Software Product Line Engineering

Preprocessors

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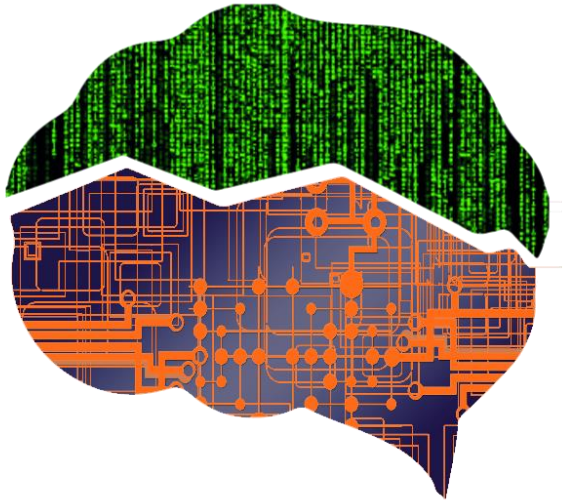
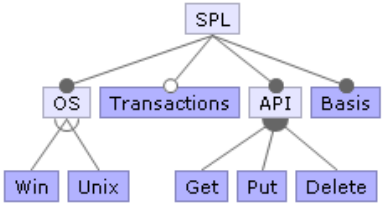


Bauhaus-Universität Weimar

How to implement variability?

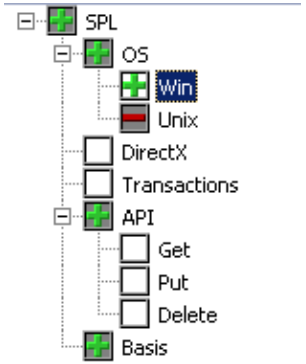
Domain Eng.

Feature Model



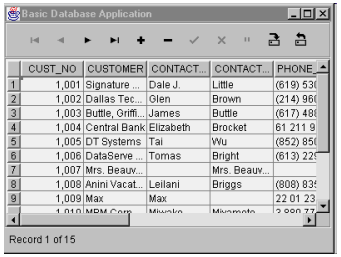
Reusable Implementation artifacts

Application Eng.



Feature Selection

Generator



Resulting Program

Variability at Compile Time

- Goal: Only the actually needed source code gets compiled
- But features should be flexibly selectable

What was Missing?

- Evaluating an „if“ not just at runtime
- Remove whole methods and classes when required
- Allow alternatives

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

Actually remove

remove

```
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;
  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();
  }
}
```

