Lecture 10
Topics in Configuration Managements

1. Componentization
2. Product-line family

Last lecture …

1. Sign a contract
2. Design by contract
   Three kinds of design contracts
3. Programming by contract
   Three kinds of programming practices by contract

Today …

1. Problems in legacy software development
2. Componentization
    1. Redundancy removal
    2. Header Restructuring
    3. Clustering (repackaging)
3. Feature oriented programming
4. Summary

1. Problems facing SE

- Software are getting more complex
  - Code size getting larger, more dependencies
  - More developers are involved
  - More users and stakeholders
  - Understandability, productivity are dropping
- Thus, Control the complexity is the central theme of software engineering
- How to improve so that people can develop in parallel and incrementally? Sync-and-Stabilize or “Daily build” approach
- Componentization and Software Product-line family are good solutions to the problem

2. Components

- Modules have high cohesion and low coupling
- To support parallel development, ideally, components can be independently compiled and tested
- A component has an interface (set of operations) through which other components can interact
- A web service is a component that has a standardized interface and interoperability regardless of programming languages

Legacy software

- Legacy software typically contains large set of program files, but not well modularized
- Redundancy: the interfaces of “components” in legacy software are bloated
  - A prolonged fresh build time
- False dependencies: including unnecessary program units for the component
  - Too complex to be understood
  - A prolonged incremental build time
- We will show C/C++ as an example, but the problem exists for other PL as well

Example 1. Hello world

```
#include <stdio.h>
void main () {
    printf (''Hello, world!'');
}
```

- How many LOC after inclusion? 767

```
gcc -E -P hello.c -o hello.o
wc hello.o
```

- How many LOC is needed? 4

```
gcc -E -P -fdump-program-unit hello.c
```

- The #include shall expand to a single line:

```
int __attribute__((__cdecl__)) printf( const char*,...);
```

2.1 Componentization

- Restructuring by removing unnecessary units in the program
- A restructuring unit is a statement *declaring*, or a *defining* of the user-defined symbols, such as *functions, variables, classes, structures, types*, etc.
- A local variable, parameter, a field or a method of the class are not considered as a restructuring unit because removing them may affect the semantic of the program
- What is the difference between declaration and definition? Declaration can occur multiple times, definition can only occur once.
- Preserving semantics: (1) maintain the dependencies such that compiler won't complain about undefined symbols; (2) make sure necessary definitions are kept in the compilation units

2.2 Redundancy removal

- As shown in previous example, redundancy happens when some program declaration are unnecessary
- How to tell this?
- In GCC 3.4.0, we change its parser such that a symbol transitively dependent by the definitions will be kept in the precompiled program
- Very efficient and beneficial
  compilation time + precompilation time < original compilation time

