OS Customization versus OS Code Modularity

ECE 344 – Fall 2006

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for helping to find interesting examples et al.

Possibly a Debugging Concern

```
#ifdef SLOWER
#ifndef SLOW
#define SLOW
#endif
#endif
#ifdef SLOW
static void
    checksubpage(struct
    pageref *pr){
        // code removed
}
… (next column)
```

OS/161 Kernel: kern/lib/kheap.c

```
#else
#define checksubpage(pr)
    ((void)(pr))
#endif

#ifdef SLOWER
static void
    checksubpages(void) {
        // code removed
}
#else
#define checksubpages()
#endif
```

Possibly a Debugging Concern

```
/* SLOWER implies SLOW */
#ifdef SLOWER
  #ifndef SLOW
  #define SLOW
  #endif
#endif
#ifdef SLOW
  static void
    checksubpage(struct
    pageref *pr){
        // code removed
  }
  … (next column)
```

OS/161 Kernel: kern/lib/kheap.c

```
#else
  #define checksubpage(pr)
    ((void)(pr))
#endif // ifdef SLOW

#ifdef SLOWER
  static void
    checksubpages(void) {
        // code removed
  }
#else
   #define checksubpages()
#endif  // ifdef SLOWER
```

Observations

- Most likely the OS designers' way of debugging memory allocation (guess)
- Multiple highly concentrated concerns to customize a part of OS for debugging
- Hard to read, understand, modify, test …
- FAST or NORMAL not even explicitly documented in code

Platform Support

```
…
#ifdef __MIPSEB__
/* For big-endian machines.  */
#define va_arg(__AP, __type)                                    \
  ((__AP = (char *) ((__alignof__ (__type) > 4                  \
                      ? ((int)__AP + 8 - 1) & -8                \
                      : ((int)__AP + 4 - 1) & -4)               \
                     + __va_rounded_size (__type))),            \
   *(__type *) (void *) (__AP - __va_rounded_size (__type)))
#else
/* For little-endian machines.  */
…
#endif
#endif
#endif /* ! defined (__mips_eabi)  */
```

- More of the above
- Hardware platform specific customizations

OS/161 Kernel: kern/arch/mips/include/stdarg.h

Error Checking Concern

- Error checking code **scatters** across code base
- It **cuts across** core logic

```
static int __init readonly(char *str) {
    if (*str)
        return 0;
    root_mountflags |= MS_RDONLY;
    return 1;
}

static int __init readwrite(char *str) {
    if (*str)
        return 0;
    root_mountflags &= ~MS_RDONLY;
    return 1;
}
```

...

Linux Kernel 2.6: kernel initialization: do_mount.c

Lock & unlock I

```
int is_orphaned_pgrp(int pgrp) {
   int retval;
   read_lock(&tasklist_lock);
   retval = will_become_orphaned_pgrp(pgrp, NULL);
   read_unlock(&tasklist_lock);
   return retval;
 }
```

- The same **scattering** and **crosscutting** of *synchronization concern* (see error checking)
- Similar pieces of code all over the place

Linux Kernel 2.6: kernel/exit.c

Lock & unlock II

```
int session_of_pgrp(int pgrp)  {
   struct task_struct *p;    int sid = -1;
   read_lock(&tasklist_lock);
   do_each_task_pid(pgrp, PIDTYPE_PGID, p) {
        if (p->signal->session > 0) {
            sid = p->signal->session;
            goto out;  }
   } while_each_task_pid(pgrp, PIDTYPE_PGID, p);
   p = find_task_by_pid(pgrp);
   if (p)
            sid = p->signal->session;
out:
            read_unlock(&tasklist_lock);
            return sid;
}
```

Multiprocessor Support I

```
static int
try_to_wake_up(task_t *p, unsigned int state, int sync) {
        int cpu, this_cpu, success = 0;
        unsigned long flags;
        long old_state;
        runqueue_t *rq;
 #ifdef CONFIG_SMP
        unsigned long load, this_load;
        struct sched_domain *sd, *this_sd = NULL;
        int new_cpu;
 #endif
        … (next slide)
```

Linux Kernel 2.6: kernel/sched.c

Multiprocessor Support II

```
    rq = task_rq_lock(p, &flags);
    old_state = p->state;
    if (!(old_state & state))
            goto out;
    if (p->array)
            goto out_running;
    cpu = task_cpu(p);
    this_cpu = smp_processor_id();
#ifdef CONFIG_SMP
    if (unlikely(task_running(rq, p)))
            goto out_activate;
    new_cpu = cpu;
    schedstat_inc(rq, ttwu_cnt);
    …
#endif
```

