Improved Error Reporting for Software that Uses Black-box Components

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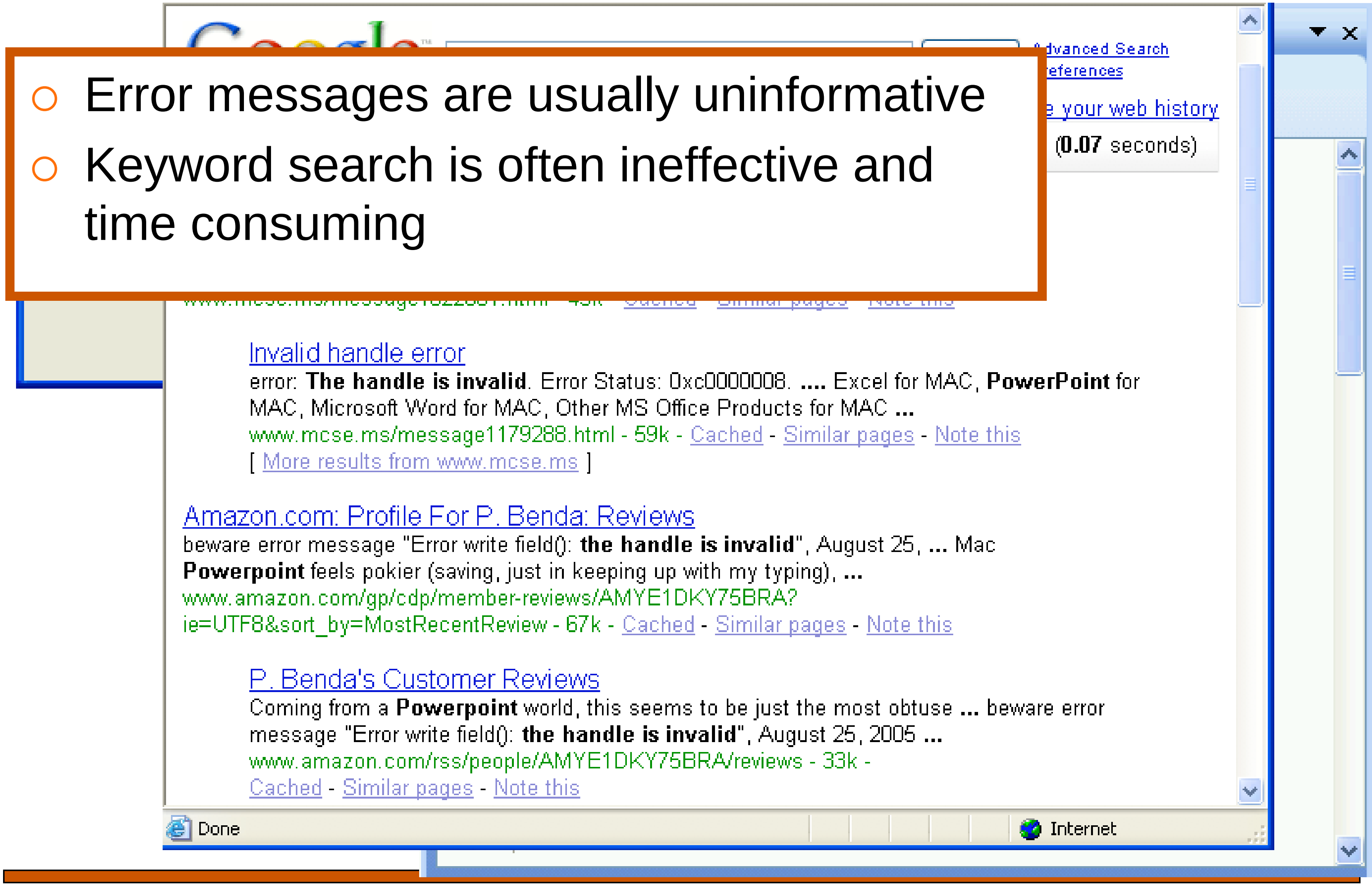
Bad Error Messages are Painful