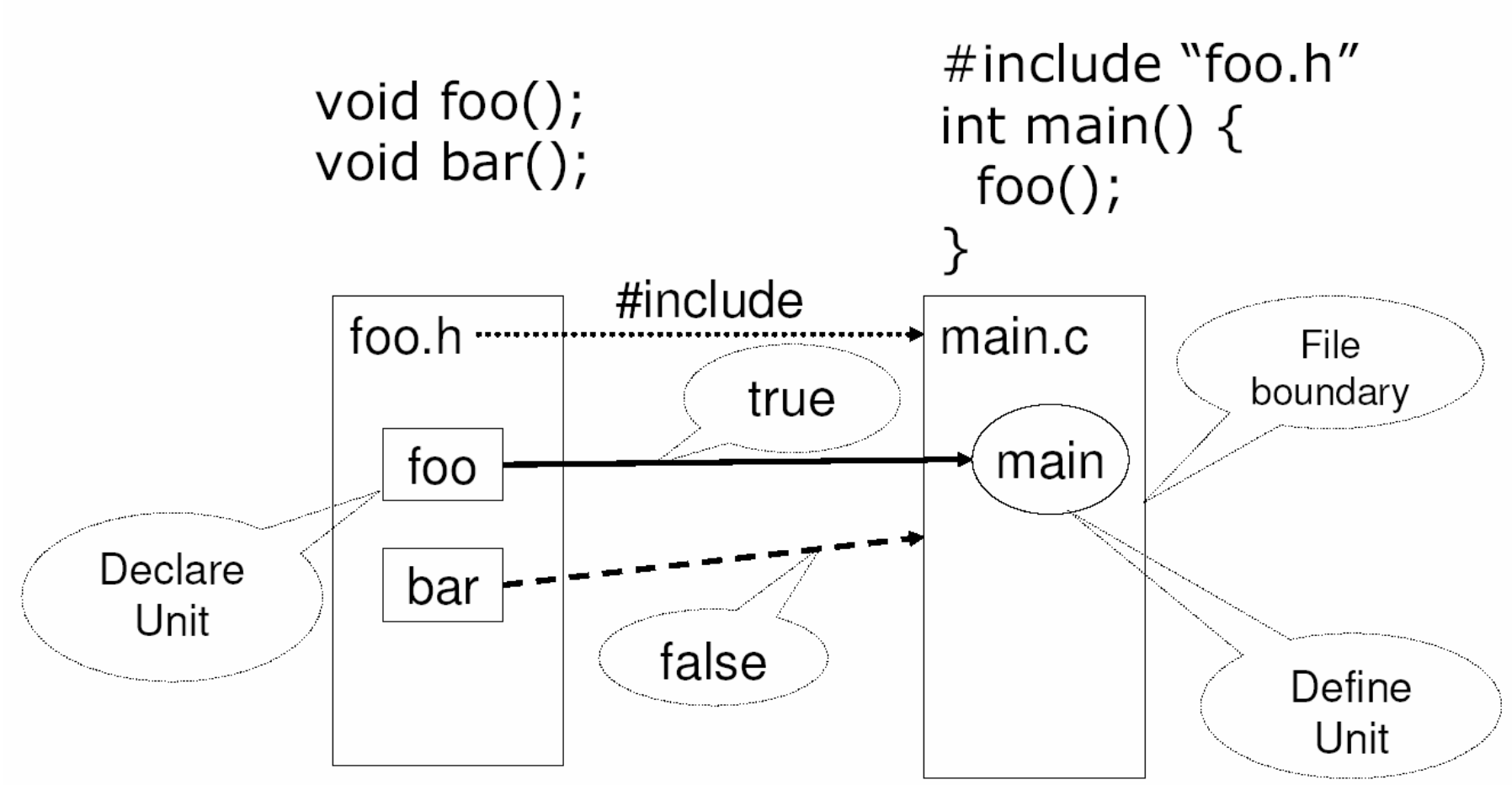
Example 2. Removing redundancies along parsing

```
1.  typedef int NUMBER;            //PU@1
2.  struct node;                   //PU@2 forward:node@2
3.  typedef struct node {          //PU@3 type:list@3
4.   float value;                  //     struct:node@3
5.   struct node* next;            //        <- PU@3, PU@2
6.  } *list;                       //
7.  struct A {                     //PU@4 struct:A
8.   union {                       //
9.     NUMBER value;               //        <- PU@1
10.  } u;                          //
11. };                             //
12. extern int                     //
13. printf(char *format,...);      //PU@5 funcdcl:printf@5
14. enum {                         //PU@6 enum:<anonymous>@6
15.   Satisfied,                   //     enumerator:Satisfied@6
16.   Denied,                      //     enumerator:Denied@6
17. };                             //
18. int main(argc, argv)           //PU@7 funcdef:main@7
19. int argc; char **argv;         //
20. {                              //
21.     list l, n;                 //        <- PU@3
22.     for (n = l; n; n=n->next)  //
23.        printf("f", n->value); //        <- PU@5
24.     return (int) Satisfied;    //        <- PU@6
25. }                              //
```

2.3 Header restructuring

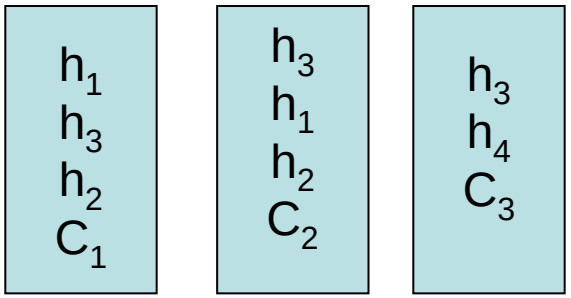
- Configuration management: to maintain the software when changes happens
  For example: CVS
- Removing redundancies in the preprocessed program does not solve the problem for incremental changes
- A compilation unit does not need to recompile when its dependent symbols are not changed at all
- Such unnecessary recompilations are caused by false dependencies

