Improved Error Reporting for Software that Uses Black-box Components

Jungwoo Ha, Christopher Rossbach, Jason Davis, Indrajit Roy, Hany Ramadan, David Chen, Donald Porter, and Emmett Witchel

Department of Computer Sciences
The University of Texas at Austin
Bad Error Messages are Painful

- Error messages are usually uninformative
- Keyword search is often ineffective and time consuming
Improved Error Reporting

- Your remote shared directory was disconnected. Please follow the steps to reconnect it.
  - Step 1. ..... 
  - Step 2. ..... 
  - ...

![Microsoft Office PowerPoint dialog box: The handle is invalid.]

[Image of Microsoft Office PowerPoint dialog box: The handle is invalid.]
Bad Error Reporting is a Serious Problem

- Bad error reporting costs money
  - 25% of sysadmin time wasted due to bad error messages [Barrett ’04]
  - Home users pay for personal assistant
    - e.g. http://www.gotomypc.com
Why Not Fix The Software?

- Black-box software components are popular
  - Source code is not available
- Practical problems
  - Abstraction obscures global context
    - Predefined error codes
    - Exceptions
  - Multiple error cases map to a single error message
  - Developers cannot anticipate all failure modes
Talk Outline

- Error reporting is a serious problem
- **Clarify: A System to Improve Error Reporting**
- Evaluation of Clarify
  - Accuracy
  - Overhead
  - Scalability
- Conclusion
Search Workarounds with Behavior Profile

- Behavior Profile (BP) replaces keyword when searching
- Behavior Profile provides the global context
  - **Clarify runtime** produces Behavior Profile at runtime using lightweight binary instrumentation
  - BP is invisible to the end-user
- Machine learning technique is used for searching
  - Training & deployment phase

![Diagram showing the interaction between end-user and Clarify runtime with Behavior Profile (BP) at runtime.](image-url)
Training the Classifier

- **Clarify classifier** - enables search for workarounds

Supporting party

- Supporting party can be
  - Support websites – Software testers, support organization
  - Open source projects – Expert users
  - User forum – Any user willing to share their experiences

Support service

- BP: Change perm.
- BP: upgrade lib.
- BP: Fix network
- BP: Load module
- BP: Change option

Support database
Clarify enabled Software Support

- Clarify enables sharing workarounds and fixes among users

Supporting party

Black Box
Clarify runtime

Support service

- Change perm.
- Upgrade lib.
- Fix network
- Load module
- Change option

Support database

Black Box
Clarify runtime

Matched!

Keyword search
“The handle is invalid”
Behavior Profile

- Behavior Profile is
  - Abstraction of software global context
  - Generated by Clarify runtime
  - Any profile that contains history of software execution can be used as behavior profile
    - e.g. Path profiling [Ball & Larus ’96]

- 2 important Behavior Profile types
  - **Call-Site Profiling (CSP)**
    - Counter for each call-site
  - **Call Tree Profiling (CTP)**
    - Summary of dynamic call tree by counting subtree pattern
Call Tree Profiling

○ Idea
  ● Dynamic Call Tree (DCT) represents the software behavior but it is huge
  ● Call patterns have meaning
    ○ e.g. `foo()` - function that reads a file
      ● Successful pattern: `open()`, `read()`, `close()`
      ● Unsuccessful pattern: `open()`

○ Call Tree Profiling - Summary of DCT
  ● Count the call patterns of depth 2
Call Tree Profiling

- When C returns
  - C’s call pattern
    - (C D E)
  - A’s call pattern
    - (A B C)
  - Increment counter for subtree of depth 2
    - (A B (C D E))

- Counter is incremented on
  - Function return
  - Some loop back-edges
# Deployment Scenarios

<table>
<thead>
<tr>
<th>Coverage</th>
<th>Live deployment</th>
<th>Forensic deployment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unknown errors can be added to the classifier</td>
<td>Known errors only</td>
<td></td>
</tr>
<tr>
<td>Behavior Profile</td>
<td>Full</td>
<td>Partial</td>
</tr>
<tr>
<td>Instrumentation</td>
<td>Full</td>
<td>Minimal</td>
</tr>
<tr>
<td>Runtime overhead</td>
<td>Higher</td>
<td>Lower</td>
</tr>
</tbody>
</table>
Talk Outline

- Error reporting is a serious problem
- Clarify: A System to Improve Error Reporting
- Evaluation of Clarify
  - Accuracy
  - Overhead
  - Scalability
- Conclusion
Benchmarks

- Ambiguous error messages from large, popular software
  - \texttt{LaTeX}: “! Undefined control sequence”
    - Misspelled \texttt{\footnote}
    - Duplicate \texttt{\footnote}
  - 4 — 27 ambiguous error cases per programs
  - 30 — 400 test inputs per each error cases
  - Clarify disambiguates error messages

- Benchmark programs
  - 3 User applications (CTP, CSP)
    - \texttt{gcc}, \texttt{LaTeX}, \texttt{mpg321}
  - 3 Linux kernel modules (CSP)
    - \texttt{iptables}, \texttt{iproute2}, \texttt{nfsmount}
Classification Accuracy

- Overall high accuracy >85%
- CTP shows better accuracy than CSP
- CTP is only available for user benchmarks
## Deployment Overhead

<table>
<thead>
<tr>
<th>Benchmark</th>
<th>Live</th>
<th>Forensic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CSP</td>
<td>CTP</td>
</tr>
<tr>
<td>latex</td>
<td>5.3%</td>
<td>97%</td>
</tr>
<tr>
<td>mpg321</td>
<td>1.2%</td>
<td>67%</td>
</tr>
<tr>
<td>gcc</td>
<td>7.0%</td>
<td>110%</td>
</tr>
</tbody>
</table>

- CSP is suitable for live deployment
- CTP is suitable for forensic deployment
Scalability with the Number of Error Cases

- LaTeX benchmark up to 81 error cases
  - Ambiguous error cases (27) + common latex errors (54)

Accuracy drops only 4.2% from 10 to 81 error cases
Related Work

- Classifying or detecting known software problems
  - [Yuan ‘06], [Brodie ‘05], [Forrest ‘00]

- Clustering software failure
  - [Podgurski ‘03]

- Markov model of software execution
  - [Bowring ‘04]

- Related problems
  - Isolating Misconfiguration - [Wang ‘04]
  - Statistical Debugging - [Liblit ‘05], [Hangal ‘02]
Conclusion

- Error reporting is an important problem
- Clarify provides a framework for error reporting
  - Improves software troubleshooting
  - Enables effective sharing of workarounds
- Clarify classifier
  - Accurately disambiguates error cases
  - Low overhead for deployment
  - Scalable with the number of error cases