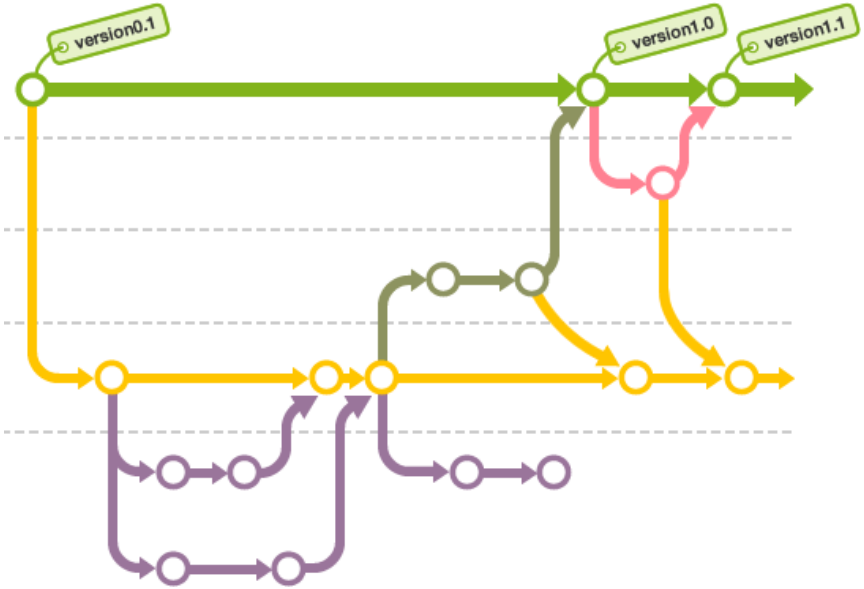
remove

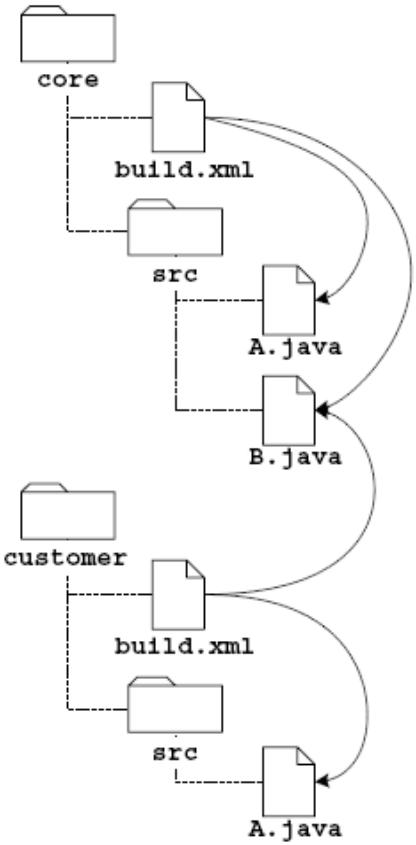
```
class Color {
  static void setDisplayColor(Color c) { ... }
}
```

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

What was Missing?

- Feature-based planning and variant generation
- Fine-granular variability
- Make feature explicit in source code





Preprocessors

Preprocessors

- Transform source code before executing the compiler
- Ranging from simple #include-Commands and conditional translation to complex macro languages and rules
- In many programming languages available
  - C, C++, Fortran, Erlang with own preprocessor
  - C#, Visual Basic, D, PL/SQL, Adobe Flex

#ifdef Example from Berkeley DB

```
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
```

Preprocessor in Java?

- No native support
- Conditional compilation only in some cases possible; only on statement level and not on class or method level

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

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

- External tools, e.g., CPP, Antenna, Munge, XVCL, Gears, pure::variants

Munge

- Simple preprocessors for Java code
- Originally for Swing in Java 1.2

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

java Munge –DDEBUG –DFEATURE2 file1.java file2.java ... target folder

Feature selection based on feature model

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

Recap: Graph Example

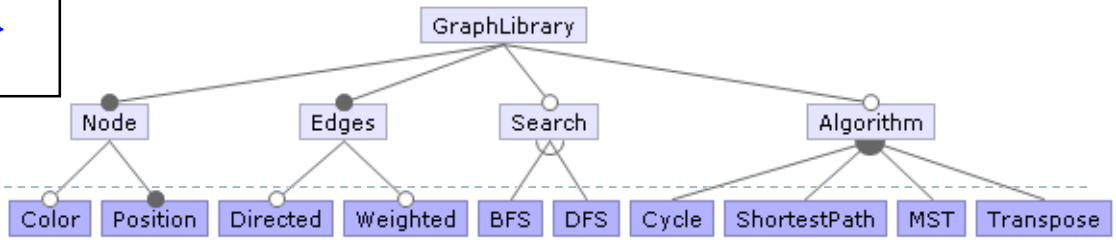
```
class Graph {
  Vector nv = new Vector(); Vector ev = new Vector();
  Edge add(Node n, Node m) {
    Edge e = new Edge(n, m);
    nv.add(n); nv.add(m); ev.add(e);
    e.weight = new Weight();
    return e;
  }
  Edge add(Node n, Node m, Weight w)
    Edge e = new Edge(n, m);
    nv.add(n); nv.add(m); 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() { ... } }
```