Example 3. False dependency

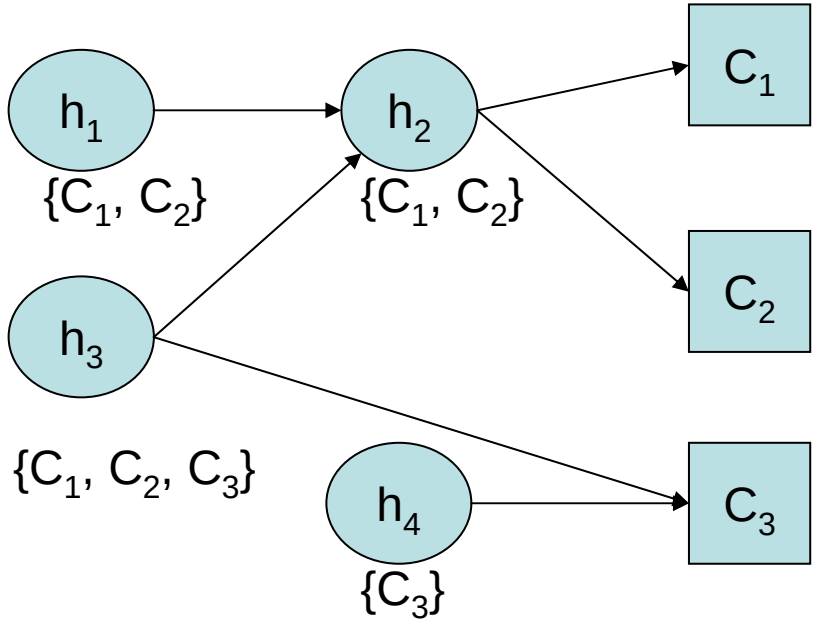


The removal of false dependencies

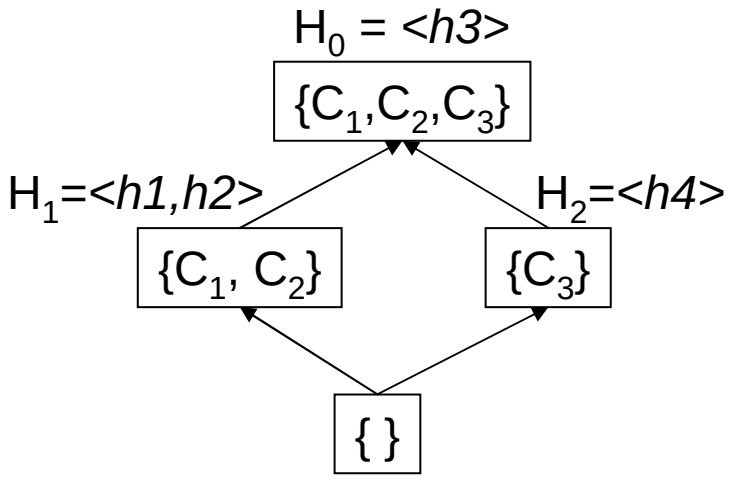
- Identify dependencies
- Partition the definition and declaration units into separate files, replacing dependencies with “#include”
- Grouping the declarations into larger headers, if it does not incur false dependency
- The code generation process can be done efficiently



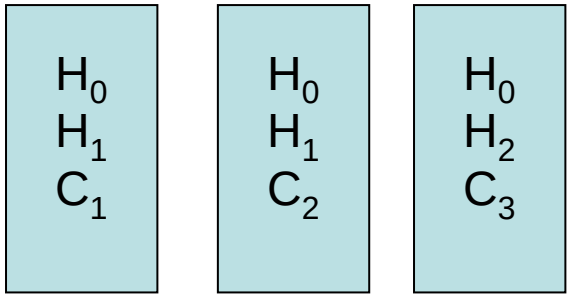
(a) Program unit sequences after redundancy removal where h_i is the i-th global declaration and C_j is the sequence of definitions in the j-th compilation unit



(b) The implicit light-weight PUDG



(c) The partitioning lattice



(d) Generating ordered header inclusions

2.4 Clustering

- Problem: too many headers are generated, because we get rid of all false dependencies
- Tradeoff: Can we tolerate some false dependency for smaller number of headers, that is, to group them further into larger files?
- Clustering is to group related things together, the technique is often used in data mining and machine learning
- We want to cluster generated headers use the hints of dependencies