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



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error: **The handle is invalid**. Error Status: 0xc0000008. **....** Excel for MAC, **PowerPoint** for MAC, Microsoft Word for MAC, Other MS Office Products for MAC **...**
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beware error message "Error write field(): **the handle is invalid**", August 25, **...** Mac **Powerpoint** feels pokier (saving, just in keeping up with my typing), **...**
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Coming from a **Powerpoint** world, this seems to be just the most obtuse **...** beware error message "Error write field(): **the handle is invalid**", August 25, 2005 **...**
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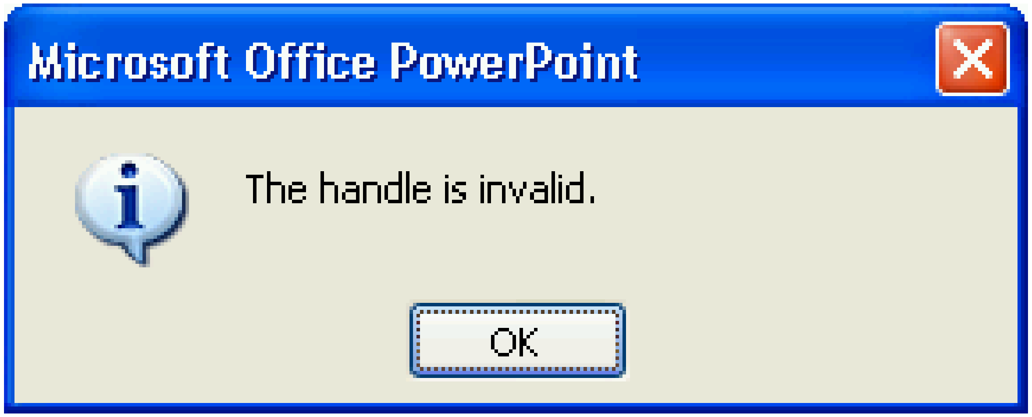
Improved Error Reporting



The handle is invalid.

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

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?

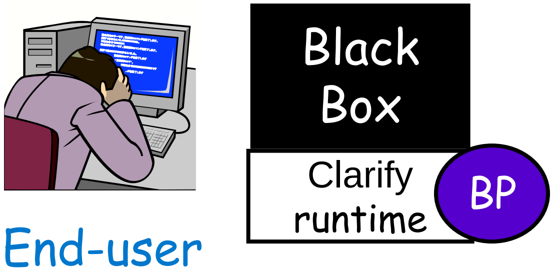
- Black-box software components are popular
  - Source code is not available
- Practical problems
  - Abstraction obscures global context
    - Predefined error codes
    - Exceptions
  - Multiple error cases map to a single error message
  - Developers cannot anticipate all failure modes