Graph Example 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();
    }
  }
}
```

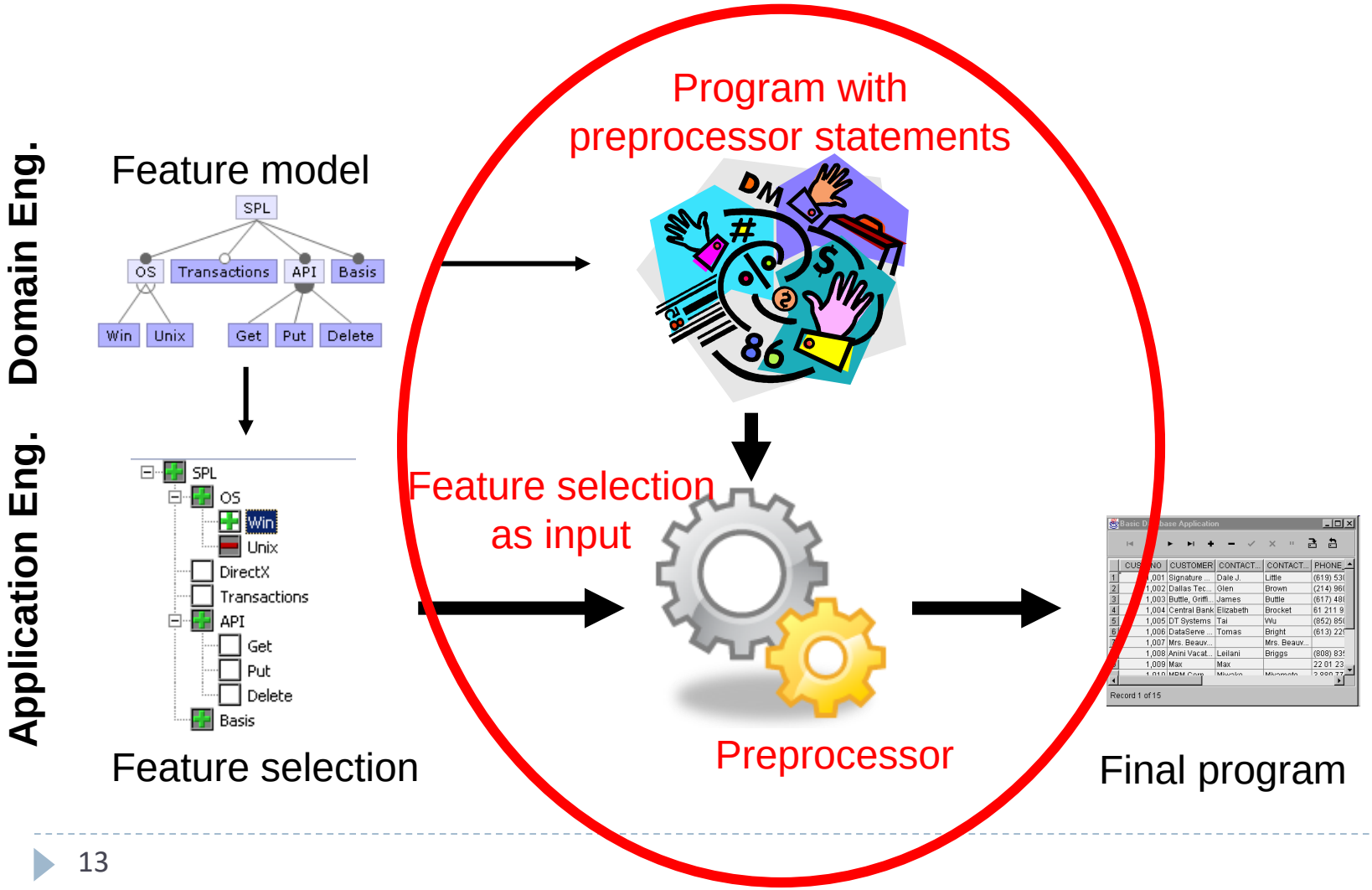
```
/*if[WEIGHT]*/
class Weight { void print() { ... } }
/*end[WEIGHT]*/
```

