17-708 SOFTWARE PRODUCT LINES: CONCEPTS AND IMPLEMENTATION

PREPROCESSORS

CHRISTIAN KAESTNER
CARNEGIE MELLON UNIVERSITY
INSTITUTE FOR SOFTWARE RESEARCH

READING ASSIGNMENT OCT 19

Bill McCloskey and Eric Brewer. 2005. ASTEC: A new approach to refactoring C. In Proceedings of the 10th European Software Engineering Conference/International Symposium on Foundations of Software Engineering (ESEC/FSE-13). ACM, New York, NY, USA, 21-30.

Understand differences to C preprocessor

Medeiros, F., Kästner, C., Ribeiro, M., Nadi, S., & Gheyi, R. The Love/Hate Relationship with the C Preprocessor: An Interview Study. In Proc. 29th European Conference on Object-Oriented Programming (ECOOP 2015), 12, 40.

LEARNING GOALS

Use the C preprocessor and build system to implement product lines

Understand the benefits and drawbacks of the preprocessor

Use the implementation technique in a disciplined way and apply other mitigation strategies for preprocessor-related problems

LIMITATIONS?

```
class Conf {
  public static boolean COLORED = true;
  public static boolean WEIGHTED = false;
}
```

```
class Graph {
 Vector nv = new Vector(); Vector ev = new Vector();
 Edge add(Node n, Node m) {
  Edge e = new Edge(n, m);
  nv.add(n); nv.add(m); ev.add(e);
  if (Conf.WEIGHTED) e.weight = new Weight();
  return e;
 }
 Edge add(Node n, Node m, Weight w)
  if (!Conf.WEIGHTED) throw RuntimeException();
  Edge e = new Edge(n, m);
  nv.add(n); nv.add(m); ev.add(e);
  e.weight = w; return e;
 }
 void print() {
  for(int i = 0; i < ev.size(); i++) {
   ((Edge)ev.get(i)).print();
  }
 }
}
```

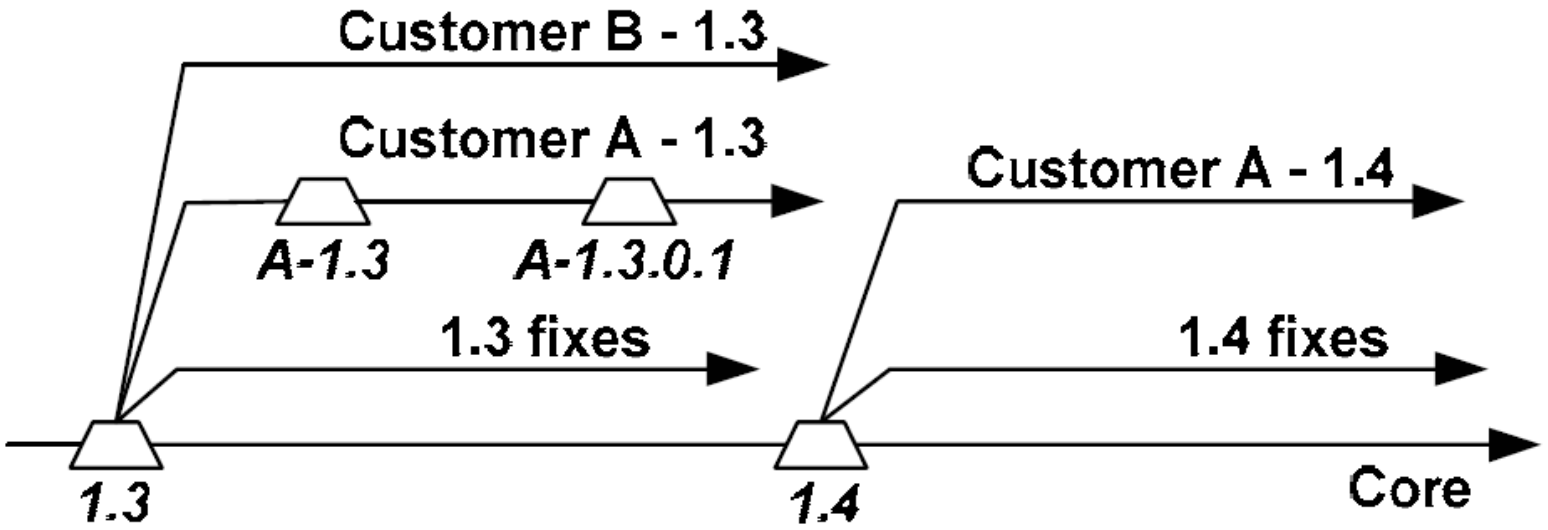
```
class Node {
 int id = 0;
 Color color = new Color();
 void print() {
  if (Conf.COLORED) Color.setDisplayColor(color);
   System.out.print(id);
 }
}
```

```
class Edge {
 Node a, b;
 Color color = new Color();
 Weight weight = new Weight();
 Edge(Node _a, Node _b) { a = _a; b = _b; }
 void print() {
  if (Conf. COLORED) Color.setDisplayColor(color);
  a.print(); b.print();
  if (Conf.WEIGHTED)  weight.print();
 }
}
```

```
class Color {
 static void setDisplayColor(Color c) { ... }
}
```

```
class Weight { void print() { ... } }
```

LIMITATIONS



BUILD SYSTEMS

BUILD SYSTEMS

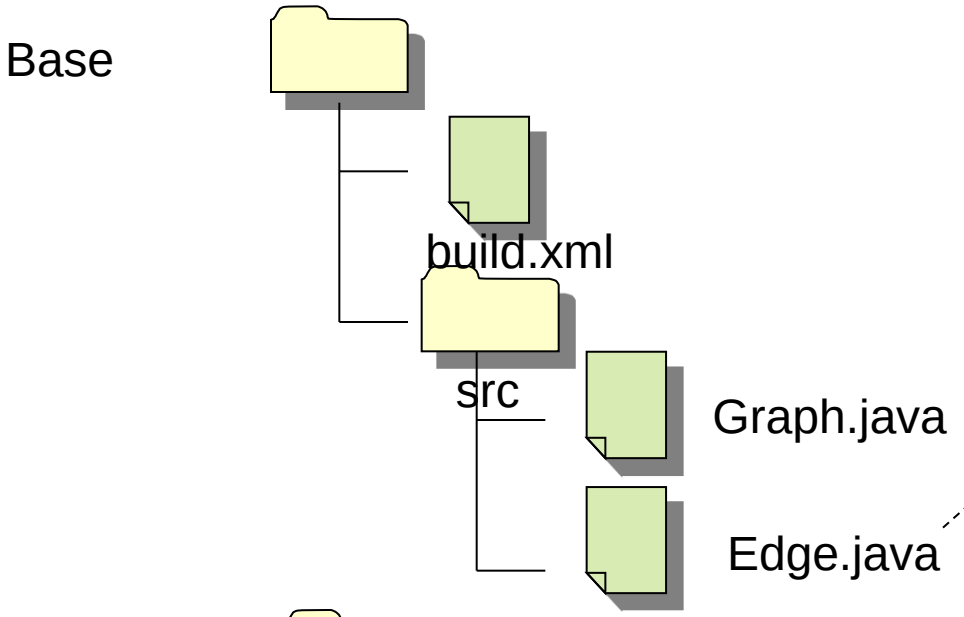
Make

Ant

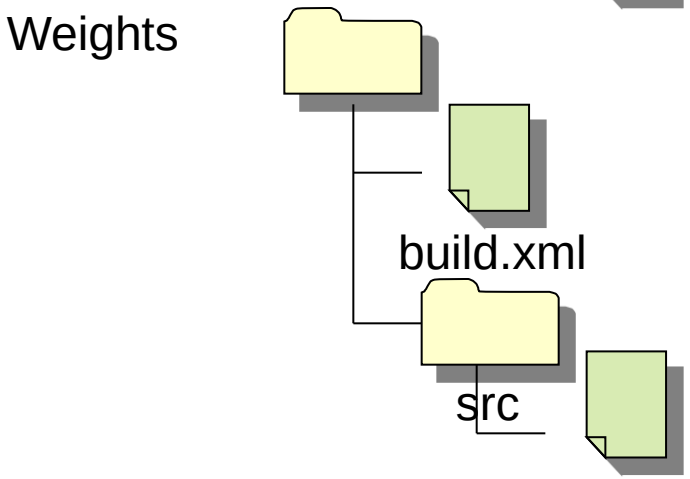
Gradle

Bazil…

VARIANTS WITH BUILD SYSTEMS




```
class Edge {
  Node a, b;
  Edge(Node _a, Node _b) { a = _a; b = _b; }
  void print() {
    a.print(); b.print();
  }
}
```




```
class Edge {
  Node a, b;
  Weight weight;
  Edge(Node _a, Node _b) { a = _a; b = _b; }
  void print() {
    a.print(); b.print();
    weight.print();
  }
}
```

```
OS=$(shell uname)
POI4R:=$(shell pwd)
DISTRIB=Poi-0.1.0

ifeq ($(OS),Linux)
CCFLAGS=-O0
else
CCFLAGS=-O2
endif

distrib:
  install Poi4R.rb $(DISTRIB)/python
  g++ -o $@ $(CCFLAGS) -I$(POI4R) poi.o

ifdef DB
distrib: createDBDir
endif

createDBDir:
  mkdir -p Poi/dbl
ifneq($(OS),Linux)
  install libgcj.5.dylib $(DISTRIB)/gcj
endif
```