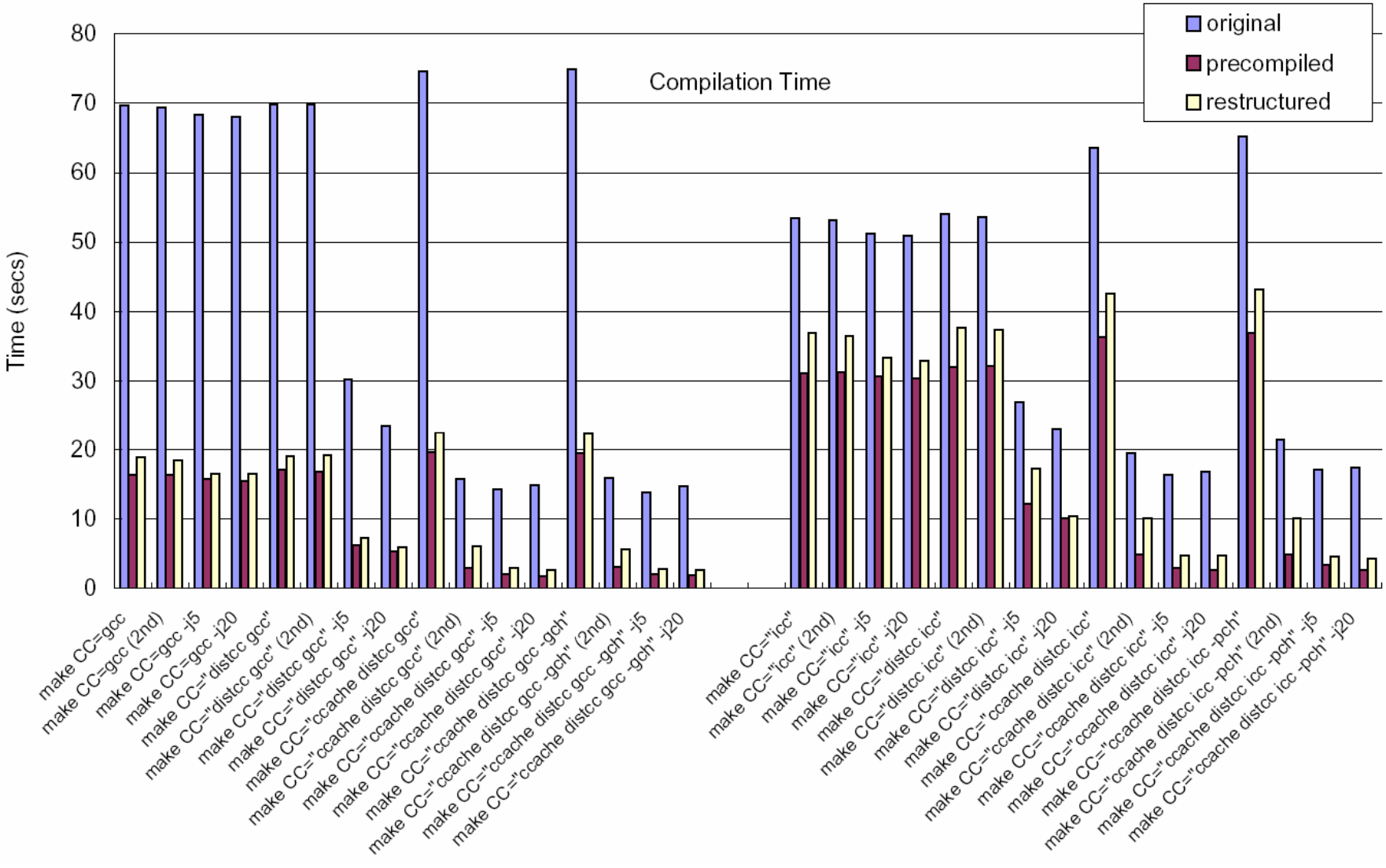
LIMBO clustering

- LIMBO is a clustering technique to minimizing information loss in dependency graphs
- Group A, B into a cluster does not have information loss if both depends on same entities, e.g.
  A depends on A1, A2
  B depends on A1, A2
- Group A, B into a cluster has information loss if they depends on different entities, e.g.
  A depends on A1, A2
  B depends on B1, B2
- The idea is to quantify the information loss and rank them so that minimal loss is the priority