```
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]*/
```

Product Line with Preprocessors



More Preprocessors

XVCL

- XML-based preprocessor
- Bases on frame hierarchy

```
<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>
```

Antenna

- Collection of Ant tasks for Java ME
- Contains preprocessor: #ifdef similar to *cpp*
- Used in many Jave ME projects

```
        /** 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/

Discussion

Advantages of Preprocessors

- In many languages already available
- Known to most developers

- Simple programming concept:
  tag and prune
- Very flexible, fine granular, and powerful

- Easy integration of variability into an already existing project

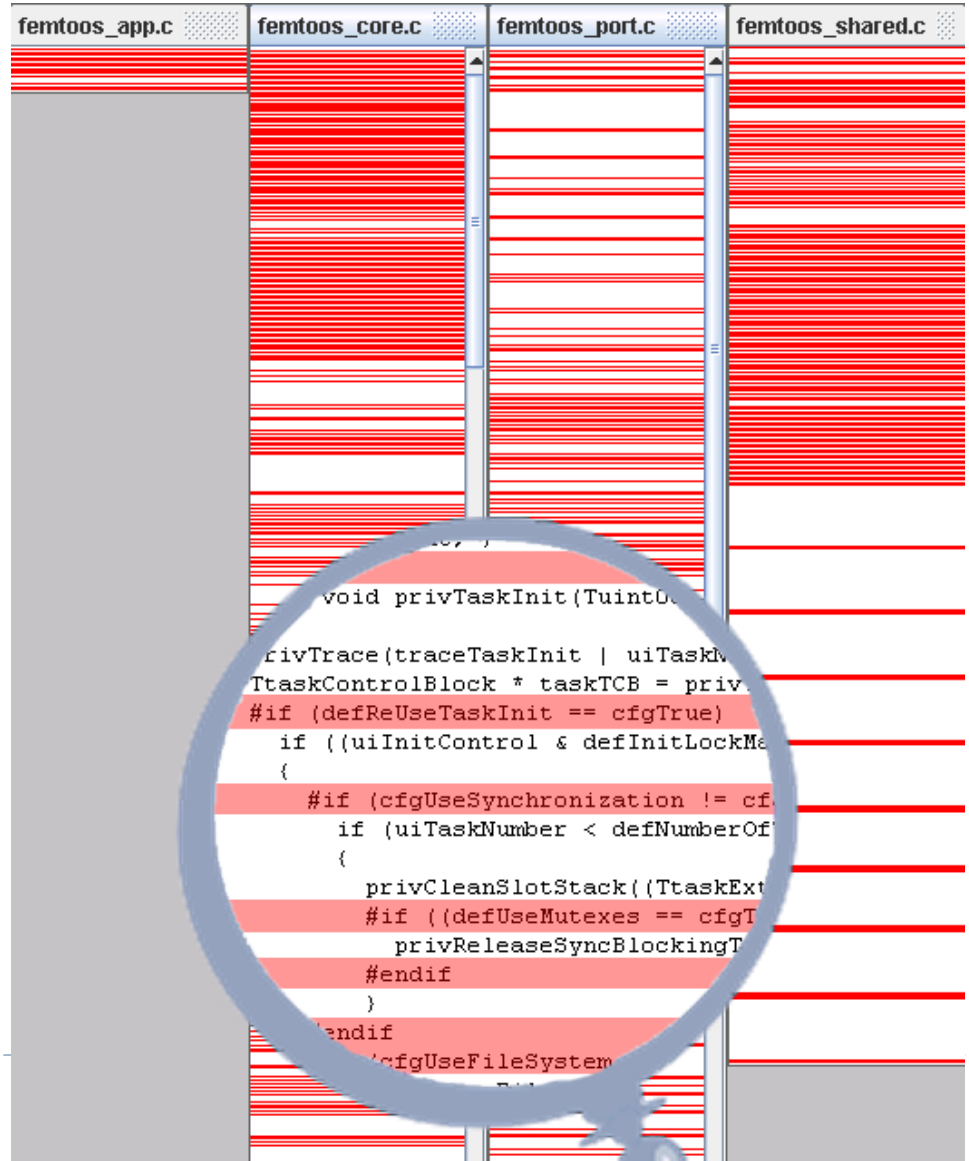
Problem: Hard to Read Source Code

- Mix of two languages (C and #ifdefs, or Java and Munge, …)
- Control flow is hard to follow
- Long annotations are hard to find
- Additional linebreaks may destroy the layout

```
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();
}}
```

➔ Better modularize features?

Preprocessor in Femto OS



Problems of Preprocessors

- Complexity due to arbitrary nesting
- Error prone due to complexity and undisciplinary usage
- Example:
  - Variable return type

```
/*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]*/ );
}
```

  - Comma in case of multiple parameters

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

Problem: Error Prone

- Syntax error

```