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



Black Box

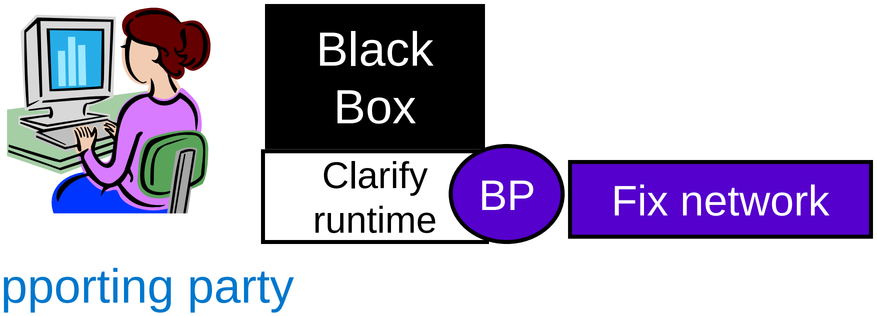
Clarify runtime

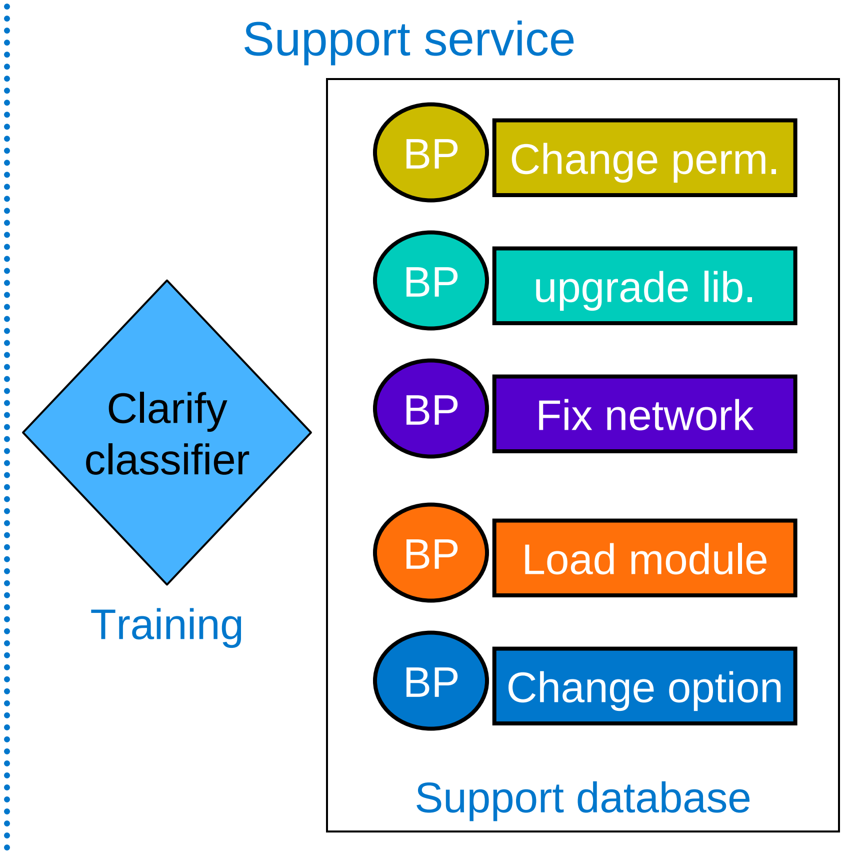
BP

End-user

Training the Classifier

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

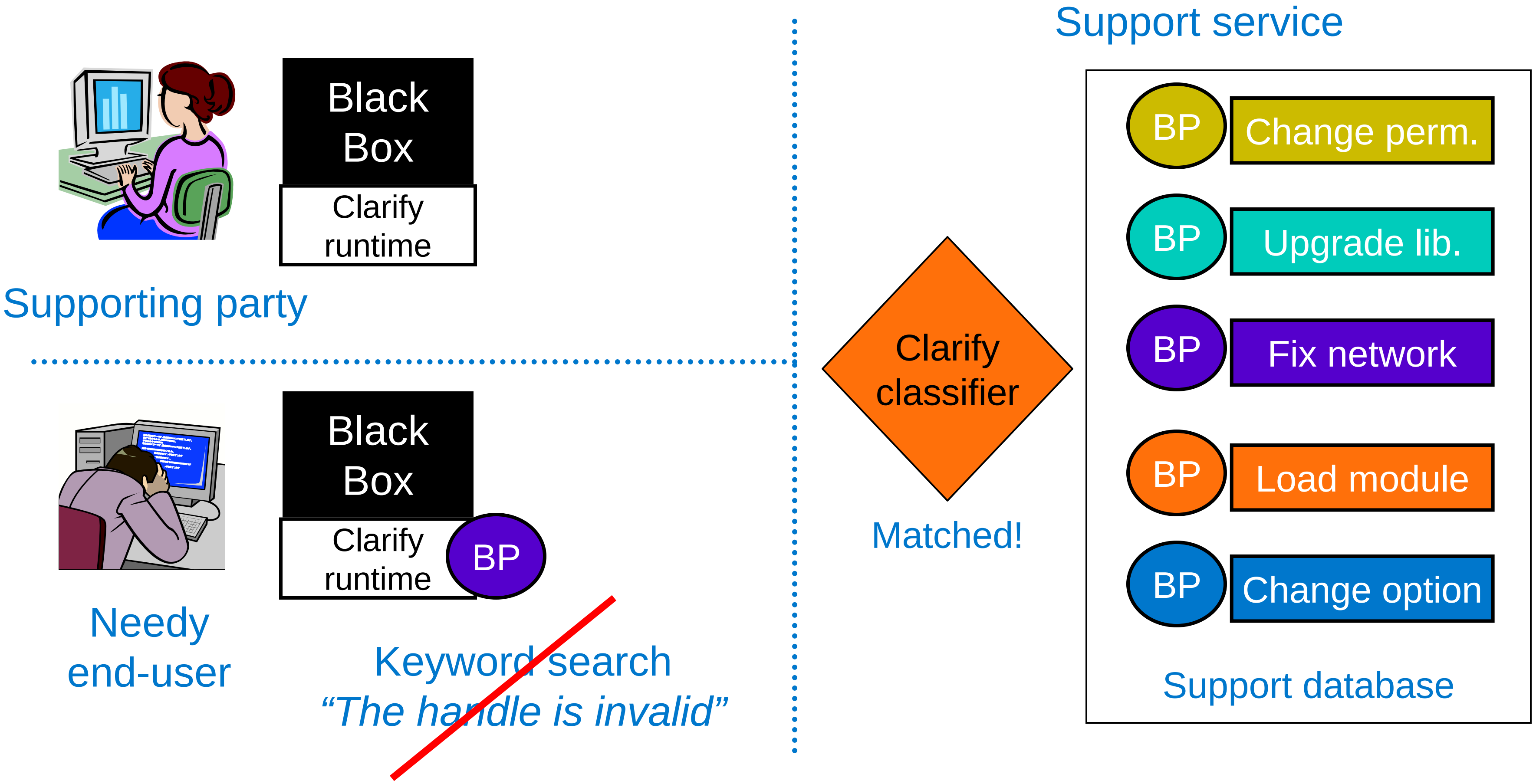




- Supporting party can be
  - Support websites – Software testers, support organization
  - Open source projects – Expert users
  - User forum – Any user willing to share their experiences

Clarify enabled Software Support

- Clarify enables sharing workarounds and fixes among users



Support service

Black Box

Clarify runtime

Supporting party

