Debugging Remote Services Developed on the Cloud

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Abstract: Cloud based development platforms are getting more widely used as the cloud services become more available and the performance of such platforms increase. One of the key issues in providing a cloud based development platform is to enable the developers to debug their code just as efficiently and effectively as they would perform in a desktop IDE development session. However, especially if the development of a remote service is being carried out, the debugging client and the server running the actual code is separated, disclosing many problems which are not present in a usual debugging session. This paper proposes a record/replay approach to deal with the problems of remote debugging. To keep the communication overhead of the proposed approach as small as possible,the debugger saves the variable values only for external data access such as getting the data from a database query or a web service call. The proposed approach is integrated to a real world cloud based development platform and the run-time overhead is measured on real world case studies to demonstrate the usefulness of the approach.

1 INTRODUCTION

Continuous shift in modern software development activities towards cloud environments and the expansion of the software ecosystem that uses remote services has made the remote debugging of web software a more appealing challenge. Developers use and develop their own remote services in various different purposes while developing web based software. However debugging of the in house developed client-server web service interaction is cumbersome since it requires an interactive tracking session where the developer needs to watch remote but yet interdependent variables and control flows.

One way to ease such a challenge for the developer is to be able to record and replay the erroneous flows that has been triggered by the remote calls to the web service including the variable values. In debugging such errors developers dig into the error logs performing a postmortem analysis which becomes a needle in a haystack problem most of the time.

In this paper we present an approach for helping the developer initiate and track a remote debugging session by being able to record and replay the errors that were triggered by the web service call. During the recording session we record the local variable values and replies from the database calls which in turn enables the developer to run a debugging session by replaying the erroneous flow of the remote service with the erroneous variable values.

We also measure the overhead presented by our approach and present a lightweight version of the approach where we significantly decrease the amount of overhead by only recording the variable evaluations that are affected by external data access like a database query. Variable evaluations that were determined solely by program flow are left to be calculated by the client instead of being recorded at the server side, reducing the amount of additional information to be stored by the remote debugging engine.

In the past, a vast amount of work have been performed on debugging web services and web applications. We have adopted the interactive record/replay approach presented in the work of Brian Burg et al. where (Burg et al., 2013) a user interface is used for capturing and replaying web application executions. In our study we have shifted the focus on the applicability of the approach on web services being used in a cloud based platform.

The rest of the paper is organized as follows: in Section 2 we present our remote debugging approach. Section 3 presents the overhead generated by applying the remote debugging approach presented. Section 4 discusses the related work in the literature and we conclude our studies and present future work in Section 5.

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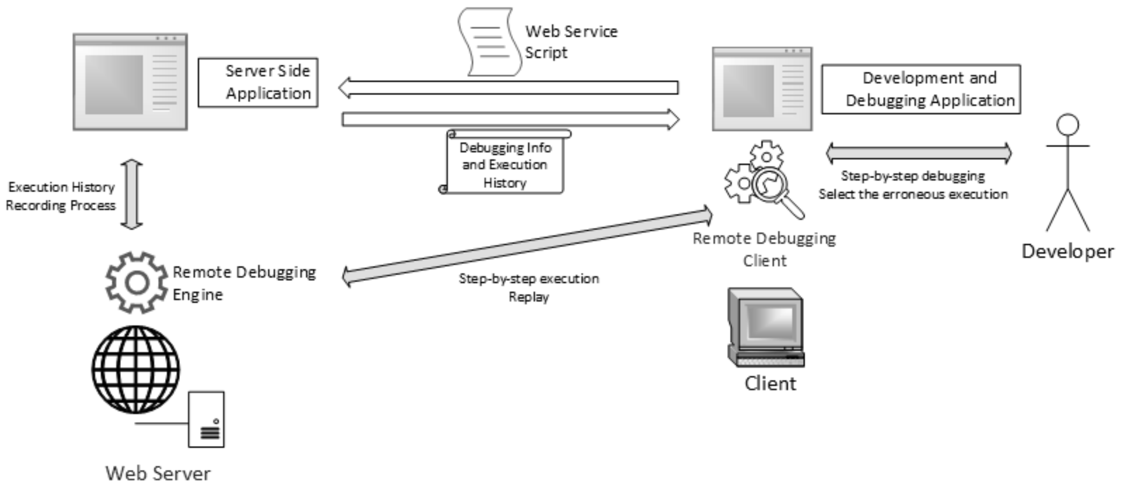

Web Service Script
Server Side Application
Development and Debugging Application
Debugging Info and Execution History
Execution History Recording Process
Step-by-step debugging
Select the erroneous execution
Remote Debugging Client
Developer
Remote Debugging Engine
Step-by-step execution Replay
Client
Web Server

Figure 1: Architectural representation of the remote debugging approach.