- pieces of *multiprocessing concern* **tangled** with core logic (1 CPU case)
- not the same piece of code as in previous cases

Summary

- Certain concerns **crosscut** the principal or **core logic** (a.k.a. crosscutting concerns)
- **Similar concern** code **scatters** across the code base
- **Different pieces** of concern code **tangled** with core logic
- Scattering, tangling, and crosscutting apparently leads to code
  - that is hard to read and understand, let alone maintain
  - where the design intent is not cleanly represented in the code
  - where concerns are not well separated and modularized
  - removing a concern is error-prone

Need for Customization

- Customization of OS code is unavoidable
- OS code is often tailored to different hardware platforms
- … creating a whole family of OS versions
- Variety of hardware features (on different platforms) have *far reaching* implication for OS code
- Traditionally dealt with
  - At configuration time (various tools)
  - At compile time `#ifdefs/#defines` (driven through a make process or by a configuration tool)
  - Dynamically loadable kernel modules

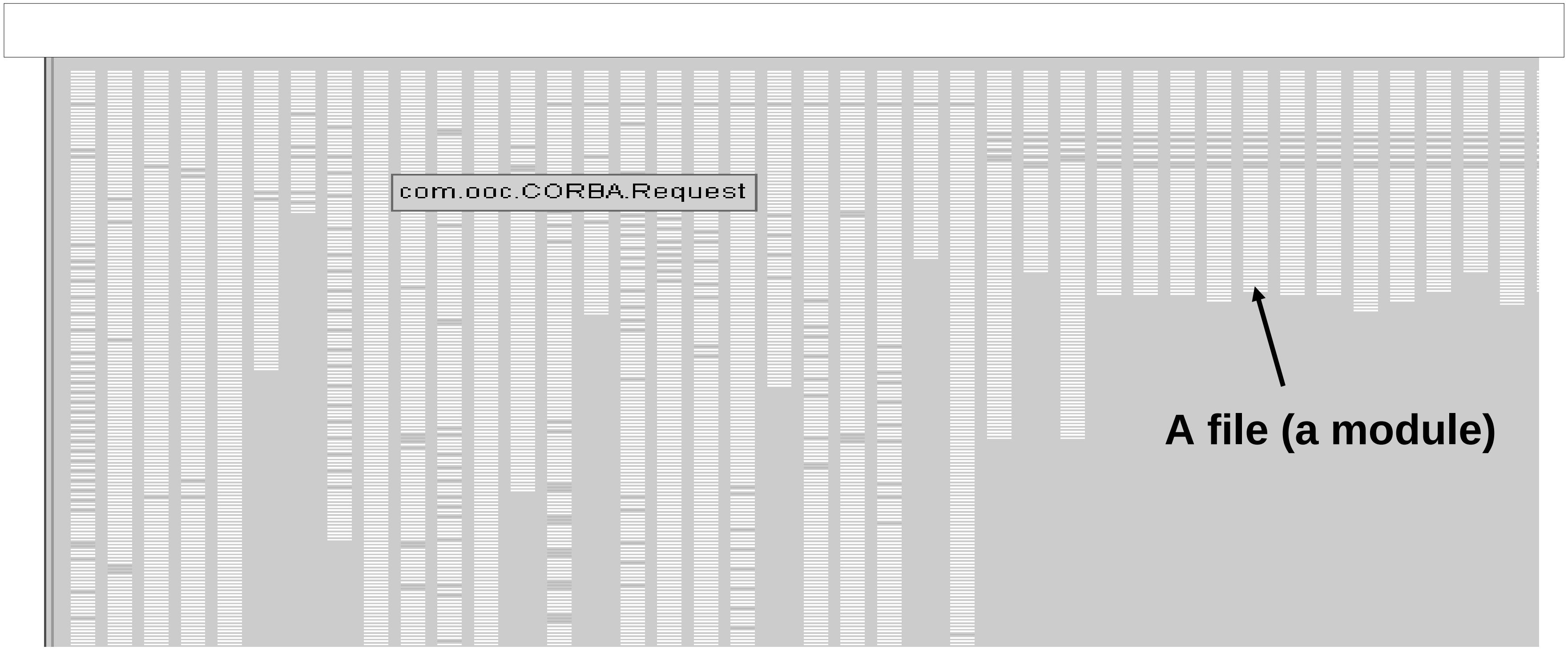
Customization in OS/161

- "options" declarations in the `config` file
  - `options dumbvm` defines `OPT_DUMBVM` in the code
- Definition of `OPT_SYNCHPROBS` leads to conditional code in
  - `kern/include/clock.h`
  - `kern/include/test.h`
  - `kern/main/menu.c`
  - `kern/test/tt3.c`
  - `kern/thread/thread.c`
- This is an example for *crosscutting conditional compilation* in OS/161