PREPROCESSOR

PREPROCESSORS

C, C++, Fortran, Erlang

C#, Visual Basic, D, PL/SQL, Adobe Flex

XVCL, M4, …

Pure::Variants, Gears

Model annotations

EXAMPLE

```
static int __rep_queue_filedone(dbenv, rep, rfp)
        DB_ENV *dbenv;
        REP *rep;
        __rep_fileinfo_args *rfp; {
#ifndef HAVE_QUEUE
        COMPQUIET(rep, NULL);
        COMPQUIET(rfp, NULL);
        return (__db_no_queue_am(dbenv));
#else
        db_pgno_t first, last;
        u_int32_t flags;
        int empty, ret, t_ret;
#ifdef DIAGNOSTIC
        DB_MSGBUF mb;
#endif
        // over 100 lines of additional code
}
#endif
```

JAVA?

No native preprocessor

Conditional compilation through if statements?

```
class Example {
    public static final boolean DEBUG = false;

    void main() {
        System.out.println(“immer”);
        if (DEBUG)
        System.out.println(“debug info”);
    }
}
```

External Tools: CPP, Antenna, Munge, XVCL, Gears, pure::variants

MUNGE

Developed for Swing in Java 1.2

```
class Example {
void main() {
        System.out.println(“immer”);
        /*if[DEBUG]*/
        System.out.println(“debug info”);
        /*end[DEBUG]*/
}
}
```

java Munge –DDEBUG –DFEATURE2 file1.java file2.java ... targetdir

http://weblogs.java.net/blog/tball/archive/2006/09/munge_swings_se.html

ANTENNA

Collection of Ant tasks for Java ME

```
        /** Read HTML and if it has links, redirect and parse the XML. */
        protected String parseHTMLRedirect(String url, InputStream is)
    throws IOException, Exception {
                //#ifdef DSMALLMEM
//#             throw new IOException("Error HTML not supported with this version.");
                //#else
                if (m_redirect) {
                        //#ifdef DLOGGING
//#                     logger.severe("Error 2nd redirect url:  " + url);
                        //#endif
                        System.out.println("Error 2nd redirect url:  " + url);
                        throw new IOException("Error url " + m_redirectUrl +
                                              " to 2nd redirect url:  " + url);
                }
                m_redirect = true;
                m_redirectUrl = url;
                com.substanceofcode.rssreader.businessentities.RssItunesFeed[] feeds =
                                HTMLLinkParser.parseFeeds(new EncodingUtil(is),
                                                          url, null, null, true
                                                          //#ifdef DLOGGING
//#                                                       ,logger,
//#                                                       fineLoggable,
//#                                                       finerLoggable,
//#                                                       finestLoggable
                                                          //#endif
                                                          );
                if ((feeds == null) || (feeds.length == 0)) {
```

http://antenna.sourceforge.net/

GRAPH WITH MUNGE

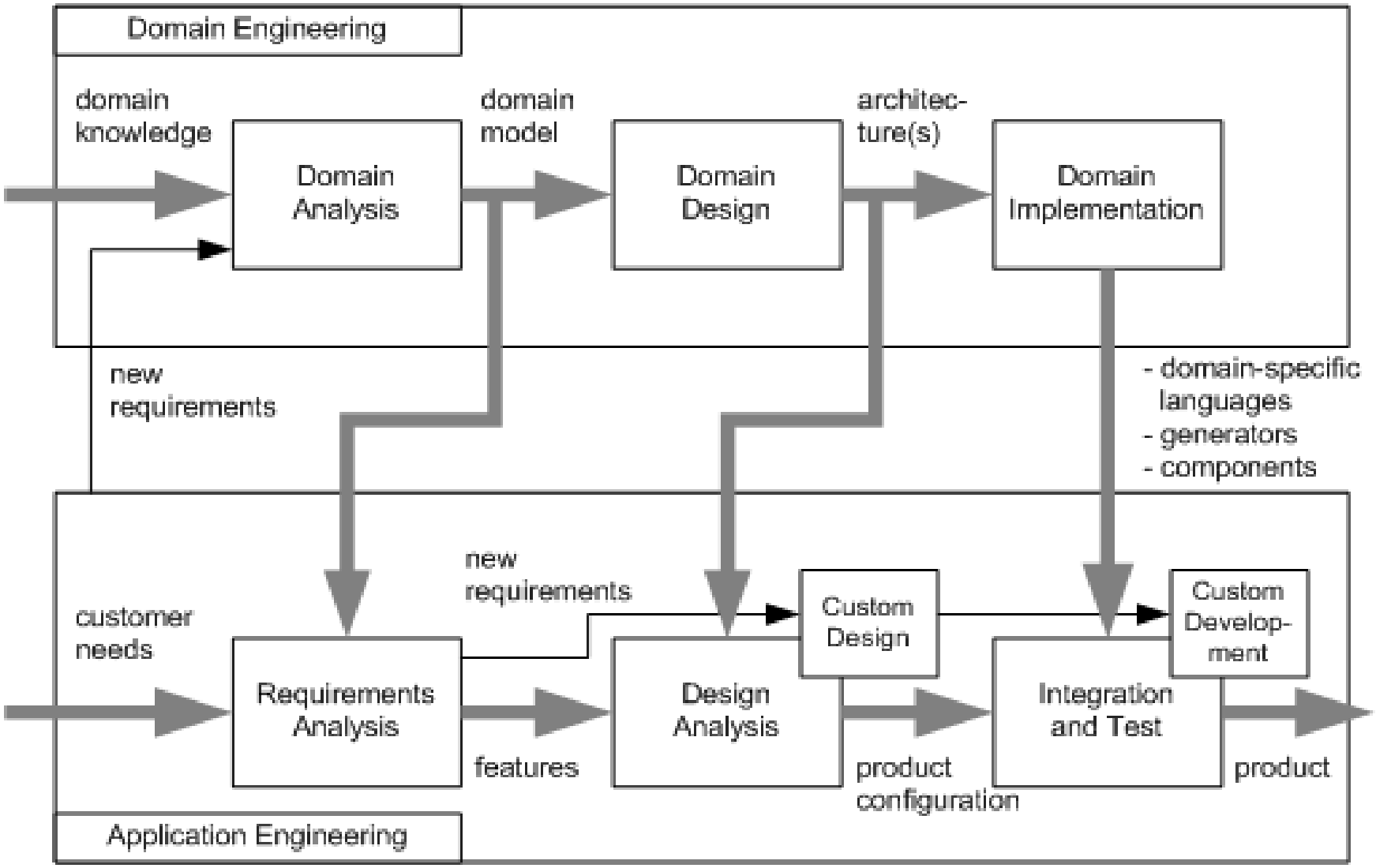
```
class Graph {
  Vector nv = new Vector(); Vector ev = new Vector();
  Edge add(Node n, Node m) {
    Edge e = new Edge(n, m);
    nv.add(n); nv.add(m); ev.add(e);
    /*if[WEIGHT]*/
    e.weight = new Weight();
    /*end[WEIGHT]*/
    return e;
  }
  /*if[WEIGHT]*/
  Edge add(Node n, Node m, Weight w)
    Edge e = new Edge(n, m);
    nv.add(n); nv.add(m); ev.add(e);
    e.weight = w; return e;
  }
  /*end[WEIGHT]*/
  void print() {
    for(int i = 0; i < ev.size(); i++) {
      ((Edge)ev.get(i)).print();
    }
  }
}
```

```
/*if[WEIGHT]*/
class Weight { void print() { ... } }
/*end[WEIGHT]*/
```

```
class Edge {
  Node a, b;
  /*if[COLOR]*/
  Color color = new Color();
  /*end[COLOR]*/
  /*if[WEIGHT]*/
  Weight weight;
  /*end[WEIGHT]*/
  Edge(Node _a, Node _b) { a = _a; b = _b; }
  void print() {
    /*if[COLOR]*/
    Color.setDisplayColor(color);
    /*end[COLOR]*/
    a.print(); b.print();
    /*if[WEIGHT]*/
    weight.print();
    /*end[WEIGHT]*/
  }
}
```

```
/*if[COLOR]*/
class Color {
  static void setDisplayColor(Color c) { ... }
}
/*end[COLOR]*/
```

```
class Node {
  int id = 0;
  /*if[COLOR]*/
```