2 REMOTE DEBUGGING APPROACH

In our study, we integrated our remote debugging approach to a target cloud platform that enable users to develop web applications on the web browser[1]. The developer can define the data model (the entities and the fields) and also she/he can design the web pages of the application. The target platform also lets user to develop the behavior associated with the web elements using MVEL scripting language (Brock and various contributors,) as well as developing their own web services.

MVEL has largely been inspired by the Java syntax, but has some fundamental differences aimed at making it more efficient as an expression language, such as operators that directly support collections, arrays and string matching, as well as regular expressions. MVEL is used to evaluate expressions written using Java syntax.

The components and the typical information flow during a remote debugging session can be seen in Figure 1. Remote debugging components let the developer in the cloud platform to be able to execute and debug the MVEL script under development line by line interactively on the server side. A sample development session in the web client using MVEL scripts can be seen in Figure 2.

By using remote debugging, the developer can use traditional debugging features such as breakpoints, stepping over, stepping inside a function. Moreover since the state of the server is changed during the debugging session, the debugging engine also saves the state in the server at each state. This extra debugging information that is being saved can be controlled by the developer. By default, the web service debugger does not perform any state recording. The developer can choose ’minimal recording’ or ’full recording’ to set the amount of state information to be saved by the debugging engine as seen in Figure 2.

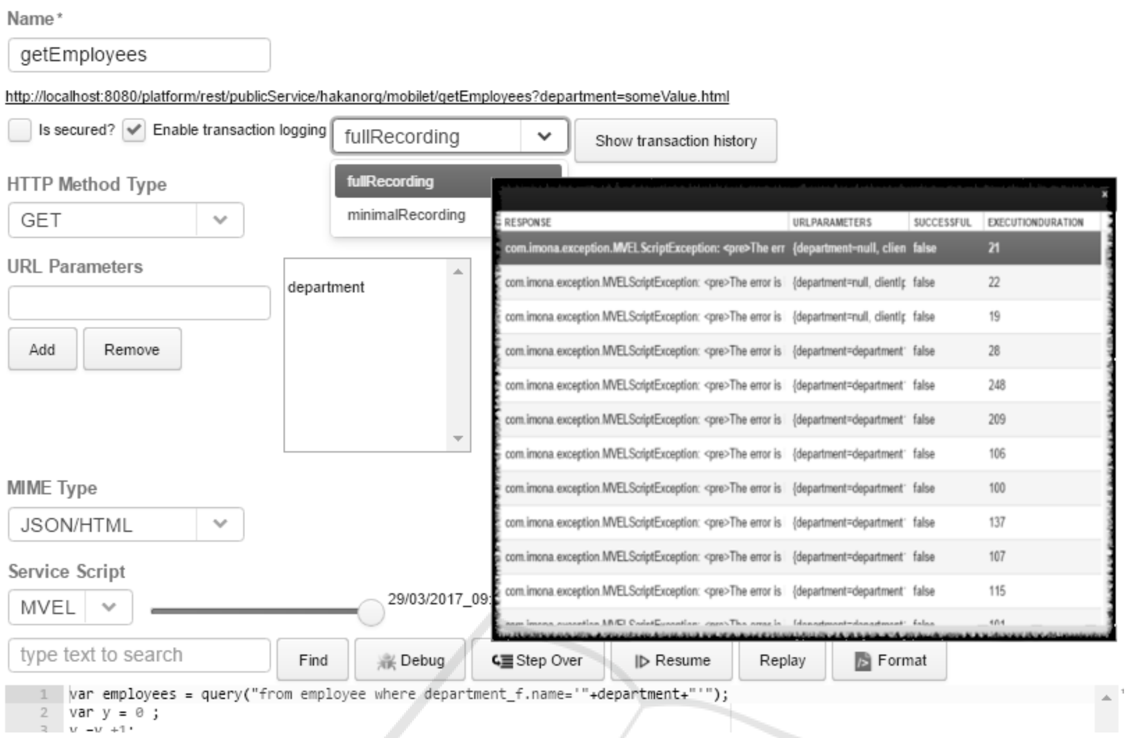
After fixing the bug, the developers need a tool to help them to make sure that the issue is solved by the fix. In our approach, the developer can use the saved input values that causes the error and re-run the program with the saved values and debug the code again to make sure that the code is working after the fix.