Clarify classifier

Matched!

BP Change perm.

BP Upgrade lib.

BP Fix network

BP Load module

BP Change option

Support database

Black Box

Clarify runtime

BP

Needy end-user

~~Keyword search~~

~~*“The handle is invalid”*~~

Behavior Profile

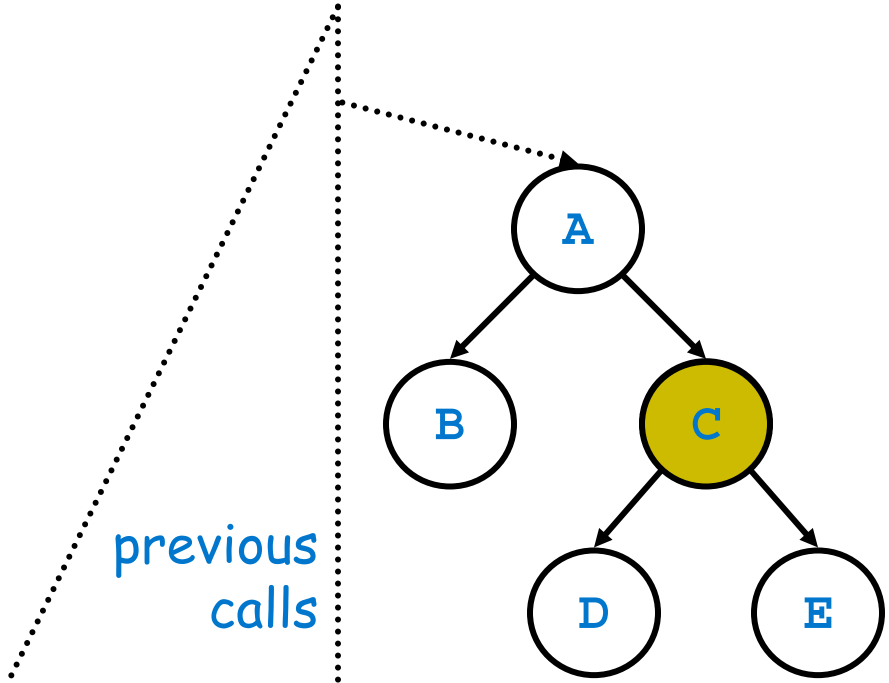
- Behavior Profile is
  - Abstraction of software global context
  - Generated by Clarify runtime
  - Any profile that contains history of software execution can be used as behavior profile
    - e.g. Path profiling **[Ball & Larus '96]**
- 2 important Behavior Profile types
  - **Call-Site Profiling (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