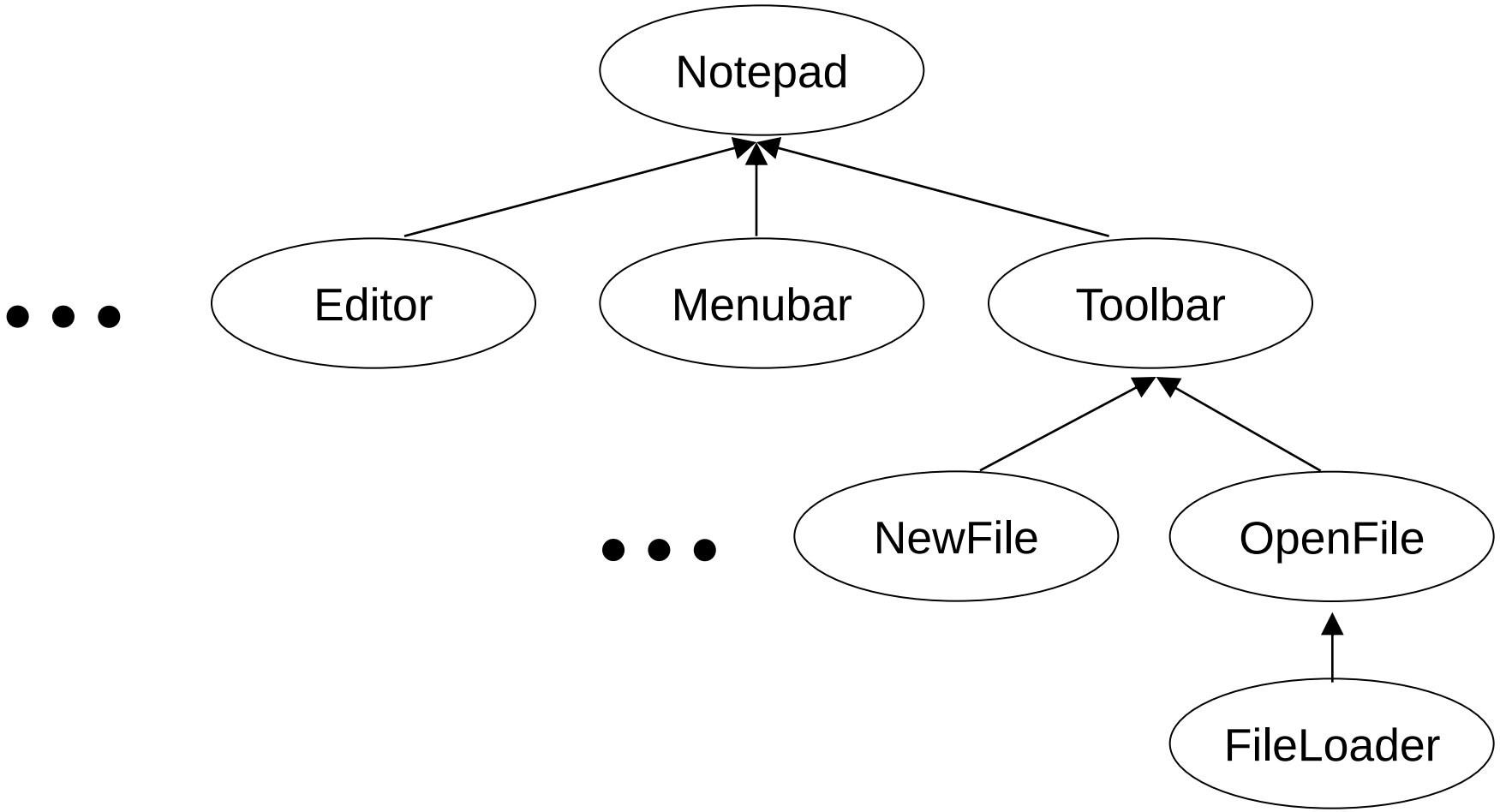

Domain Engineering
domain knowledge
Domain Analysis
domain model
Domain Design
architec-ture(s)
Domain Implementation
new requirements
- domain-specific languages
- generators
- components
customer needs
Requirements Analysis
new requirements
Custom Design
Design Analysis
Custom Develop-ment
Integration and Test
features
product configuration
product
Application Engineering

XVCL

```
<x-frame name="Notepad">
import java.awt.*;
class Notepad extends JPanel {
    Notepad() {
        super();
        …
    }
    public static void main(String[] args) {
        JFrame frame = new JFrame();
        frame.setTitle("<value-of expr="?@TITLE?"/>");
        frame.setBackground(
            Color.<value-of expr="?@BGCOLOR?"/>);
        frame.show();
    }
    <adapt x-frame="Editor.XVCL"/>
    <adapt x-frame="Menubar.XVCL"/>
    <adapt x-frame="Toolbar.XVCL"/>
    …
}
</x-frame>
```

```
<x-frame name="Toolbar">
<set-multivar="ToolbarBtns" value="New,Open,Save"/>
private Component createToolbar() {
      JToolBar toolbar = new JToolBar();
      JButton button;
<while using-items-in="ToolbarBtns">
  <select option="ToolbarBtns">
      <option value="-">
      toolbar.add(Box.createHorizontalStrut(5));
      </option>
      <otherwise>
      button = new JButton(new ImageIcon(
          "<value-of expr="?@Gif@ToolbarBtns?"/> "));
      toolbar.add(button);
      </otherwise>
  </select>
</while>
      toolbar.add(Box.createHorizontalGlue());
      return toolbar;
}
</x-frame>
```

XVCL


Notepad
Editor
Menubar
Toolbar
NewFile
OpenFile
FileLoader

TAG AND PRUNE

```
/*@feature:RECV_MIN@*//*@!file_feature!@*/
(...)
void cfdp_receiver_handle_PDU(cfdp_receiver* const me, struct cfdp_buffer* PDU_buffer,
CFDP_PDU_type_t PDU_type) {
    {
        /*@feature:RECV_INACTIVITY@*/
        /* Restart inactivity timer */
        cfdp_timer_start(&(me->timer_inactivity),me->config.timeout_inactivity);

        /* Handle PDU and dispatch it depending on its type */
        switch (PDU_type)
        {
            /*@feature:RECV_MIN_ACK@*/
            case CFDP_PDU_ACK_FINISHED:
            {
                cfdp_receiver_handle_PDU_eof_no_error(me,PDU_buffer);
            }
            break;
            case CFDP_PDU_EOF_NO_ERROR:
            {
                cfdp_receiver_handle_PDU_eof_no_error(me,PDU_buffer);
            }
            break;
        }
        (...)
    }
}
```