2.1 Full Recording

When the developer chooses full recording, the remote debugging engine running on the the server will execute the web service by storing the variable evaluations during assignment statements. Variable evaluations will be stored as tuples containing line number of the assignment, the variable name and its value. Hence, at any time the developer can choose and replay the erroneous execution by selecting it from the list of execution records as seen in Figure 2.

For each debugging session, the execution engine saves the requests that were sent by the client to the server. The developer may replay the recorded debugging session later by using the remote debugging system. When the developer replays an execution, the platform will get the saved data according to its time and display them in the variable table as seen in Figure 3

[1]Imona Cloud:https://www.imona.com/



Name*: getEmployees

http://localhost:8080/platform/rest/publicService/hakanorg/mobilet/getEmployees?department=someValue.html

Is secured? ☐ Enable transaction logging ✓ fullRecording

HTTP Method Type: GET

URL Parameters: department

MIME Type: JSON/HTML

Service Script: MVEL 29/03/2017_09:

```
var employees = query("from employee where department_f.name='"+department+"'");
var y = 0 ;
```

RESPONSE	URLPARAMETERS	SUCCESSFUL	EXECUTIONDURATION
com.imona.exception.MVELScriptException: <pre>The err	{department=null, clien	false	21
com.imona.exception.MVELScriptException: <pre>The error is	{department=null, clientI;	false	22
com.imona.exception.MVELScriptException: <pre>The error is	{department=null, clientI;	false	19
com.imona.exception.MVELScriptException: <pre>The error is	{department=department'	false	28
com.imona.exception.MVELScriptException: <pre>The error is	{department=department'	false	248
com.imona.exception.MVELScriptException: <pre>The error is	{department=department'	false	209
com.imona.exception.MVELScriptException: <pre>The error is	{department=department'	false	106
com.imona.exception.MVELScriptException: <pre>The error is	{department=department'	false	100
com.imona.exception.MVELScriptException: <pre>The error is	{department=department'	false	137
com.imona.exception.MVELScriptException: <pre>The error is	{department=department'	false	107
com.imona.exception.MVELScriptException: <pre>The error is	{department=department'	false	115

Figure 2: Selecting the type of recording session and web service to be debugged. Bordered window on the right shows the list of recorded debugging sessions.

At every step of the execution the debugging client will update the variable values in the table and the corresponding line will be highlighted. Even though full recording produces a significant amount of overhead it might be necessary to store the whole environment to be able to store the data retrieved by database query or a service call during the debugging session.

2.2 Minimal Recording

To reduce the amount of overhead presented by the approach the developer may select the minimal recording option. During minimal recording the platform will save the variable values only for external data access such as getting the data from a database query or a web service call. During replaying of a debugging session with minimal recording, the lines that contain external data access will be updated by the recorded history. Otherwise the related line will be executed directly and the variable values will be updated from the execution result.