static int _rep_queue_filedone(...)
    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
```

- Type error

```
#ifdef TABLES
class Table {
  void insert(Object data,
        Txn txn) {
      storage.set(data,
        txn.getLock());
  }
}
#endif
class Storage {
#ifdef WRITE
   boolean set(…) { ... }
#endif
}
```

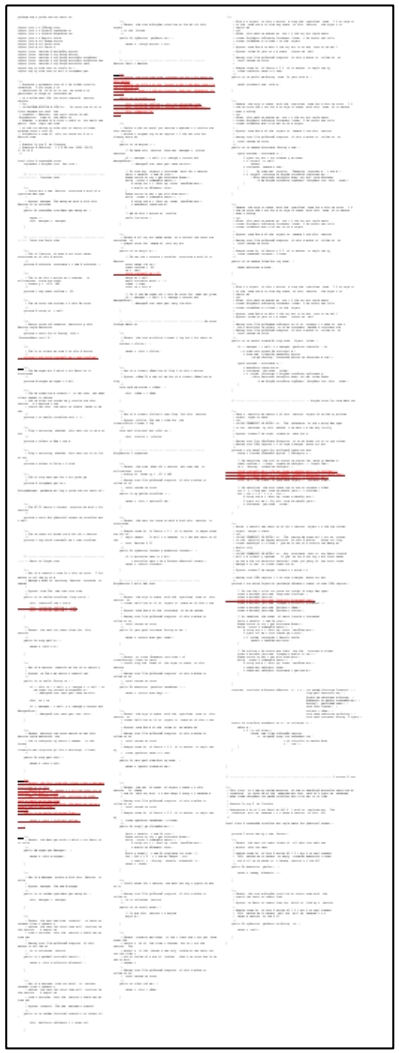
Problems of Preprocessors II

- Feature code is scattered through the whole code base
  - ➔ Feature traceability problem
  - How to find an error in feature *Weight*?
- Hinders/complicates tool support
  - Experience from C/C++ (refactoring, analysis, …)
  - Munge and others: Definition in comments

A Question of Size

ApplicationSession

StandardSession



ServerSession

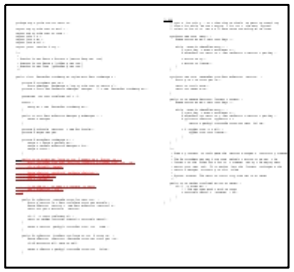
Example: Time management in sessions of Apache Tomcat server as part of the session management

SessionInterceptor

StandardManager

StandardSessionManager

ServerSessionManager



The Feature Tracability Problem

Problem: Scattered Implementation

- Feature disappears in implementation
  - What belongs to an individual feature?
  - Search through whole code base for maintenance tasks
- Difficult division of work
  - There may be different experts for different features; but all have to work at the same code fragment
- Lower productivity, complex evolution
  - To add a new functionality, developers have to take care of many concerns, which may be distracting (readability, understandability)