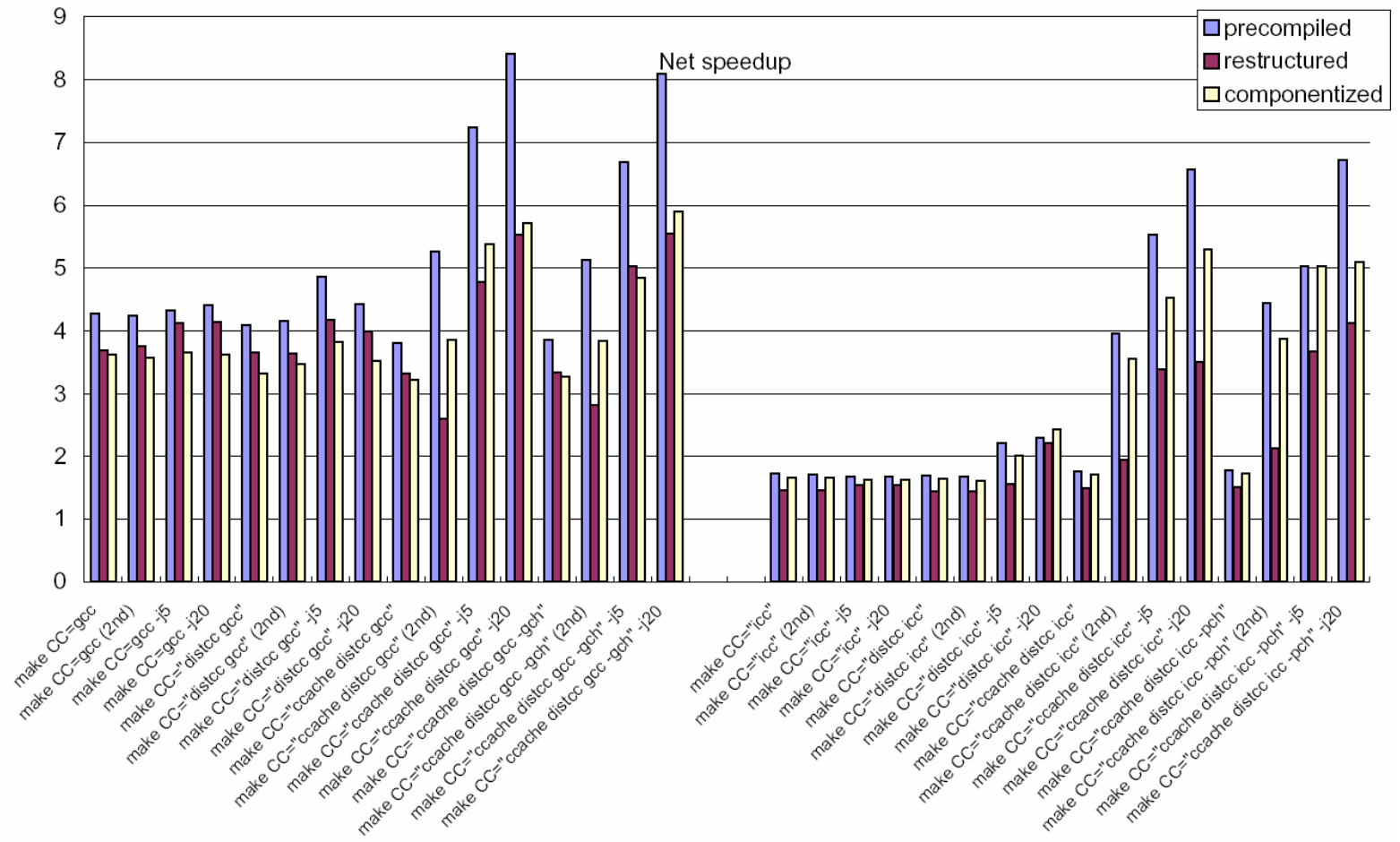
Example 4. VIM 6.2

- We have removed around 70% redundancies in LOC
- We have removed all false dependencies, which generates 952 headers
- Using dependencies and the LIMBO clustering, we got only 3 clusters (corresponds to the MVC architectural pattern) and 5 headers

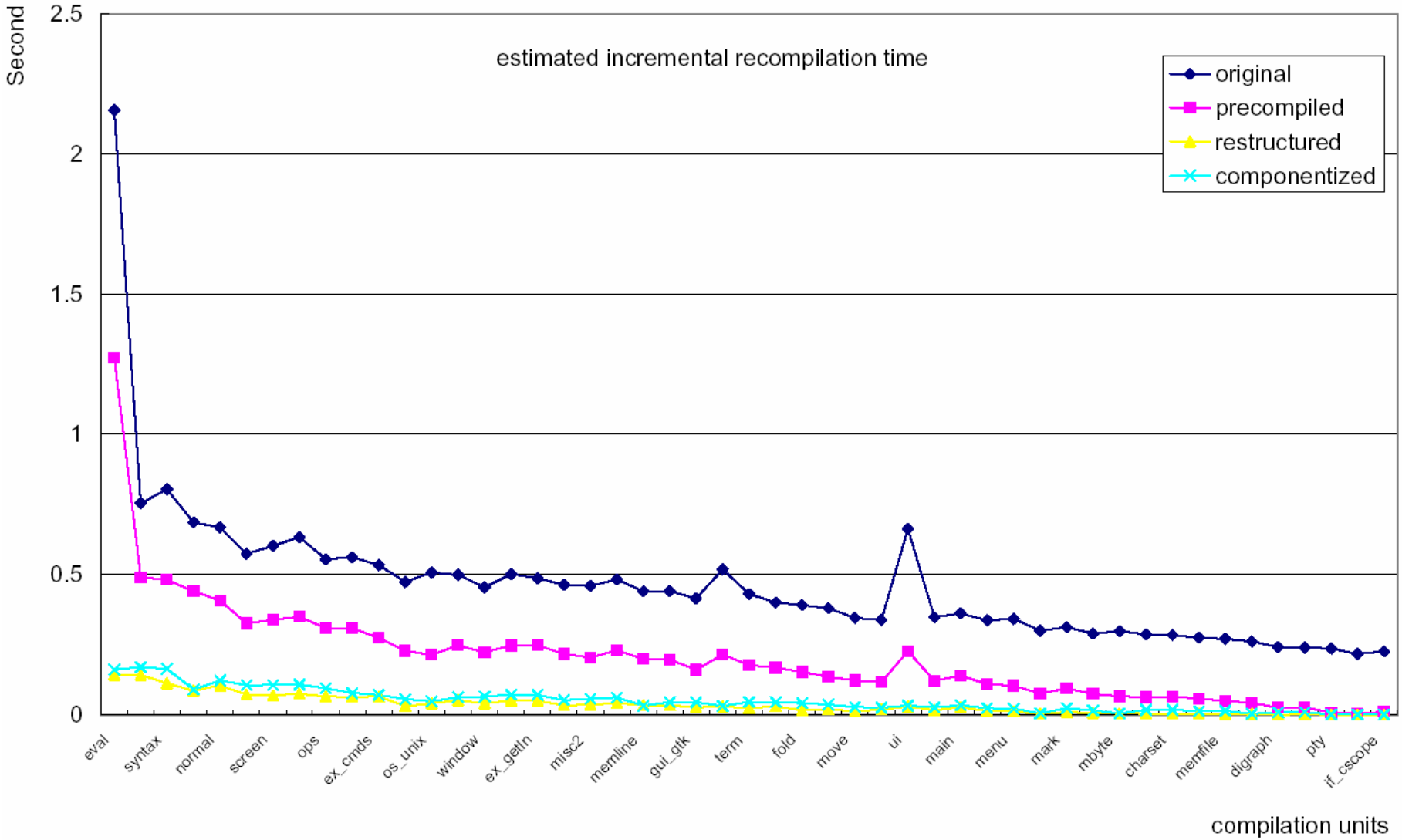
Experiments: fresh build time



Experiments: fresh build speedups



Experiment: incremental build time



2.5 More code removal?

- Dead code elimination

```
int add(int x, int y) {
   int r1 = x + y;
   int r2 = x * y;
   return r1;
}
```