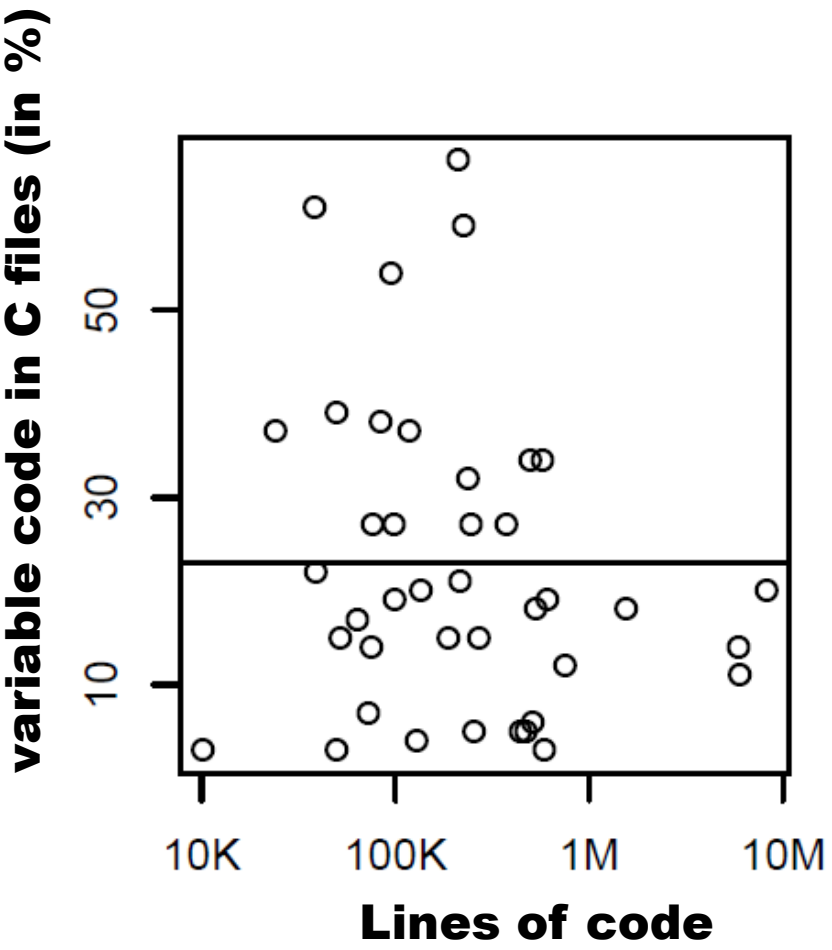
Patrick Heymans, Quentin Boucher, Andreas Classen, Arnaud Bourdoux, Laurent Demonceau: A code tagging approach to software product line development - An application to satellite communication libraries. STTT 14(5): 553-566 (2012)

DISCUSSION

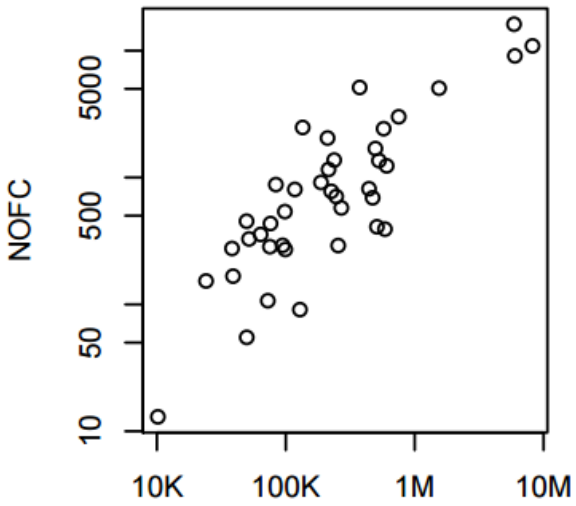
ADVANTAGES

[ICSE'10, AOSD'11]

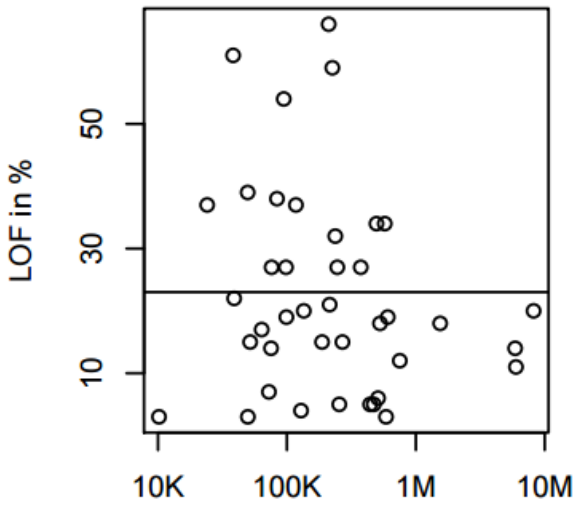
40 Open-Source C Projects



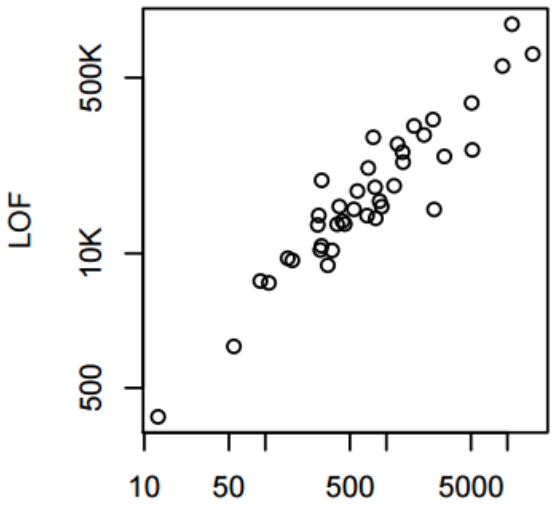
apache, berkely db, cherokee, clamav, dia, emacs, freebsd, gcc, ghostscript, gimp, glibc, gnumeric, gnuplot, irssi, libxml, lighttpd, linux, lynx, minix, mplayer, mpsolve, openldap, opensolaris, openvpn, parrot, php, pidgin, postgresql, privoxy, python, sendmail, sqlite, subversion, sylpheed, tcl, vim, xfig, xine-lib, xorg-server, xterm



a) LOC (correlation coefficient: 0.57)



b) LOC (correlation coefficient: 0.58)



c) NOFC (correlation coefficient: 0.74)

OBJECTIONS / CRITICISM

Designed in the 70th and hardly evolved since

"#ifdef considered harmful"

"#ifdef hell"

"maintenance becomes a 'hit or miss' process"

"is difficult to determine if the code being viewed is actually compiled into the system"

"incomprehensible source texts"

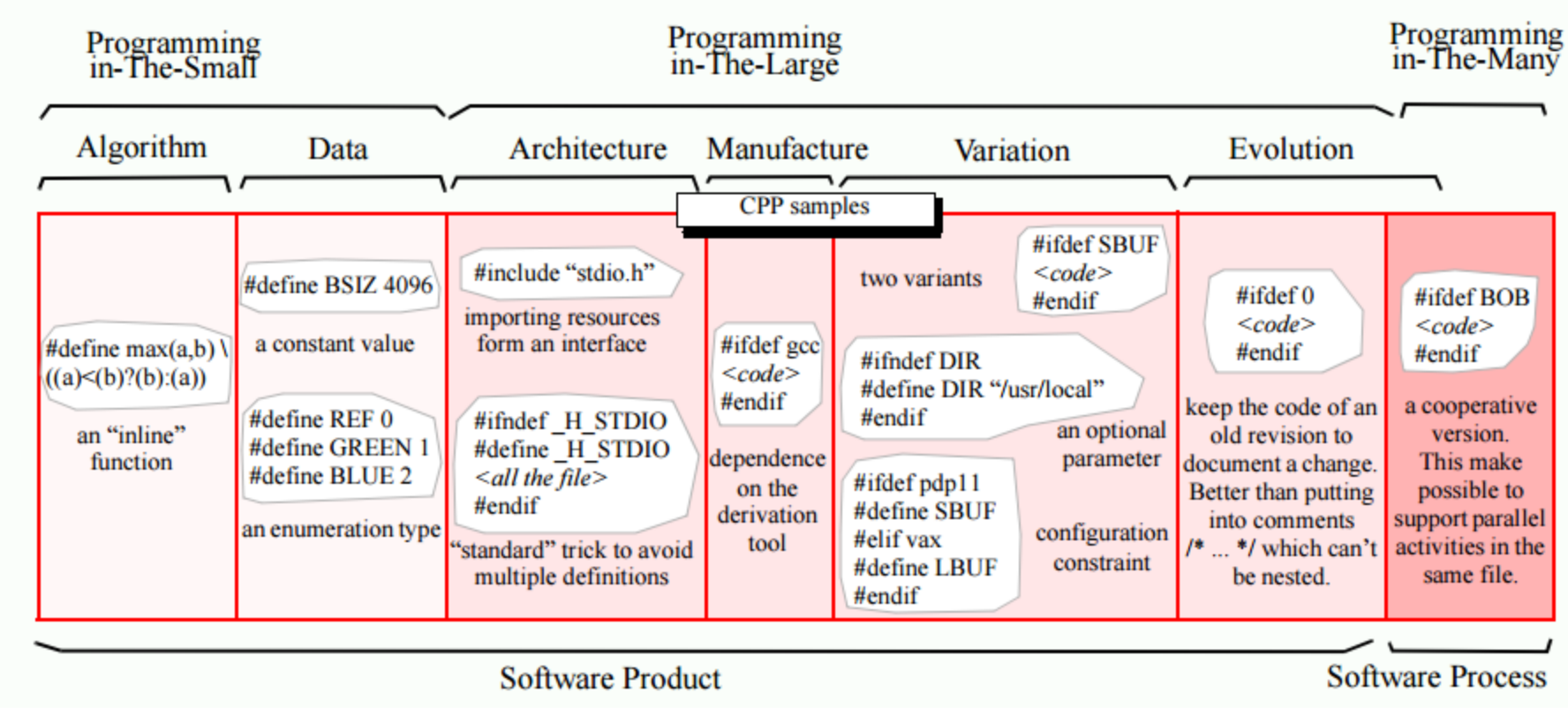
"programming errors are easy to make and difficult to detect"

"CPP makes maintenance difficult"

"source code rapidly becomes a maze"

"preprocessor diagnostics are poor"

CPP CRITICISM



Favre, Jean-Marie. "Understanding-in-the-large." Program Comprehension, 1997. IWPC'97. Proceedings., Fifth International Workshop on. IEEE, 1997.