Features in the Graph Example

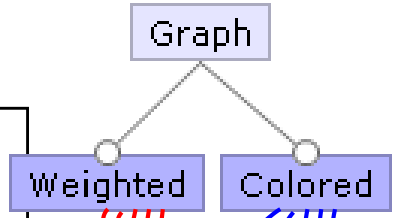
```
class Graph {
  Vector nv = new Vector(); Vector ev = new Vector();
  Edge add(Node n, Node m) {
    Edge e = new Edge(n, m);
    nv.add(n); nv.add(m); ev.add(e);
    e.weight = new Weight();
    return e;
  }
  Edge add(Node n, Node m, Weight w)
    Edge e = new Edge(n, m);
    nv.add(n); nv.add(m); 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() { ... } }
```



Consequences

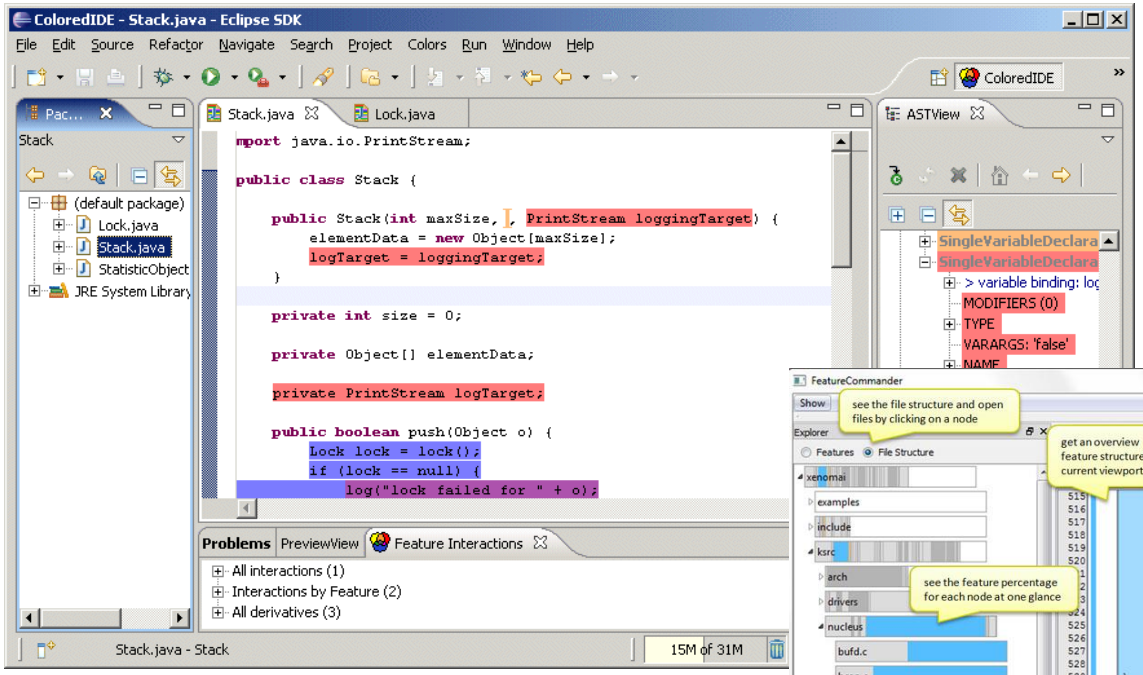
```
class BusinessClass
  //... Datenfelder
  //... Logging Stream
  //... Cache Status
  public void importantOperation(
        Data data, User currentUser, ...){
    // prüfe Autorisierung
    // Objekt sperren für Synchronisation
    // Aktualität des Puffers prüfen
    // Start der Operation loggen
    // eigentliche Operation ausführen
    // Ende der Operation loggen
    // Sperre auf Objekt freigeben
  }
  public void alsoImportantOperation(
        OtherData data, User currentUser, ...){
    // prüfe Autorisierung
    // Objekt sperren für Synchronisation
    // Aktualität des Puffers prüfen
    // Start der Operation loggen
    // eigentliche Operation ausführen
    // Ende der Operation loggen
    // Sperre auf Objekt freigeben
  }
}
```

- What code belongs to the authentification feature?
- The locking mechanism should be changed: Which code needs to be adapted?
- Users could delete data without logging into the system: where is the error?