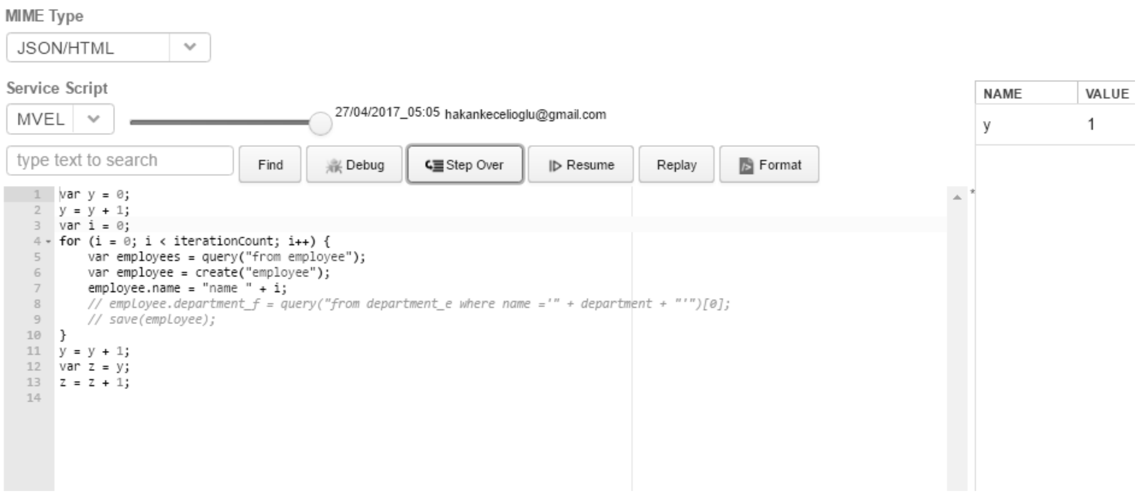
3 EVALUATION

To evaluate the overhead produced by remote debugging, we prepared sample web services to measure the effect of three different metrics:

1. m_1: Number of database queries/service calls
2. m_2: Lines of Code (LOC)
3. m_3: Number of variables

Our experimentation environment consists of a client and a server machine that reside in the same local network to eliminate the latency introduced by network access. Client computer consists of 8 gigabytes of memory and a 4 core 2.20 Ghz processor where server contains 32 GB memory and double 4 core 3.5 Ghz processors. The only application stack hosted by the server is debugged development environment server and a single developer runs the proposed debugging approach at a time. MySQL 5.7 is used in database operations required by the proposed debugging approach and the debugging application is hosted as an add-on to the development platform that is hosted in an Apache Tomcat 7.0.82 application server.

In Figure 4 we compare the execution time of the sample web service without any recording options towards the overhead presented by the full and minimal recording for the debugging session. To eliminate the effect of environmental factors on the execution we repeat the experiment 20 times and present the error rate as well in the figure. In Figure 4 we can notice that the minimal recording method performs better