Dynamic Call Tree

- 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

	Live deployment	**Forensic deployment**
Coverage	Unknown errors can be added to the classifier	Known errors only
Behavior Profile	Full	Partial
Instrumentation	Full	Minimal
Runtime overhead	Higher	Lower

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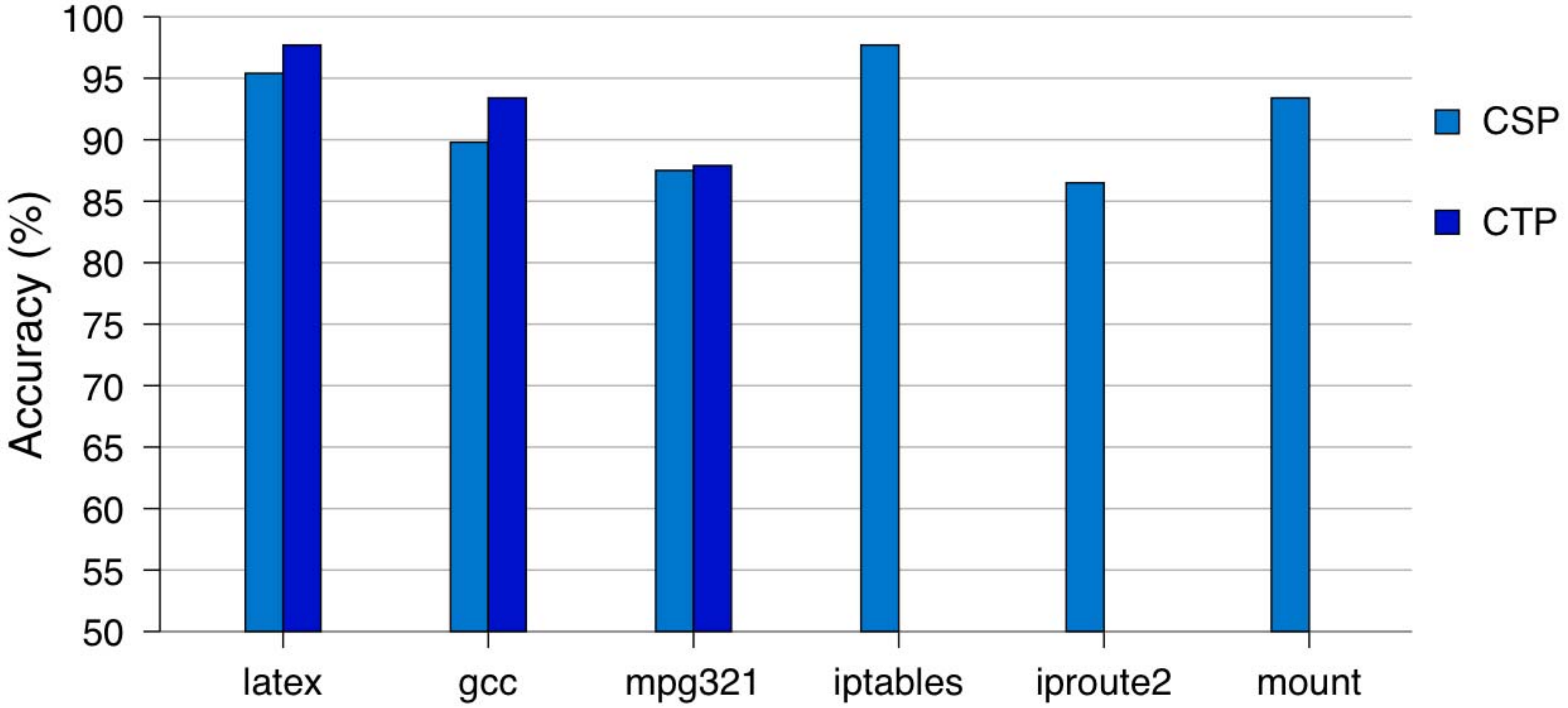
Benchmarks