Crosscutting

- Crosscutting phenomenon is often not due to bad design
- But tied to the characteristics of traditional development techniques
- … the decomposition mechanism of traditional development paradigms
  - Files, functions, structures
  - Classes, objects, interfaces, methods

Conventional Programming Paradigms

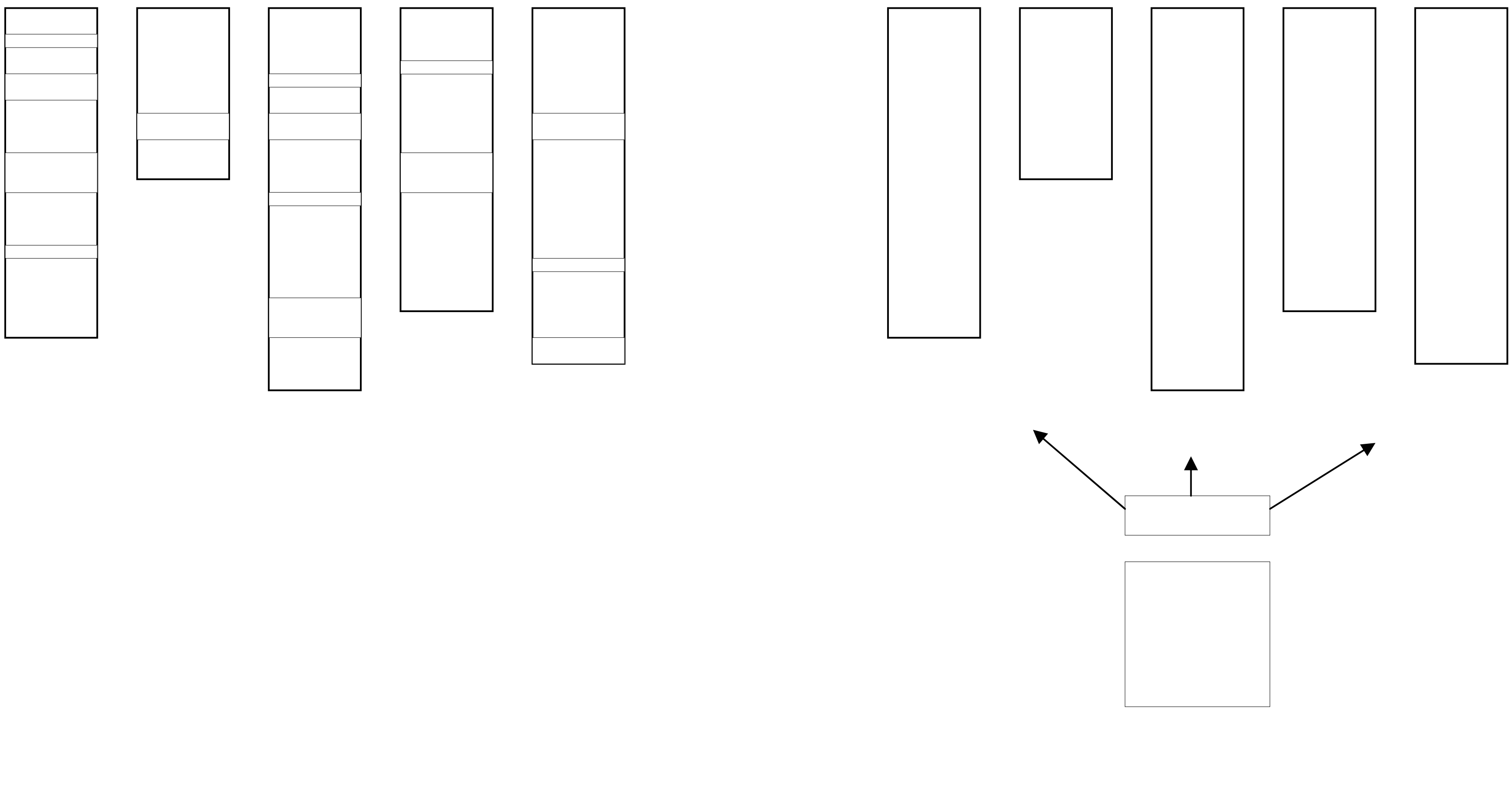


- Red shows lines pertaining to a given concern
- Not in just one place (i.e., file, function)
- Not even in a small number of places (files or functions)
- Example is a bit out of context for operating systems
- OS code would show very similar footprints

Is there a Solution?