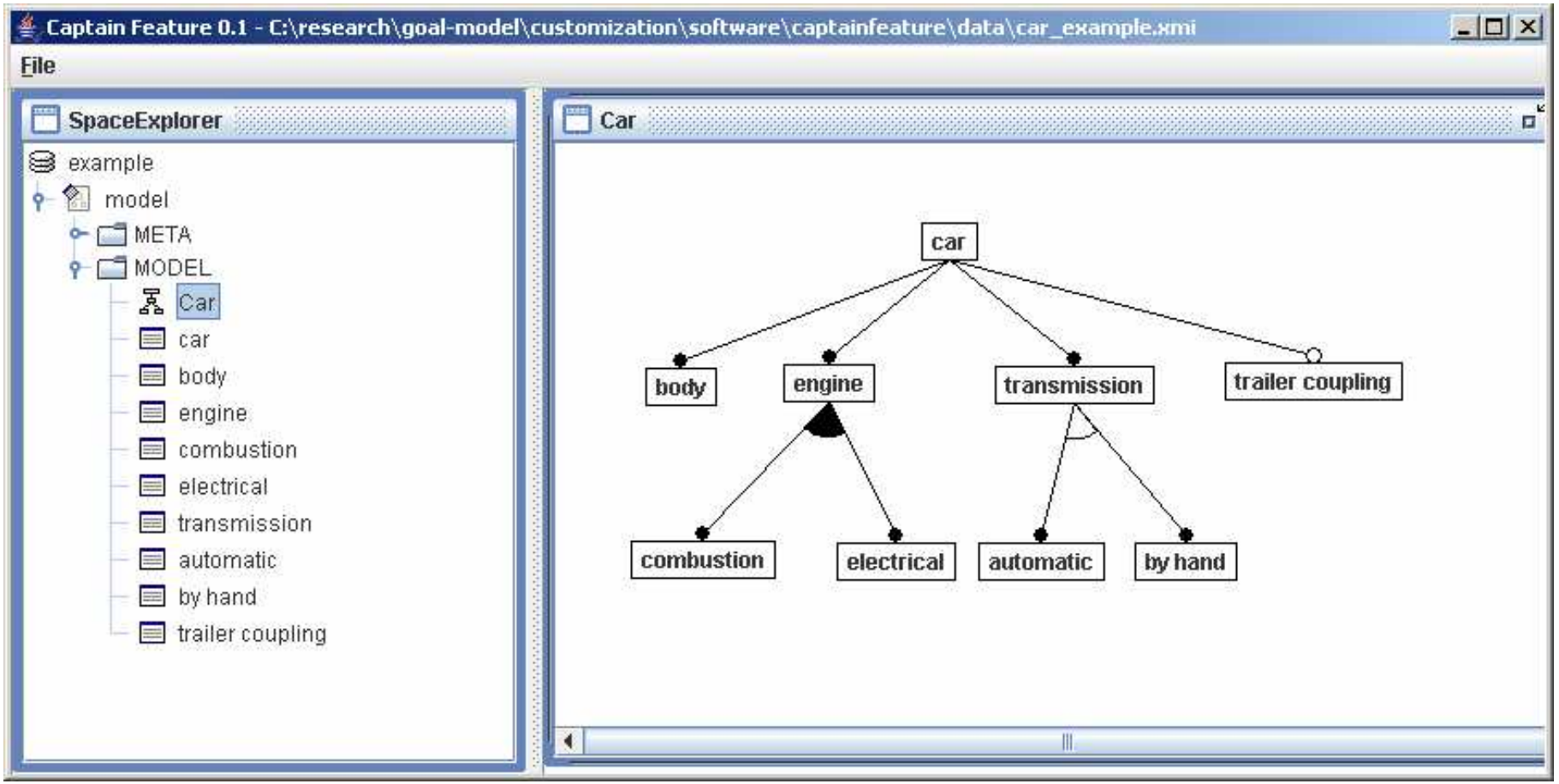
- Unused fields and methods

```
class A {
   double value;
   int getValue() { return value; }
   public static void main(String args[]) {
       printf("Hello world!");
   }
};
```

3. Variability in Product-line Family

- Consider Daimler Chrisler (car manufacturer), every product out of the product-line is different from each other –-- [Czarnecki]
- Why? Because the Factory produces software that variability in every feature of the car
- Can we do the same in software industry? SAP's approach: Domain engineering
- Feature models capture variability in the solution space, whereas goal models capture variability in the problem space