GRANULARITY AND READABILITY

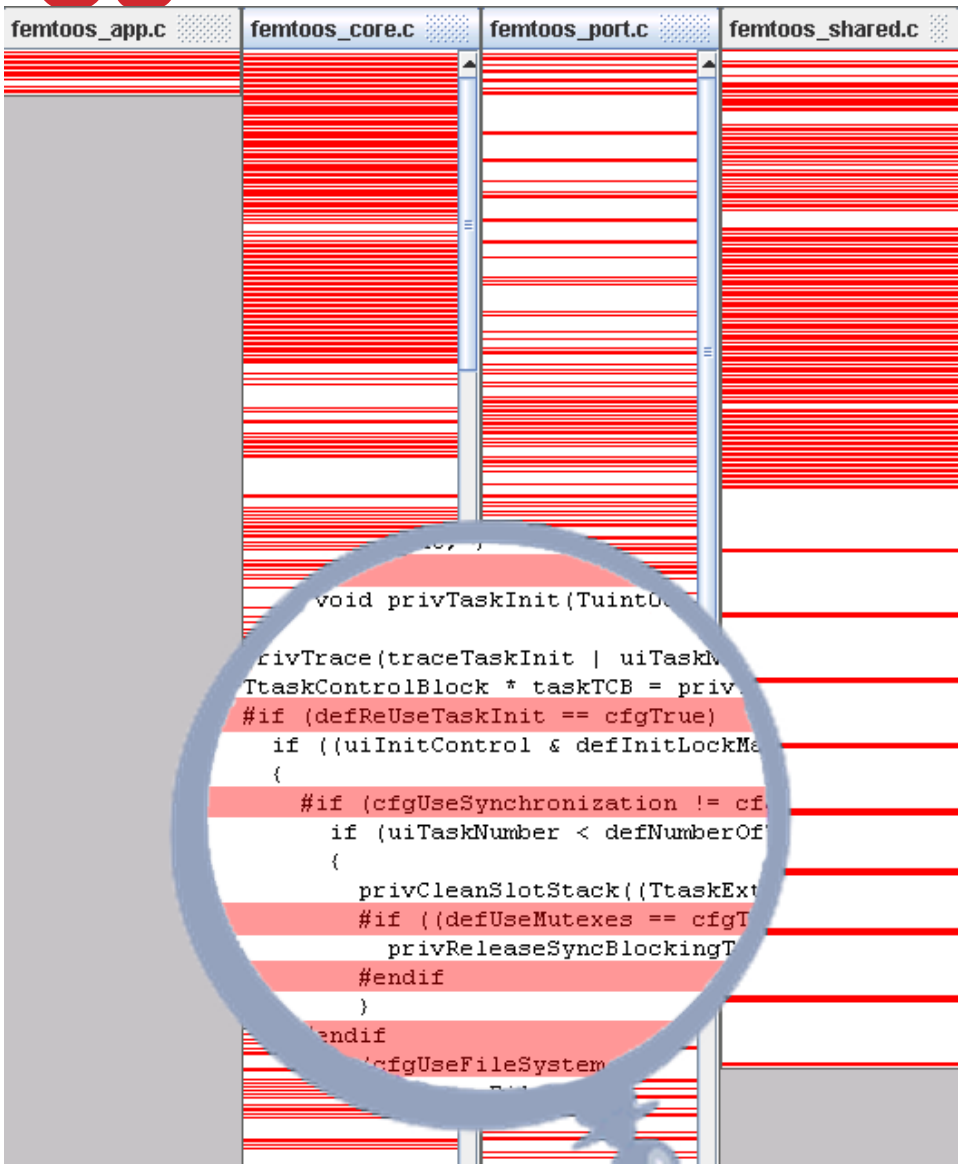
```
class Stack {
void push(Object o
#ifdef SYNC
, Transaction txn
#endif
) {
    if (o==null
#ifdef SYNC
        || txn==null
#endif
        ) return;
#ifdef SYNC
    Lock l=txn.lock(o);
#endif
    elementData[size++] = o;
#ifdef SYNC
    l.unlock();
#endif
    fireStackChanged();
}}
```

GRANULARITY AND READABILITY

```
/*if[WEIGHT]*/W/*end[WEIGHT]*/Edge add(Node n, Node m /*if[WEIGHT]*/, int w/*end[WEIGHT]*/) {
    return new /*if[WEIGHT]*/W/*end[WEIGHT]*/Edge (n, m /*if[WEIGHT]*/, w/*end[WEIGHT]*/ );
}
```

```
Edge set(/*if[WEIGHT]*/int w/*if[COLOR]*/, /*end[COLOR]*/ /*end[WEIGHT]*/ /*if[COLOR]*/int c/*end[COLOR]*/ ) {
    …
}
```

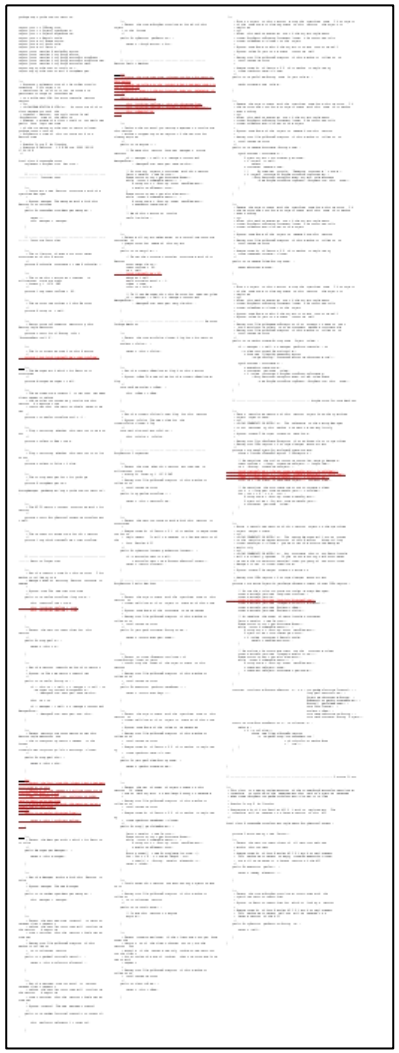
PREPROCESSOR IN FEMTO OS



SCATTERING

ApplicationSession

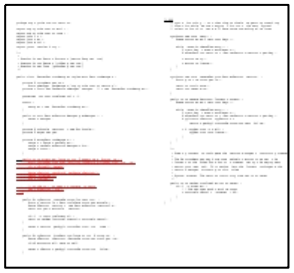
StandardSession



ServerSession

SessionInterceptor

ServerSessionManager



StandardManager

StandardSessionManager

- Example: Session expiration in the Apache Tomcat Server

```
  int n = N
#ifndef F
  w = curwi
#else
  for (w =
      w = w
#endif
    if (n =
      retu
```

```
int put_eol(fd)
    FILE *fd;
{
  if (
#ifdef USE_CRNL
    (
#ifdef MKSESSION_NL
      !mksession_nl &&
#endif
      (putc('\r', fc) < 0)) ||
#endif
      (putc('\n', fd) < 0))
    return FAIL;
  return OK;
}
```

TRACEABILITY

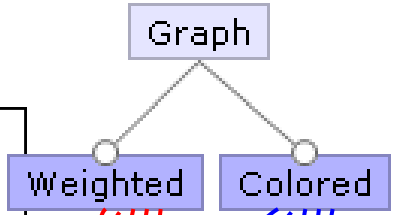
```
class Graph {
  Vector nv = new Vector(); Vector ev = new Vector();
  Edge add(Node n, Node m) {
    Edge e = new Edge(n, m);
    nv.add(n); nv.add(m); ev.add(e);
    e.weight = new Weight();
    return e;
  }
  Edge add(Node n, Node m, Weight w)
    Edge e = new Edge(n, m);
    nv.add(n); nv.add(m); ev.add(e);
    e.weight = w; return e;
  }
  void print() {
    for(int i = 0; i < ev.size(); i++) {
      ((Edge)ev.get(i)).print();
    }
  }
}
```

```
class Node {
  int id = 0;
  Color color = new Color();
  void print() {
    Color.setDisplayColor(color);
    System.out.print(id);
  }
}
```

