Listening to Programmers

/* -- Taxonomies and Characteristics of Comments in Operating System Code */

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Motivation

- Many innovations to improve software quality & productivity:
  - PL, IDE, bug detection tools, annotation languages, ...
  - Valgrind, Splint, Linux's Sparse, Microsoft SAL, TagSEA, Mylyn, ...

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- Helpful to know what developers want

Comments Reveal Needs

- User studies:
  - Examples: CMU, Microsoft Research HIP
  - Challenges: Hard to collect representative data

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- Our novel observation:
  - **Comments reveal what developers want.**

Potential of Comments (I)

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- Motivate language support & bug detection tools
- Motivate IDE features for better navigation capability

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- Motivate bug detection tools [TanSOSP'07]

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See our paper for more examples.

Prevalence of Comments

Software	Linux	FreeBSD	OpenSolaris	Mozilla	MySQL	Eclipse
Lines of Comments	1.2M	0.6M	1.1M	1.2M	0.3M	1.7M

(kernel only for OSs, excluding blank lines, including copyright notices)

- Millions lines of comments (23-30%) exist.
  - Various languages: C, C++, Java
  - Written by thousands of developers or more

Our Contributions

- First comprehensive comment study on semantics:
  - Manually examine 2100 randomly sampled comments from 6 large popular software projects (in C, C++, Java)
  - Many findings and implications:
    - Provide guidance to the design of tools/languages
  - New comment taxonomies & analysis tools
    - Available at http://ece.uwaterloo.ca/~lintan/CComment

Outline

- Motivation
- Methodology & Taxonomies
- OS Comments: Findings and Implications
- Non-OS Comments: Similarities & Differences
- Related Work & Conclusions

Our OS Comment Source

Software	Linux	FreeBSD	OpenSolaris
Lines of Code	5.2M	2.4M	3.7M
Lines of Comments	1.2M	0.6M	1.1M
% of Comments	23.1%	25.0%	29.7%

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# of Comments (delimited by /* */ or //)	729,923	289,413	380,111

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- Randomly sampled 1050 comments
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Java & C++ code later

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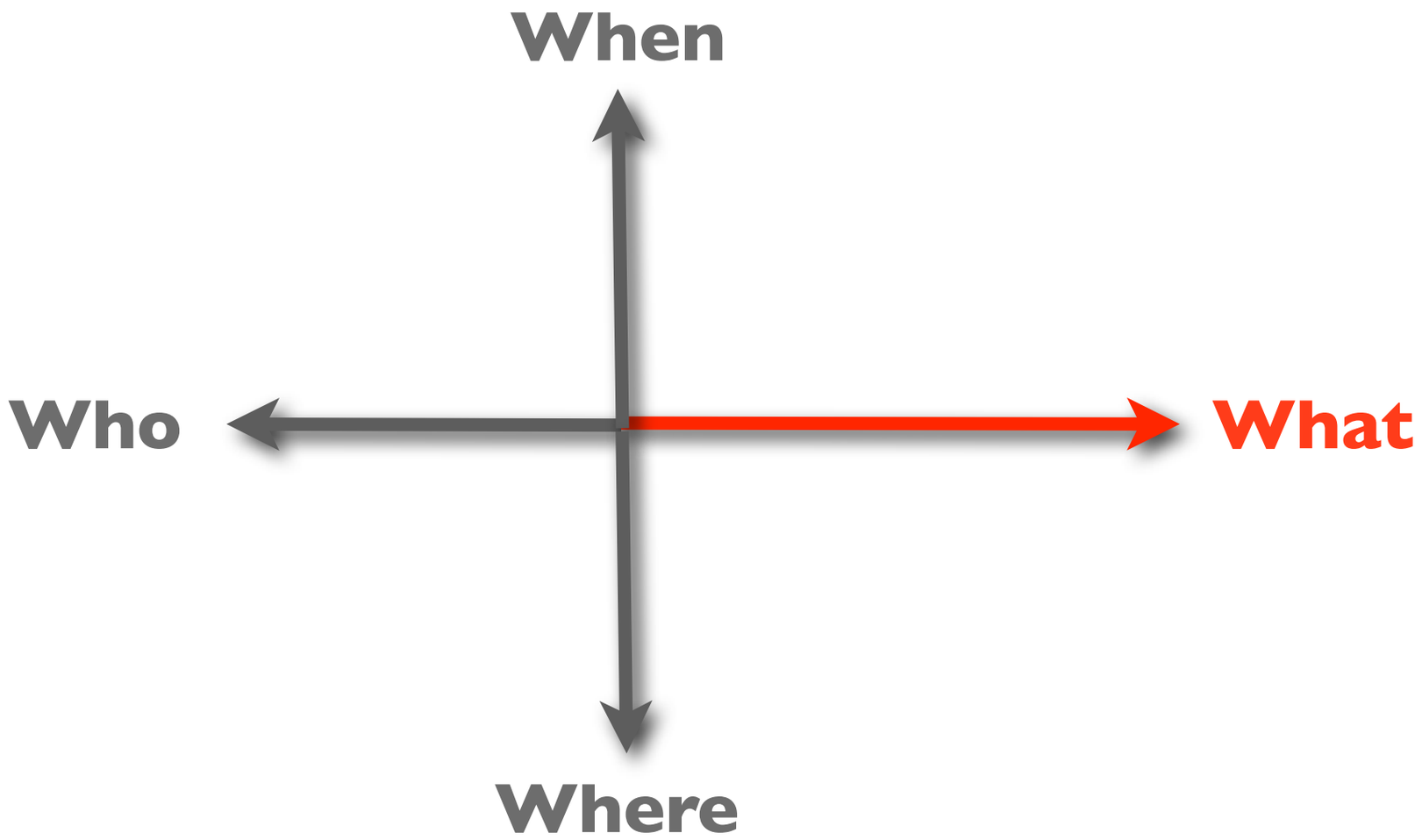
Dimensions of Taxonomies



