations and publications, YSU QUEST 2018 participation and writing the final report. The students will also be mentored to prepare a conference paper that will be sent to the International Conference on Program Comprehension (ICPC) or the International Conference on Mining Software Repositories (MSR).

The primary responsibility of the student is to participate in all phases of the project: proposal, development, experiments, analysis, and dissemination. The student will be required to do weekly independent work and to schedule team meetings with the faculty advisors. The faculty advisor will meet with the student every week. Email and a central repository (Basecamp and Slack) will be used for questions, announcements, and document interchange. A blog will also be setup during the first week with clear shared responsibility for updates.

Faculty Activities and Responsibilities

Dr. Sharif has conducted over 15 empirical studies in the field of software engineering using various means of data collection such as questionnaires and mostly eye tracking hardware

and software. She will be responsible for developing concrete research methods for each of the research questions mentioned above. She will mentor the student to design the experiments that address the research questions. This will involve experimental design including selection of variables, selection of tasks, and appropriate methods before the study is implemented. The students will be part of the design and variable selection. After the data is collected, she will also be responsible for guiding the student to choose appropriate methods of analyzing the data and help with publication write-up. This CREU project will directly impact work in PI Sharif's research group and due to this will require the student to actively collaborate with her senior research students.

Dr. Alina Lazar will work to actively mentor the student and continuously supervise their progress during the one-year period. She together with her colleague (Dr. Sharif) will meet with the students on regular basis to guide their activities and answer their questions related to the project. Dr. Lazar has extensive experience in data mining, machine learning and artificial intelligence and she has written several papers related to that field. Dr. Lazar will help the students with the data analysis, and with the final report and also with the preparation of a conference paper. She will lead and oversee the data analysis aspect of the project.

The overall guidance and mentoring will not refer only to this project but also provide insights about how to apply and how to succeed in graduate school, about being a female scientist and what the options are after graduate school.

Project Timeline

Please refer to Table 1 for the project timeline.

Table 1. Project Timeline

Task Name	2017				2018							
	S	O	N	D	J	F	M	A	M	J	J	A
Literature review on studies using Stack Overflow.												
Experimental design of the study including research questions, variable selection, task selection, threats to validity, and study instrumentation. Submit IRB application for approval.												
Conduct study with students and industry practitioners.												
Analyze study results. Use various sequence analysis methods in R and Matlab to find common patterns in developer eye movement behavior. Devise a set of heuristics observed from the recorded sessions.												
Statistically analyze the results via normality and regression analysis or parametric/non-parametric tests. Write up final report and conference publications.												
Dissemination of results through papers and communications at specific conferences.												

Budget

For the proposed project we are requesting $3000 for our student. The additional $1500 will be used to support the student travel to TAPIA/GHC. While working on the project the student will be encouraged to apply for the Undergraduate Student Research Grant Award sponsored by the Youngstown State University and other scholarships. We plan on applying for the summer

extension next February. All other equipment is available at PI Sharif's lab. A summary of the budget is given below.

Items	
Academic year for Natalie	$3000
Travel allowance	$1500
Total requested:	**$4500**

Role of the CREU project within the larger scope of this research

The Department of Computer Science and Information Systems at Youngstown State University has always valued undergraduate research and provided resources for projects. The Chair, the Dean, and the Provost all encourage research activity and provide faculty with necessary time to conduct such research with students. The faculty advisors created a new usability lab in 2012 as part of an internal grant that has access to state-of-the-art machines and eye trackers that students can use for research projects. Another lab that our students will use is the Software Engineering Research and Empirical Studies Lab that was established by Dr. Sharif. The students will use both labs for conducting the eye tracking studies, data analysis and running the experiments. Recently, this lab was expanded into a new room to make room for a latest state-of-the-art eye tracker to help conduct studies at a finer grained level of sampling.

The results of this project will directly impact other projects that are currently underway at the Software Engineering and Empirical Studies Lab. Natalie will collaborate with other SERESL members to make sure the results of her work is extensible to other related projects. This will help advance not just this project but also other projects that are conducted in the lab.