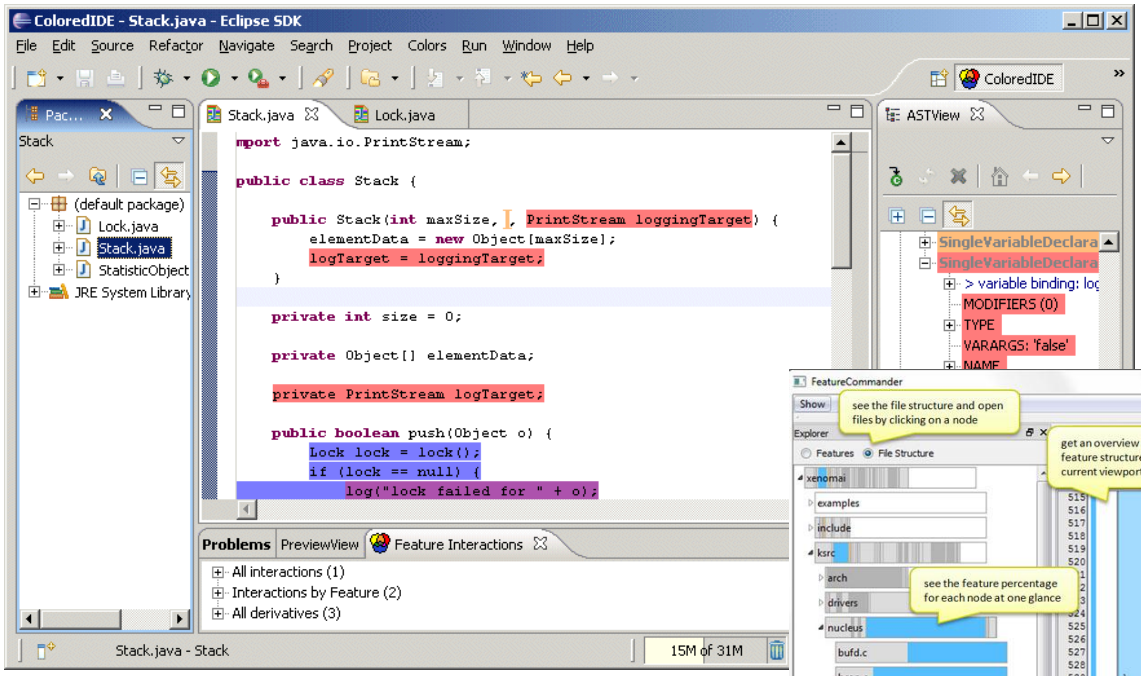
```
class Edge {
  Node a, b;
  Color color = new Color();
  Weight weight;= new Weight();
  Edge(Node _a, Node _b) { a = _a; b = _b; }
  void print() {
    Color.setDisplayColor(color);
    a.print(); b.print();
    weight.print();
  }
}
```

```
class Color {
  static void setDisplayColor(Color c) { ... }
}
```

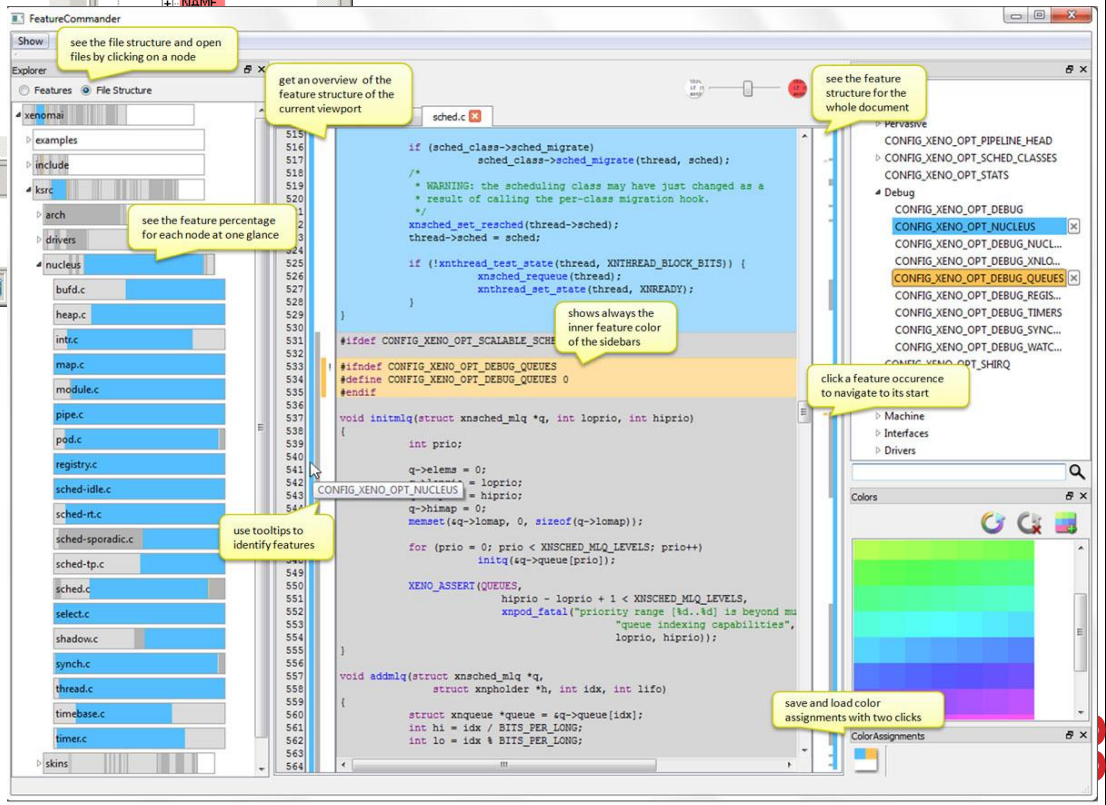
```
class Weight { void print() { ... } }
```