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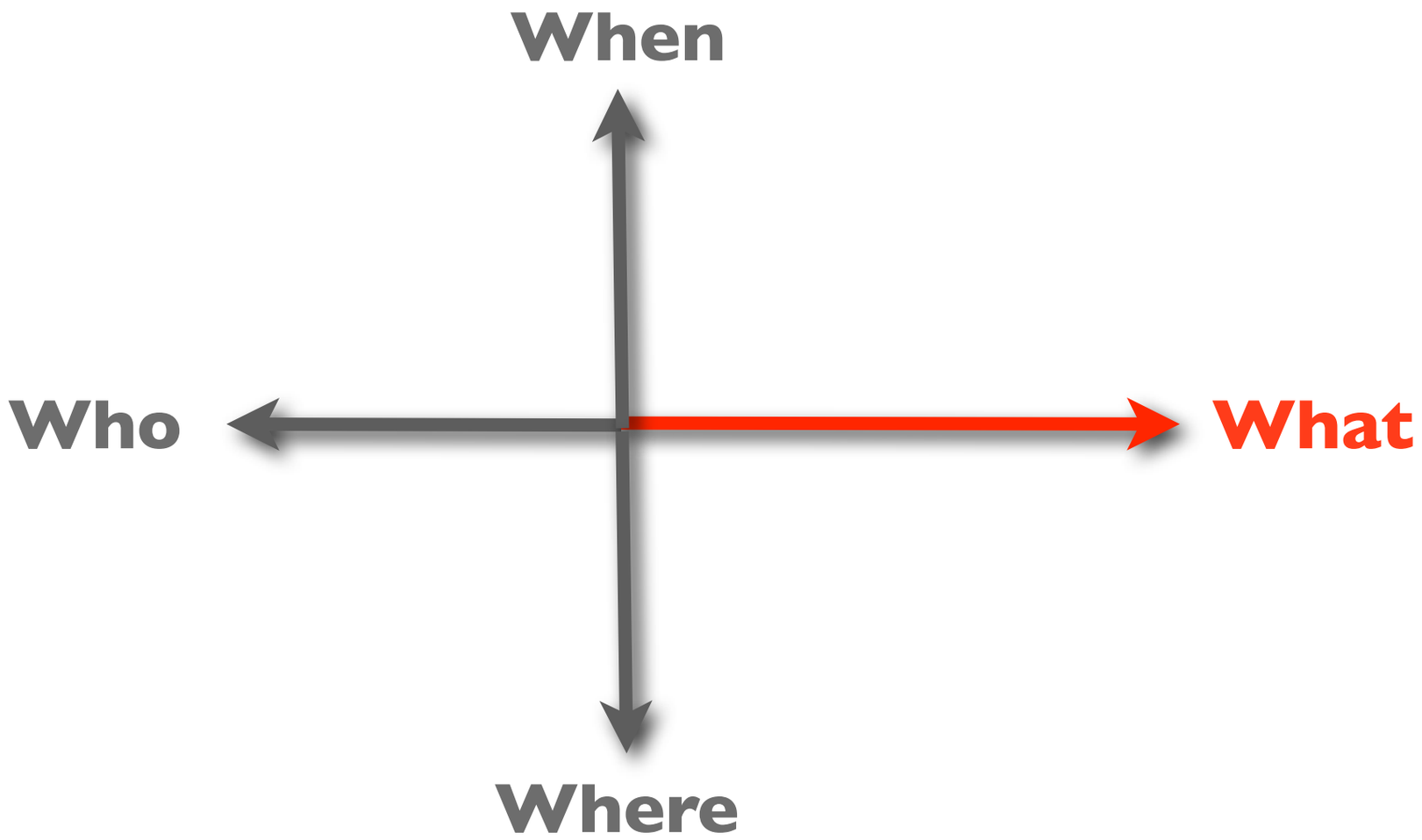

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- How to use these comments?