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```
var y = 0;
y = y + 1;
var i = 0;
for (i = 0; i < iterationCount; i++) {
    var employees = query("from employee");
    var employee = create("employee");
    employee.name = "name " + i;
    // employee.department_f = query("from department_e where name ='" + department + "'")[0];
    // save(employee);
}
y = y + 1;
var z = y;
z = z + 1;
```

NAME	VALUE
y	1

Figure 3: MVEL script development window and variable evaluations table (on the right).

than the full recording as expected when we are increasing the number of m_1.

In Figure 5 and Figure 6 we repeated our experiments for m_2 and m_3 using the same experimentation environment. For m_2 the full recording method performance decreases dramatically as LOC increases. Minimal recording performs significantly better in this case. For m_3, changing the number of variables will not affect the performance of the full recording because the platform stores the data for each line and it is not related to the number of variables. The minimal recording is not affected as well.

4 RELATED WORK

In our study we present a remote web service debugging approach by using a record/replay technique on the remote server where web service is being hosted. Record and Replay is a good concept to detect the errors in the running systems so we can use the recorded information to detect the errors. A similar record/replay approach by Brian Burg et al. records the inputs, the variables which are related to the system state and the web calls for the web applications. When the developer wants to debug the program a user interface is presented to the developer for the current state of the program using the stored data (Burg et al., 2013).

Tools like TRACR (Troberg et al., 2015) provides developer with live editing features. By using TRACR the developer can change the JavaScript code and see the result without running the web application again, a feature of the remote debugging system that we have implemented in our study as well.

We use the server side associated with the request from the client to debug the web services. Fiddler (Telerik,) uses the client side to analyze the web services responses.

One of the main concerns in applying the record/replay technique is the amount of information that has to be stored during the recording phase. One of the approaches to deal with this problem is reducing the number of statements that the developer can check during the debugging. In our study we realize this approach by repeating the execution of the erroneous code with the stored values that causes the error.

The developer can understand the root cause of the error by debugging the execution history stored with the values that cause the error. An alternative way to recording histories can be using the statistical debugging to detect the place of the error by finding the probable location error automatically as in the case of the HOLMES framework (Chilimbi et al., 2009). Paths profiles give the developer extra information about the execution that leads to the error.

Using Holmes, the program will not use extra resources if there are no errors until facing an error. In case of an error, Holmes will update the application to detect the error. Our approach is similar to HOLMES to optimize the performance by recording the execution only if the service is throwing an exception. So after throwing the exception we execute the service again to record all the details.

HOLMES will combine the information collected from the static analysis of the code with the information collected from the bug reports to specify the programs parts that are most probably related to the errors.

Another approach to selectively debug execution paths is to use slicing techniques. For instance, Cheng

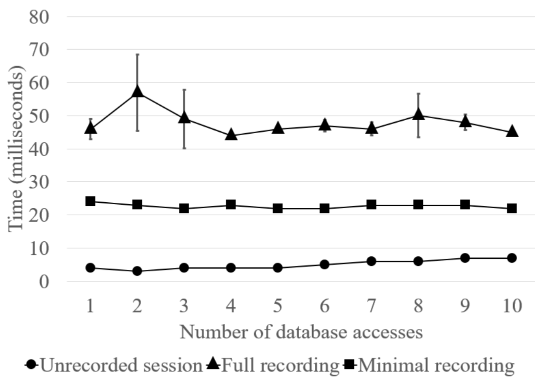

Figure 4: Execution time with respect to varying m_1.

Zang et al. separated the slicing operation to offline and online slicing to make the slicing operation faster (Zhang et al., 2012). In their study two slices has been obtained, one forward from root cause and one backward from the bug site, defining the scope to validate a fix. Time consuming operations, like static analysis, are done in the offline part of the system and the results are stored in the database and afterwards loaded into the memory when necessary.

In our method we record the erroneous executions so the developer can use the recording data later to test the scripts without the limitation of waiting the permission from the user to start the remote debugging.

Another work by James Mickens uses JavaScript's built-in reflection capabilities to provide a debugging environment that can work remotely (Mickens, 2012). If the user does not want to allow the developer to debug remotely then the debug server sends test scripts to the client. The client executes the scripts and send the result to the server to get reports about the error.

There also exists a vast amount of work on using historical execution information and execution traces to debug a program (Engblom, 2012)(Pothier and Tanter, 2009) but to the best of authors' knowledge the area of using such debuggers in remote debugging is an open area of research.

5 CONCLUSION AND FUTURE WORK

In this paper we introduced a record/replay debugging approach that can be used in debugging services developed on the cloud. We used a cloud based system where developers can implement services on a remote server by using web based clients. In our approach, we also present a minimal recording option where we record only the variable evaluations affected by web service calls and/or database operations in order to provide the developer with a debugging session that contains the original interactions that caused the bug present in the service being developed. Lightweight recording sessions produce much more scalable debugging sessions in terms of run-time efficiency.

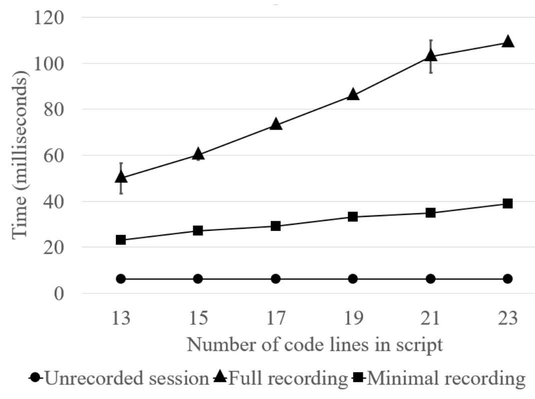

Figure 5: Execution time with respect to varying m_2 .

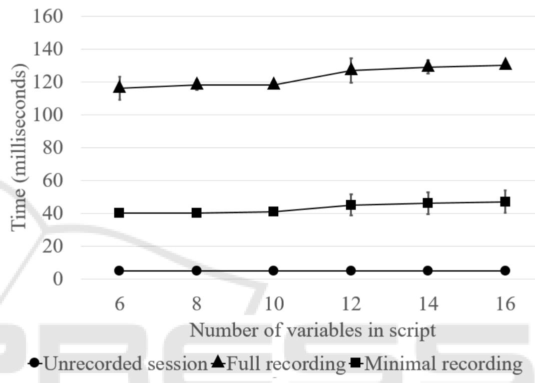

Figure 6: Execution time with respect to varying m_3 .

Our approach can be improved in a variety of different directions. For instance, it is possible to develop a time-traveling debugger allowing debugger to step backwards as well. In the literature, a similar time-traveling debugger is implemented by taking snapshots of the program state at regular intervals and recording all non-deterministic environmental interactions (Barr and Marron, 2014) (Barr et al., 2016). The minimal recording approach in our study uses similar concepts by storing the variable value only when it is related to system state. Another field to further improve the minimal recording memory footprint is to store delta differences of only the variables that are related to the error (Hammoudi et al., 2015). The impact of the proposed approach on programmer productivity is another possible area of research.

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