- For separating crosscutting concerns from core code
- Pick and choose the concerns required (based on hardware platform etc.)

Yes ☺ !



Aspect-oriented Programming (AOP)

- AOP is a programming paradigm that aims to support **the modularization of crosscutting concerns in software**
- AOP is **complementary** to existing paradigms
- Emerged about 10 years ago from different research efforts studying the **Separation of Concerns** in software
- Supported in industry today by IBM, BEA,…
- AOP support is available for Java, C, C++ …
- **AspectJ, AspectC, AspectC++**

Key Idea

- Crosscutting concerns are represented by **aspects** in the program sources
- Required **aspects** are **woven** into the program
- The **program is fully unaware** of the aspect (i.e., in the sources, there is no aspect code inside the program)
  - Note, there are a few AOP approaches around today that do not fully follow this model (i.e., some code present in program)
- The program is often referred to as the **base program** or the **core advised** by **the aspect code**
- Aspects specify **when** and **what code** to execute
- This specification is declarative and outside the core
- For AspectC weaving happens at **compile time** (other models are **load time** or **run-time** weaving.)

Example: Key Idea

OS/161 src/kern/aspect/trace.ac:

```
before():   call ( $  $bootstrap$(...) )
{
    kprintf("> Entering %s \n", this->funcName);
}
```

- Join point declaration
- Pointcut declaration
- advice

Join Points

- Well-defined points in the execution of a program
  - The point a function is called
  - The point a function is executed
- Examples for C
  - Function calls (before/after) (call site)
  - Function execution (before/after) (called site)
  - …
- Examples for Java
  - Method calls & execution
  - Field reads & writes
  - Exceptions
  - …

Pointcuts

- Declaratively define sets of join points
- **Call pointcut** (all join points associated with the call of a function)
- **Execution pointcut** (all join points associated with the execution of a function)
- Example

  call($ $bootstrap$(...))

  - All call join points involving functions that contain the word “bootstrap” in the function name
  - With any list of input parameter types
  - With any return value type

Advice

- The code executed when the associated pointcut matches a join point

Example: Memory Profiling I

```
size_t totalMemoryAllocated;
int totalAllocationFuncCalled;
int totalFreeFuncCalled;
void initProfiler(){
        totalMemoryAllocated = 0;
        totalAllocationFuncCalled = 0;
        totalFreeFuncCalled = 0;
}
void printProfiler(){
        printf("total memory allocated = %d bytes\n",
                totalMemoryAllocated);
        …
                totalAllocationFuncCalled);
        …
                totalFreeFuncCalled);
}
```

Example: Memory Profiling II

```
before(): execution(int main()) {
            initProfiler();
}
after(): execution(int main()) {
            printProfiler();
}
before(size_t s): call($ malloc(...)) && args(s) {
        totalMemoryAllocated += s;
        totalAllocationFuncCalled ++;
}
```

Example: Memory Profiling III

```
before(size_t n, size_t s): call($ calloc(...)) && args(n, s) {
        totalMemoryAllocated += n * s;
        totalAllocationFuncCalled ++;
}
before(size_t s): call($ realloc(...)) && args(void *, s) {
        totalMemoryAllocated += s;
        totalAllocationFuncCalled ++;
}
before() : call(void free(void *)) {
        totalFreeFuncCalled++;
}
```

Example: Memory Profiling IV

- Is the code thread safe?
- Is thread-safety an aspect?
- Left as an exercise for the reader.

Use of AOP

- Build aspects into systems right from the start (i.e., design with aspects in mind)
- Use aspects to aid in debugging, analyzing, policy checking …
- Use aspects to refactor existing systems
  - Tailoring and customization
  - Adaptation
  - Extension

AspectC

- Developed by Michael Gong and myself
- Aspect-oriented extension to C
- ANSI-C compliant
- gcc source-compatibility
- Compiler and generated code is portable (mostly ☹)
- Seamless Linux, Solaris and Windows support (Mac OS X support in progress.)
- Integration in existing build processes possible
- Code transparency through source-to-source transformations
- Based on open source license and compiler

AspectC Resources

- http://www.AspectC.net
- Assignment 0 handout
- AspectC Tutorial
- AspectC Language Specification
- See the AspectC web site for submitting a bug report, if you think you found one

Resources

- Aspect-oriented Software Development Portal
  - http://www.aosd.net
- AspectJ
  - http://www.eclipse.org/aspectj/
- AspectC++
  - http://www.aspectc.org
- AspectC
  - http://www.AspectC.net