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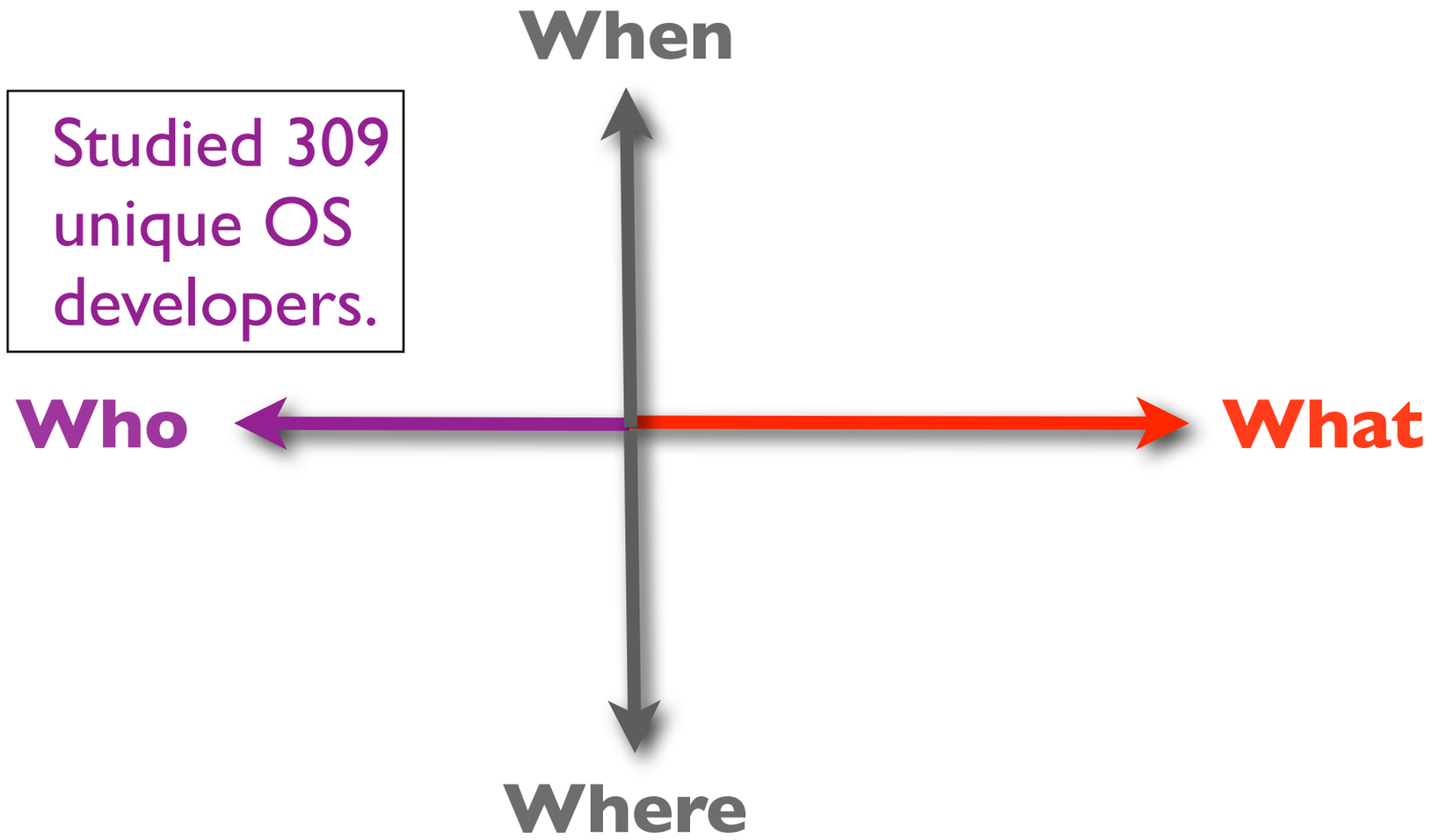

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Classification Process

- Iterative process
- Double verification
- A tool to help
  - Automatically extract author, time and related entities

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- Subjectivity
- Outdated comments

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Exploitable Comments

- At least 52.6 ±2.9% or ~736,109 comments in the 3 OSs:
  - Could be leveraged by existing or to-be-proposed techniques
  - Could guide the design of language features, IDE features, annotation languages and bug detection tools

Finding 1: Integers

- 22.1% of the exploitable comments clarify the usage and meaning of integers and integer macros.