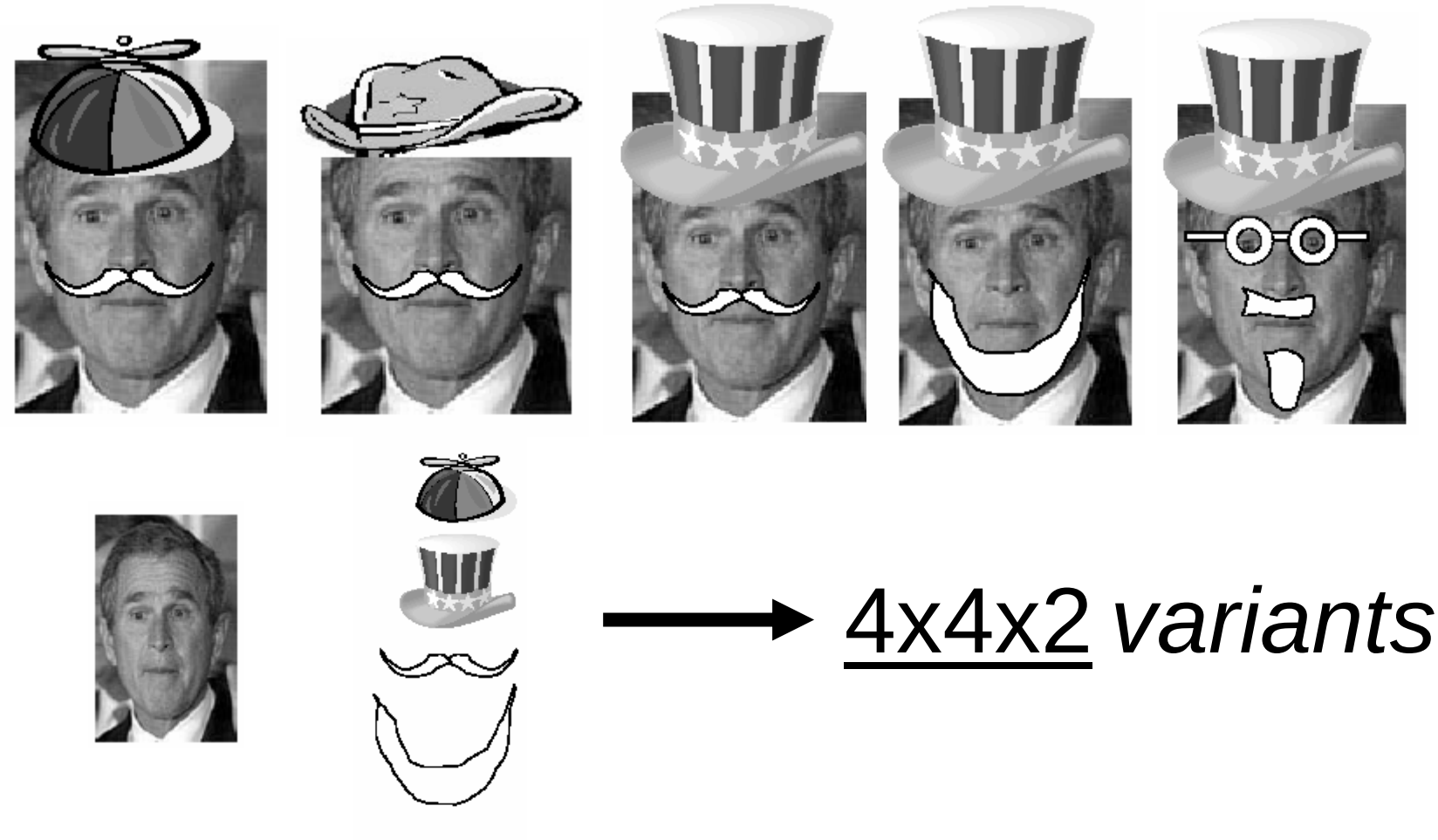
3.1 Feature model



CaptainFeature is a feature modeling tool [Czarnecki]

A feature is either Mandatory, Optional, Alternative or (Inclusive) Or.