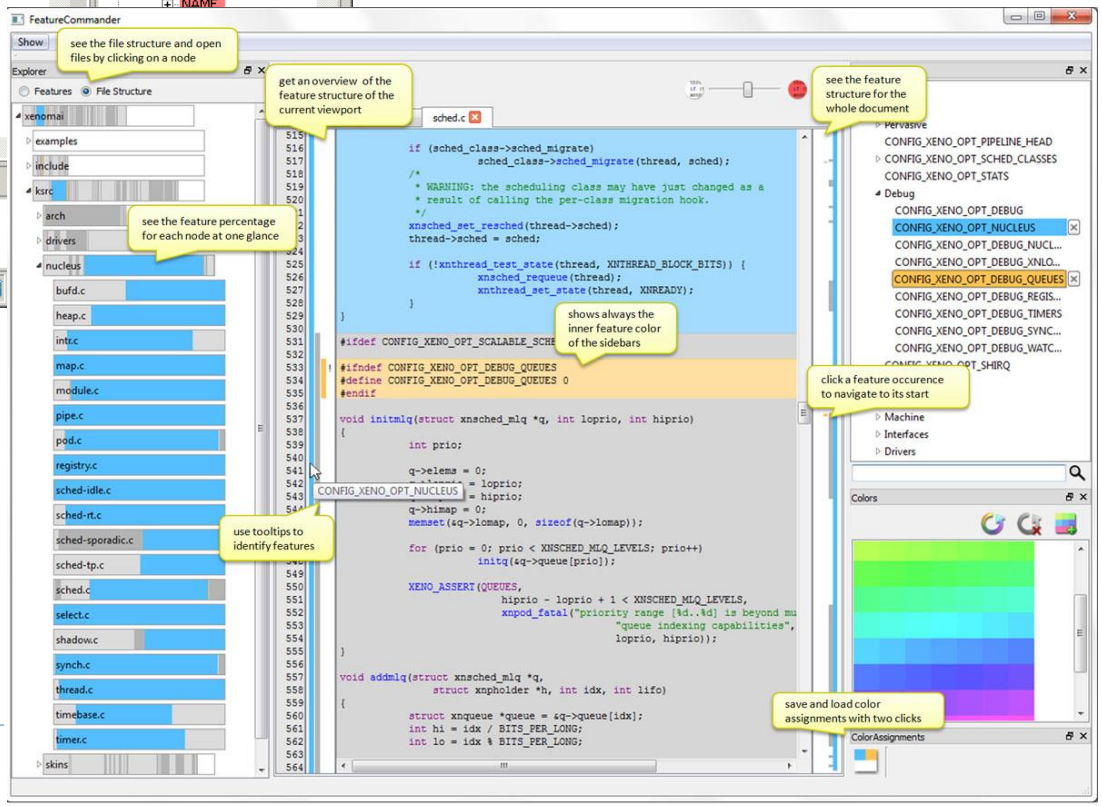
Feature Traceability

- Keep the relationship between code and feature
- Ideally, one module per feature
- Detours and compromises are inevitable if modularization is not possible
  - Comments and annotations in the source code (e.g., the whole authentication code is marked with „//auth“)
  - Naming conventions (e.g., all authentication methods start with „auth_“)
  - Additional tooling, such as IDE-plugins
- Preprocessors support already annotations for features

CIDE



FeatureCommander



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

Outlook

- Modular forms for implementing features
- Crosscutting concerns
- Possible improvements of preprocessors

Quiz

- How many source-code variants are possible?

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

- Where is the error?

(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
}
```