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- Should pay more attention to integers and integer macros
  - Domain specific languages, extended types, bug detection tools, ...

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- Exploit such comments to provide better navigation capabilities
- Inspire techniques to express code relationships and evolution

Finding 3: Locking

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   static int reset_hardware(…) {…}
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1. /* **Caller must hold instance lock!** */
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2. /* Locking key to struct socket:
   * (a) constant after allocation, no locking required.
   *
   * ...
   * **(h) locked by global mutex so_global_mtx.** ... */
   struct socket { ...
   short so_type; /* (a) generic type, see socket.h */
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   so_gen_t so_gencnt; /* **(h) generation count** */ ...
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- Design easy-to-use annotations to express lock-related concerns

Finding 4: Annotation Convertible

- At least 10.7% of the exploitable comments can be expressed by existing annotations languages.
  - Linux's Sparse, Microsoft's SAL, Sun's Lock_Lint, Splint, Deputy

opensolaris/intel/io/acpica/resources/rscalc.c:

```
/* … AmlBufferLength - Size of AmlBuffer … */
ACPI_STATUS AcpiRsGetListLength (
    UINT8                               *AmlBuffer,
    UINT32                              AmlBufferLength, ...)
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- Automatically convert these comments into annotations

Open vs. Closed Source

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Linux						
FreeBSD						
OpenSolaris						

Open vs. Closed Source

Software	Comments					
Linux	23.1%					
FreeBSD	25%					
OpenSolaris	29.7%					

Open vs. Closed Source

Software	Comments	Exploitable				
Linux	23.1%	55.7%				
FreeBSD	25%	51.7%				
OpenSolaris	29.7%	50.3%				

Open vs. Closed Source

Software	Comments	Exploitable	Integers	Relationship	Locking	Annotation Convertible
Linux	23.1%	55.7%	26.7%	19.5%	5.1%	8.2%
FreeBSD	25%	51.7%	21.5%	14.9%	5.5%	12.7%
OpenSolaris	29.7%	50.3%	17.6%	15.9%	3.4%	11.4%

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OpenSolaris	29.7%	50.3%	17.6%	15.9%	3.4%	11.4%

- OpenSolaris (started as closed software) exhibits similar characteristics from its open source counterparts.
  - Complement the results of previous study [SpinellisICSE'08]
  - Our findings are general across different OSs.

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Non-OS Comment Source

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Software Type	OS	OS	OS	Browser	DB Server	IDE
Language	C	C	C	C/C++	C/C++	Java
Lines of Code	5.2M	2.4M	3.7M	4.5M	1.2M	6.1M
Lines of Comments	1.2M	0.6M	1.1M	1.2M	0.3M	1.7M
Sample Size	350	350	350	350	350	350

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Non-OS Comment Findings

Software						
OS						
Non-OS						

- Mostly similar, but OS has more locking & integer comments
  - See our paper for other differences

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Software	Comments					
OS	23.1-29.7%					
Non-OS	21.8-28.5%					

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Software	Comments	Exploitable				
OS	23.1-29.7%	52.6±2.9%				
Non-OS	21.8-28.5%	57.5±2.9%				

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Non-OS Comment Findings

Software	Comments	Exploitable	Relationship	Annotation Convertible	Locking	
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Non-OS	21.8-28.5%	57.5±2.9%	21.2%	13.7%	1.7%	

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  - Exceptions are not always used.
  - Still use comments to explain the exception types

```
/* return 1 if ACK, 0 if NAK, -1 if error. */
static int slhci_transaction(...) { ... }
```

Related Work

- Comment studies

  [WoodfieldICSE'81], [Etzkorn'99], [Stamelos'02], [Warren'02], [YingMSR05], [Marin'05], [JiangMSR'06], [Fluri'07], [StoreyICSE'08], ...

  - Usefulness of comments for program understanding [WoodfieldICSE'81]
  - Impact of already commented code [Marin'05]
  - TODO comments [YingMSR05], [StoreyICSE'08]

Conclusions

- **Comments reveal interesting findings**, which guide the design of new tools and languages:
  - *Abusive use of integers*
  - *Lack of expressing power on code relationship and evolution*
  - *Many can be expressed by existing annotation languages*
- New taxonomies, tools & examined comments
  - Available at http://ece.uwaterloo.ca/~lintan/CComment

More findings and
implications in our paper