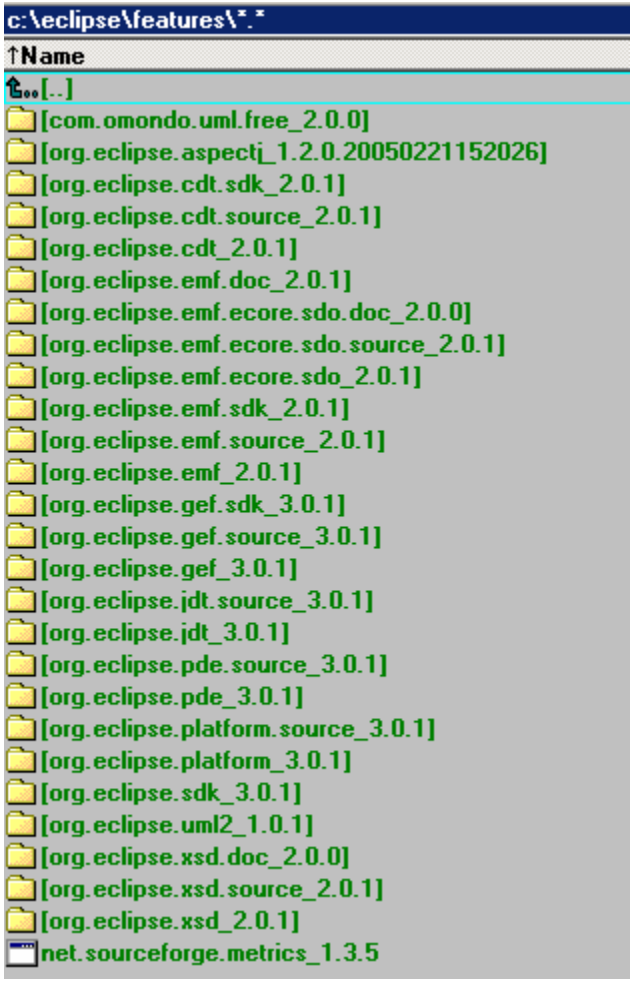
Example from Batory's tutorial



4x4x2 *variants*

Software Feature Model

- A software system is composed of features
- Features can be organized in a hierarchy
- Example
  eclipse/features/feature.xml
  …
  eclipse/plugings/plugin.xml…



3.2 Feature oriented programming

- Supported by the AHEAD tool suite
- Key idea is to represent a feature as a layer of the incremental pieces of modules
  - In Hyper/J, this is called “concern graph”
  - In AspectJ, it is called aspect crosscutting
- FOP versus AOP?

Program Synthesis Paradigm

Note: each feature crosscuts multiple classes

Program P = **featureZ • featureY • featureX**

By composing features, packages of fully-formed classes are synthesized

Example

```
class A {
  data1; method1;
  data2; method2;
  data3; method3;
};
```

```
class A {};                          …Core prg. as a constant c
class A { data1; method1; }; …Feature as a function i
class A { data2; method2; }; …Feature as a function j
class A { data3; method3; }; …Feature as a function k
```

- Mixing them k(j(i(c)))
- Advantages:
  Incremental and parallel development
  Step-wise refinement
- Risk:
  How to guarantee the semantics and information hiding?

3.3 Generative programming

- Templates in C++: `stack<int>`
- Templates in code generators (Eclipse)
  Generating class, method, test cases, etc.
- Generated code in the Visual programming
  Visual Studio, Visual Editor, etc. Generating GUI code
- What else does generative programming do? Derives a configuration from the feature model. Each configuration leads to one variant of the product
  - `#if engine==GASOLINE`
    `...`
    `#endif`
  - `-Dengine=GASOLINE`
  - CaptainFeature -> Configuration (XML)
- You may apply the variability configuration at compile-time, deploy-time, run-time

3.4 Industrial practice: Partial classes

- .NET framework 2.0 (ASP.NET magazine)
- Implemented in the CLR: C#, C++, VB
- Proposed to solve problem for mixing generated code (visual programming) and user code
- Now a class definition can scatter over multiple files as long as there is a “partial” modifier

```
partial class A { data1; method1; };
partial class A { data2; method2; };
partial class A { data3; method3; };
```

- The weaving is done by the .NET compiler

4. Your exercise

- Consider componentization of your modules: minimize the interface
- Each component is a module that implements part of a feature, they can be organized into a (layered) feature model, and converting the program into a set of features (FOP)
- Create a feature model to show the distinctiveness of your product over other teams? ----- bonus J
- Use feature model to know whether you can produce a generic software as a product line family, to integrate with other team's various products

5. Summary

- Why componentization is important?
- How can you turn legacy software into components?
- How can you decompose components into features and assemble them back?
- What's the relation among CBSE (COTS), FOP and AOP?

Further readings

- R. Adams, W. Tichy, A. Weinert. “The cost of selective recompilation and environment processing”, ACM Trans. on Software Engineering Methodologies, 3, 3-28. 1994.
- D. Batory, J. N. Sarvela, A. Rauschmayer. “Scaling step-wise refinements”, IEEE Trans. On Software Engineering. 30(6):355-371. 2004.
- K. Czarnecki and U. Eisenecker. *Generative Programming: Methods, Tools, and Applications*, Addison-Wesley, Reading, MA, USA, 2000.
- H. Dayani-Fard, Y. Yu, J. Mylopoulos, P. Andritsos. “*Improving the build architecture of legacy C/C++ software systems*”, Fundametal Approaches in Software Engineering. 2005.
- Y. Yu, J. Mylopoulos, A. Lapouchnian, S. Liaskos, J.C.S.P. Leite. “From stakeholder goal models to high variability design”, Technical report CSRG-509. 2005.
- Y. Yu, H. Dayani-Fard, J. Mylopoulos, P. Andritsos. “Reducing build time through precompilations for large-scale software”. Technical report CSRG-504. 2004
- Y. Yu, H. Dayani-Fard, J. Mylopoulos. “*Remove false code dependencies to speedup up build process*”, CASCON’03.