CIDE

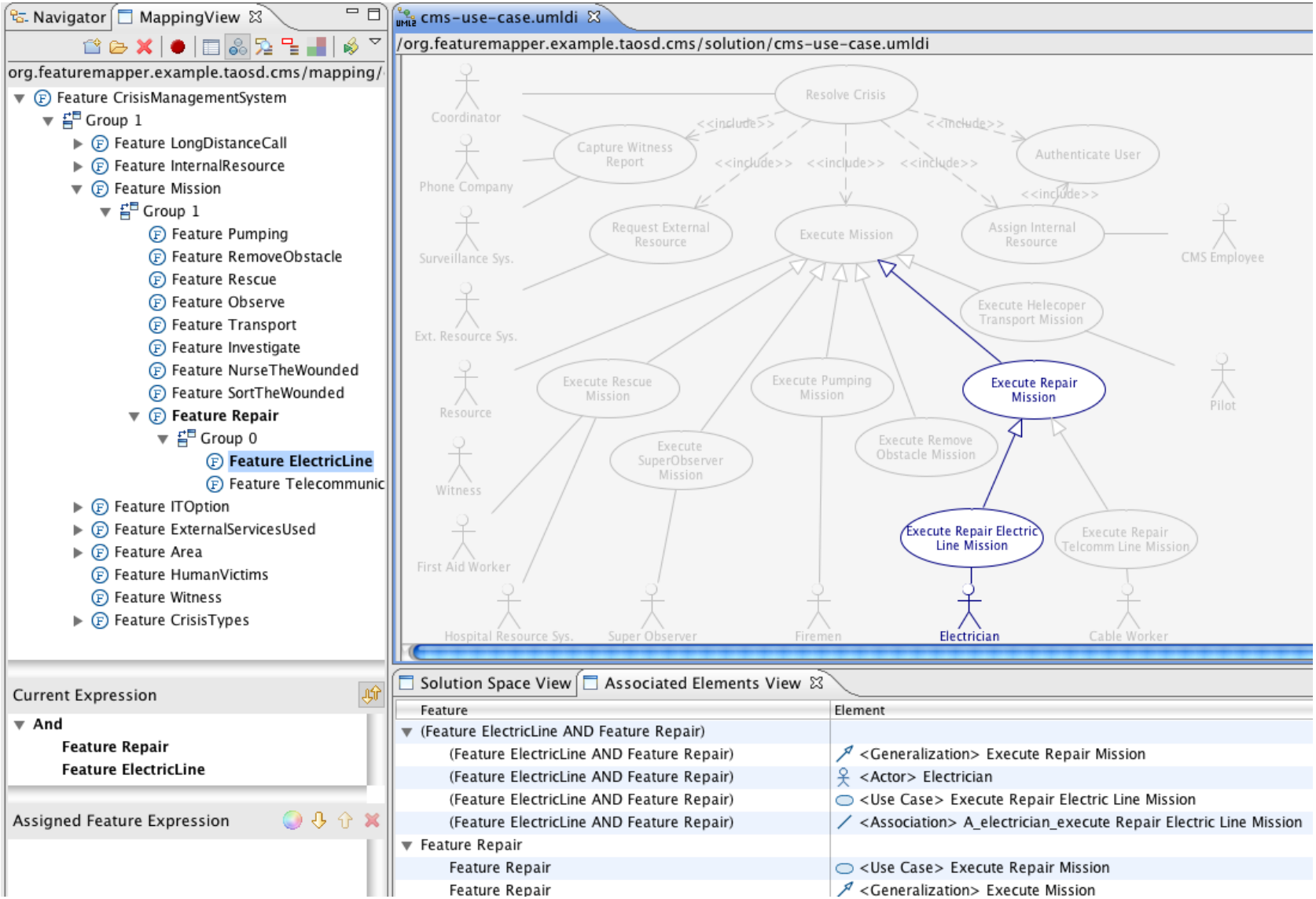


FeatureCommander



http://fosd.net/cide
http://fosd.net/fc

FEATUREMAPPER



ERROR PRONE?

How many configurations?

```
int a = 1;
#ifdef A
int c = a;
#endif
if (c) {
  c += a;
#ifdef A && B
  c /= a;
#endif
}
```

Bugs?

(a)

```
int a = 1;
int b = 1;
#ifdef A
int c = a;
#else
char c = a;
#endif
if (c) {
  c += a;
#ifdef B
  c /= b;
}
#endif
```

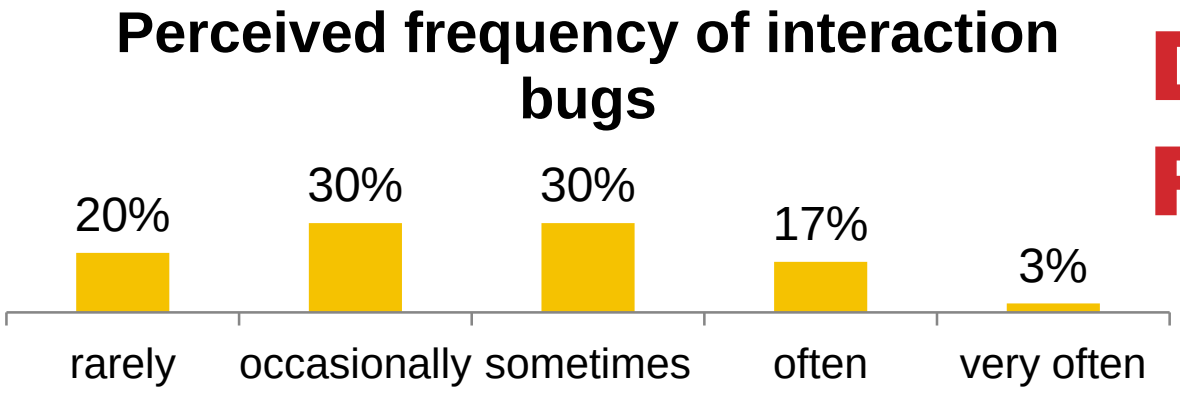
(b)

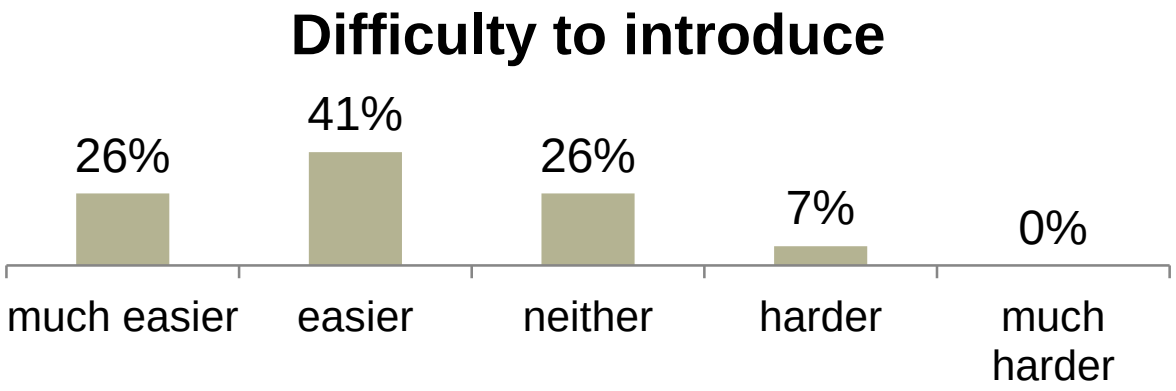
```
int a = 1;
int b = 1;
#ifdef A
int c = a;
#else
char d = a;
#endif
if (c) {
  c += a;
#ifdef B
  c /= b;
#endif
}
```

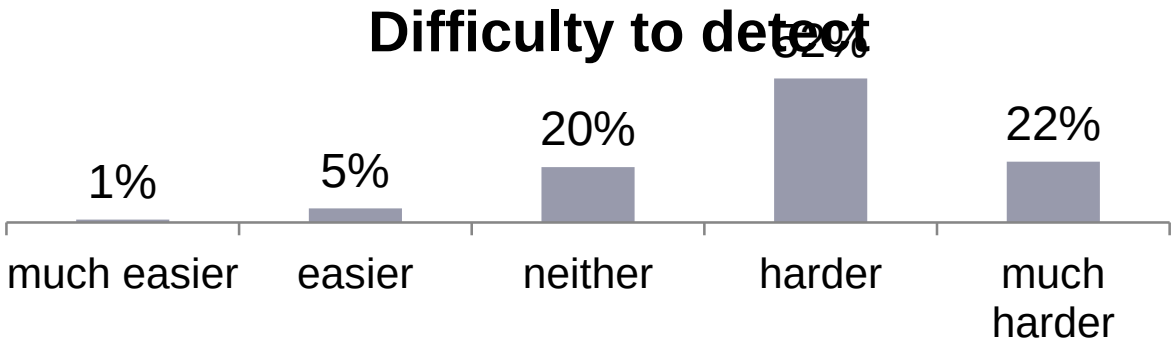
(c)

```
int a = 1;
int b = 0;
#ifdef A
int c = a;
#else
char c = a;
#endif
if (c) {
  c += a;
#ifdef B
  c /= b;
#endif
}
```

DEVELOPER PERCEPTION?







[Medeiros, ECOOP'15]

```c
void function (){

#ifdef OS1
  /* Code 1 here.. */
#endif

#ifdef OS2
  /* Code 2 here.. */
#endif

}
```

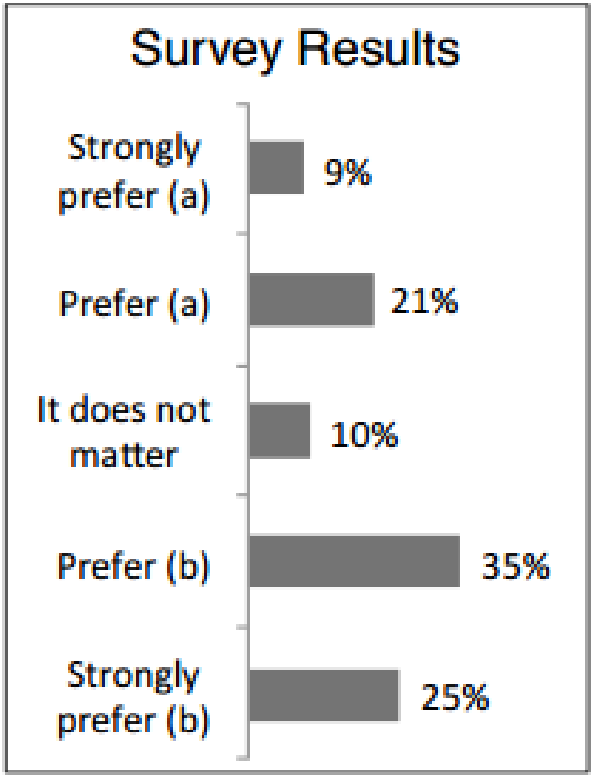
(a)

```c
// FILE: OS1.c
void function (){
  /* Code 1 here.. */
}

// FILE: OS2.c
void function (){
  /* Code 2 here.. */
}
```

(b)

In (b), only OS1.c or OS2.c is compiled depending on the platform. It is controlled at makefile level.