This CREU project fits into a larger ongoing research undertaking by PI Sharif and her colleagues on learning how developers seek information and uses eye trackers for data collection. The unique and novel aspect is the use of an Eclipse plugin namely iTrace, developed in house by PI Sharif and her team that automatically maps eye tracking data to low level semantic elements. Natalie's work on this CREU project will significantly advance how we can further improve heuristics to help automate helping a software developer solely based on eye gaze.

Prior results of CREU projects

Alina Lazar and Bonita Sharif worked with students Jenna Wise, Ali Morris, and Alyssa Pawluk during the CREU 2016-2017 project titled: "*Improving Stack Overflow Tag Prediction Using Eye Tracking*". Jenna presented the results of this project at YSU's QUEST in April 2017. We also presented the results of this work at the Ohio Celebration of Women in Computing (OCWIC) in February 2017 and at the Choose Ohio First Research Poster Conference in April 2017. Jenna won best poster at the Choose Ohio First Conference. In addition, Jenna will be presenting this as a poster submission at the upcoming GHC in 2017. We are also happy to report that Jenna will be attending graduate school at CMU in Fall 2017 to seek a PhD in Software Engineering.

Bonita Sharif and Alina Lazar worked with students Jenna Wise and Jessica Whitely during the CREU 2015-2016 project titled: "*Predicting Areas of Interest in Code Reading*". Jenna presented the results of this project at YSU's QUEST in April 2016. We also got a poster accepted at ACM TAPIA Conference 2016. Jenna will be presenting this work in September 2016. Jenna also did this analysis as part of her senior project.

Bonita Sharif and Alina Lazar also worked with students Jenna Wise and Jessica Whitely during the CREU 2014-2015 project titled: "*Mining Eye-tracking Data to Determine Developer*

Expertise and Task Difficulty in Software Development". Jenna and Jessica presented the project "*An Eye-tracking Experiment Studying Problem Solving Behavior*" at the Ohio Celebration of Women in Computing (OCWIC 2015) conference and a talk at YSU's QUEST 2015 - a forum for student scholarship. Jessica also presented her senior project *"Towards Understanding Student Problem Solving Behavior in Algorithms via Eye Tracking"* in the department.

Alina Lazar and Bonita Sharif advised Sarah Ritchey during the CREU 2013-2014 project titled: "*Classification Algorithms for Detecting Duplicate Bug Reports in Large Open Repositories*". We got two papers published at the International Conference on Mining Software Repositories in May 2014. Sarah also presented this work at YSU's QUEST 2014, a forum for student scholarship, Ohio MAA Spring Sectional Mathematics Meeting, and the Pi Mu Epsilon meeting. We also got a poster accepted at the Grace Hopper Celebration 2014. This was presented by Dr. Sharif as Sarah had other engagements during that time. Sarah is now doing her Ph.D. at Duke University.

Bonita Sharif and Alina Lazar guided student Rachel Turner during the CREU 2012 -2013 project titled: "*An Empirical Investigation on Code Debugging and Understanding: An Eye-tracking Perspective*". Rachel presented the poster "*C ++ vs. Python: An Eye-tracking Assessment*" at the Ohio Celebration of Women in Computing (OCWIC 2013) conference and a talk at the YSU's QUEST 2013 A Forum for Student Scholarship. We also published a paper at the Eye Tracking Research and Applications Conference (ETRA) in March of 2014.

Alina Lazar advised two prior CREU projects in 2004-2005 and 2006-2007, and one MROW project in 2007-2008. Darcy Davis the participant student in the 2004-2005 project just finished her PhD in Computer Science and Engineering at Notre Dame University. Louise Popio who participated as a student during 2006-2007, received her Master's in Information Sciences and Technology from Pennsylvania State University in 2010. Irena Lanc participated in the 2007-2008 MROW project and received her Ph.D. in Computer Science and Engineering from The University of Notre Dame in 2014. Erin Pfeil the other student that did the 2007-2008 MROW project, is working on her PhD in Ecology at the University of Pittsburgh.

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