- Ambiguous error messages from large, popular software
  - LaTeX: “*! Undefined control sequence*”
    - Misspelled `\fooootnote`
    - Duplicate `\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)
    - gcc, LaTeX, mpg321
  - 3 Linux kernel modules (CSP)
    - iptables, iproute2, nfsmount

Classification Accuracy



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

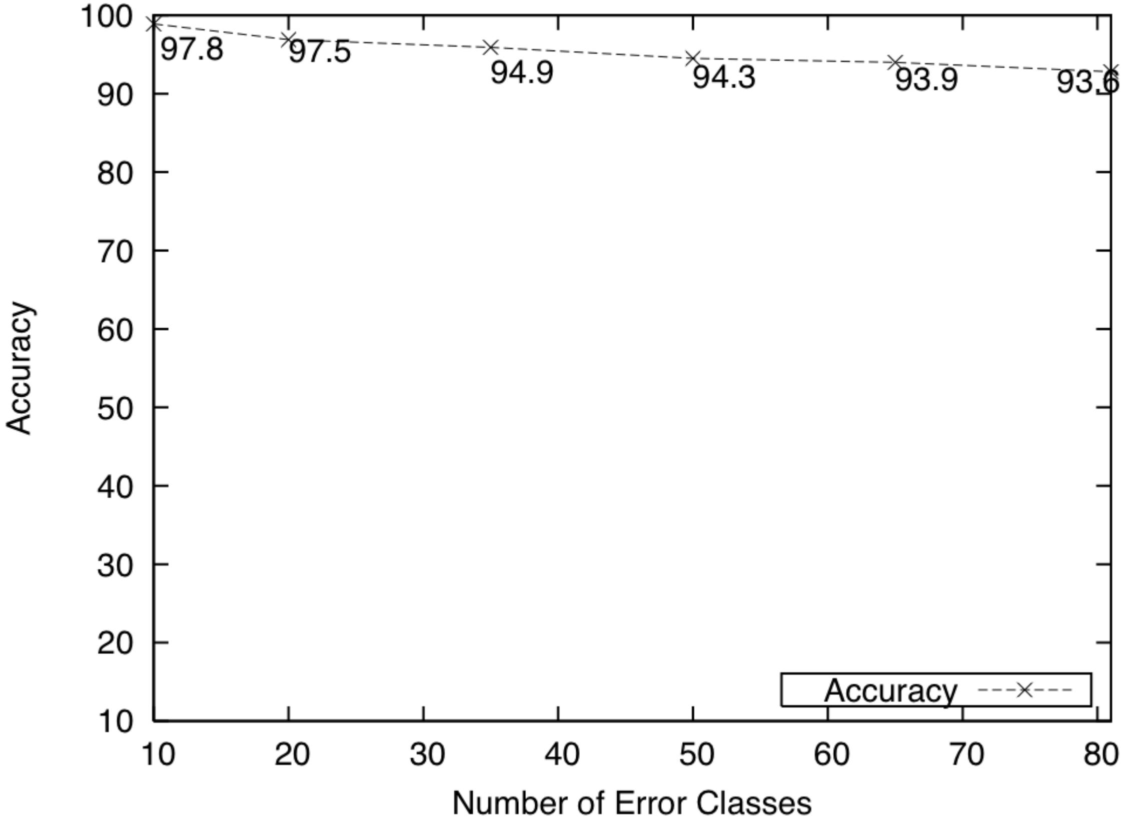
Deployment Overhead

Benchmark	**Live**		**Forensic**	
	CSP	**CTP**	**CSP**	**CTP**
latex	5.3%	97%	0.6%	1.1%
mpg321	1.2%	67%	0.3%	1.3%
gcc	7.0%	110%	1.0%	9.9%

- 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