Medeiros, F., Kästner, C., Ribeiro, M., Nadi, S., & Gheyi, R. The Love/Hate Relationship with the C Preprocessor: An Interview Study. In Proc. 29th European Conference on Object-Oriented Programming (ECOOP 2015), 12, 40.

```
1. #ifdef USE_NTLM_AUTH
2. if (priv->sso_available) {
3.   conn->state = SSO_FAILED;
4. } else {
5. #endif
6.   conn->state = NTLM_FAILED;
7. #ifdef USE_NTLM_AUTH
8. }
9. #endif
```
(a)

```
1. #ifdef USE_NTLM_AUTH
2. if (priv->sso_available) {
3.   conn->state = SSO_FAILED;
4. } else {
5.   conn->state = NTLM_FAILED;
6. }
7. #else
8. conn->state = NTLM_FAILED;
9. #endif
```
(b)

```
1. boolean failed = TRUE;
2. #ifdef USE_NTLM_AUTH
3. if (priv->sso_available) {
4.   conn->state = SSO_FAILED;
5.   failed = FALSE;
6. }
7. #endif
8. if (failed){
9.   conn->state = NTLM_FAILED;
10.}
```
(c)

Figure 7 **(a)** Undisciplined annotation. **(b)** Alternative that clones code. **(c)** Alternative that generates compiler warnings.

Medeiros, F., Kästner, C., Ribeiro, M., Nadi, S., & Gheyi, R. The Love/Hate Relationship with the C Preprocessor: An Interview Study. In Proc. 29th European Conference on Object-Oriented Programming (ECOOP 2015), 12, 40.

LEXICAL VS SYNTACTIC PREPR.

Feature	CPP example	ASTEC example
⊕ Include files	`#include "header.h"`	`@import "header.h";`

⊕ Conditional compilation	`#if defined(X) && Y > 3`
	`int z;`
	`#endif`
		`@if(@defined(X) && Y > 3) int z;`

⊕ Macros	`#define M(x) ((x)+2)`
	`#define RETURN(x) return x;`
	`#define u32 unsigned int`
		`@macro int M(int x) = x+2;`
		`@macro RETURN(x) { return x; }`
		`@type u32 = unsigned int;`

⊕ Dynamic scoping	`#define Z() ptr->x->y->z`	`@macro char *Z([T *ptr]) = ptr->x->y->z;`
⊕ Reference arguments	`#define M(x, y) x = 2*(y);`	`@macro M(int &x, int y) { x = 2*y; }`
⊕ First-class types	`#define SIZE(T) \\` `(sizeof(T) + sizeof(int))`	`@macro SIZE(@type T) =` `sizeof(T) + sizeof(int);`

⊕ First-class statements	`#define FOR_EACH(x, list) \\`
	`for (x=(list); x; x = x->next)`
	`...`
	`FOR_EACH(it, list) { ... }`
		`@macro FOR_EACH(x, List *list, @stmt S) {`
		`for (x=(list); x; x = x->next) S;`
		`}`
		`... FOR_EACH(it, list, { ... });`

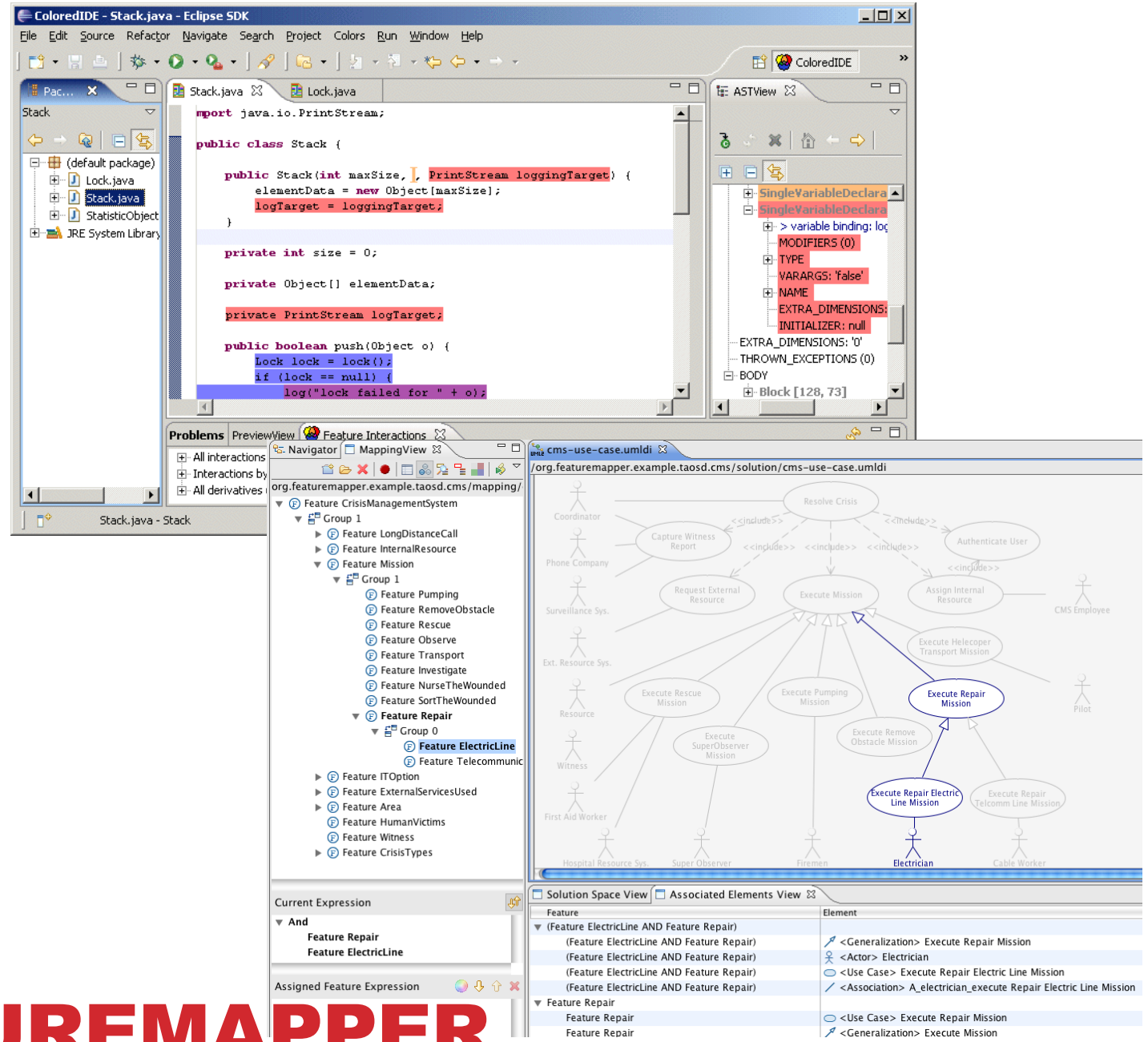
⊕ First-class names	`#define offsetof(T, field) \\` `(size_t)(&((T*)0)->field)`	`@macro offsetof(@type T, @name field) =` `(size_t)(&((T*)0)->$(field))`
⊕ Declaration "decorators"	`#define NONNULL(args...) \\` `__attribute__((nonnull(args)))`	`@decorator NONNULL(args...) =` `__attribute__((nonnull(args)))`

⊕ Declaration macros	`#define DECLARE_LIST(name) \\`
	`List name = { .head = NULL };`
	`... DECLARE_LIST(hello)`
		`@module DECLARE_LIST(@name name) {`
		`List $(name) = { .head = NULL };`
		`};`
		`... @import DECLARE_LIST($hello);`

⊕ Stringization and concatenation	`#define DECLARE_STRING(name, s) \\`
	`char *name##_str = #s;`
		`@module DECLARE_STRING(@name name,`
		`@expr s) {`
		`char * $(name ## $_str) = @stringize(s);`
		`};`

Bill McCloskey and Eric Brewer. 2005. ASTEC: A new approach to refactoring C. In Proceedings of the 10th European Software Engineering Conference/International Symposium on Foundations of Software Engineering (ESEC/FSE-13). ACM, New York, NY, USA, 21-30.

CIDE



FEATUREMAPPER

TOOL SUPPORT

Refactoring

Navigation support

Static analysis

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