Was bringt die aspektorientierte Programmierung?

Eine Einführung am Beispiel von AspectC++

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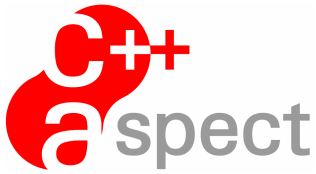
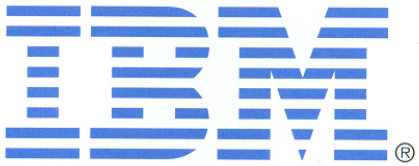


Aspektorientierte Programmierung

in den Nachrichten (http://www.aspectmentor.com/training/reasons.html)

„AOP is vital for our survival“
Daniel Sabbah



„Microsoft will adopt AOP“
Bill Gates

„Aspects will become mainstream“
Grady Booch

In zehn Jahren in jedem Automobil?

Aspektorientierte Programmierung

in den Nachrichten (http://www.aspectmentor.com/training/reasons.html)

„AOP is vital for our survival“

IBM

„Aspects will become mainstream“

Grady Booch

UNIFIED MODELING LANGUAGE

In zehn Jahren in jedem Automobil?

Was macht AOP so interessant?
Was bringt es dem SW-Entwickler konkret?

Wer wir sind

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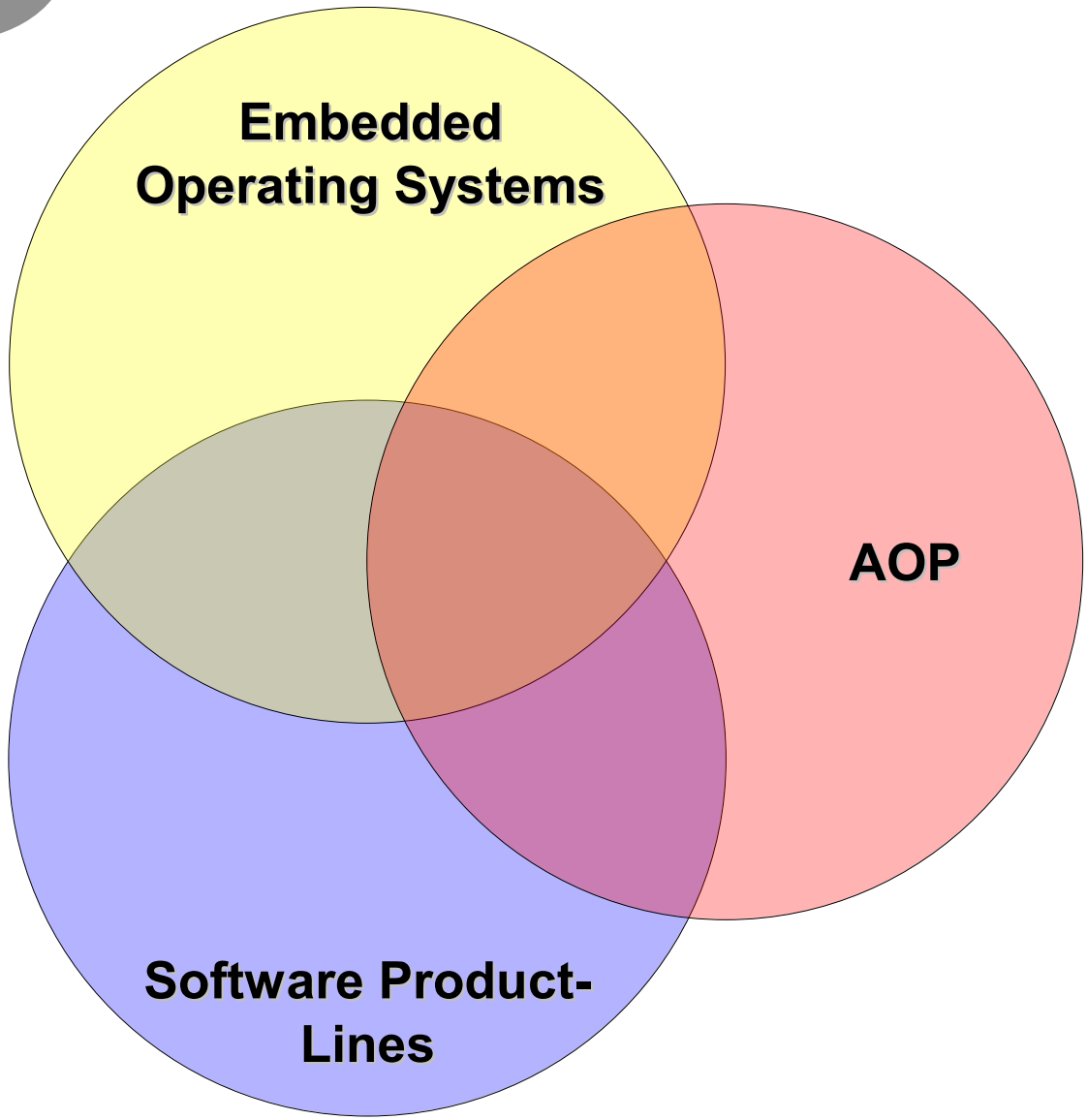
Was wir forschen



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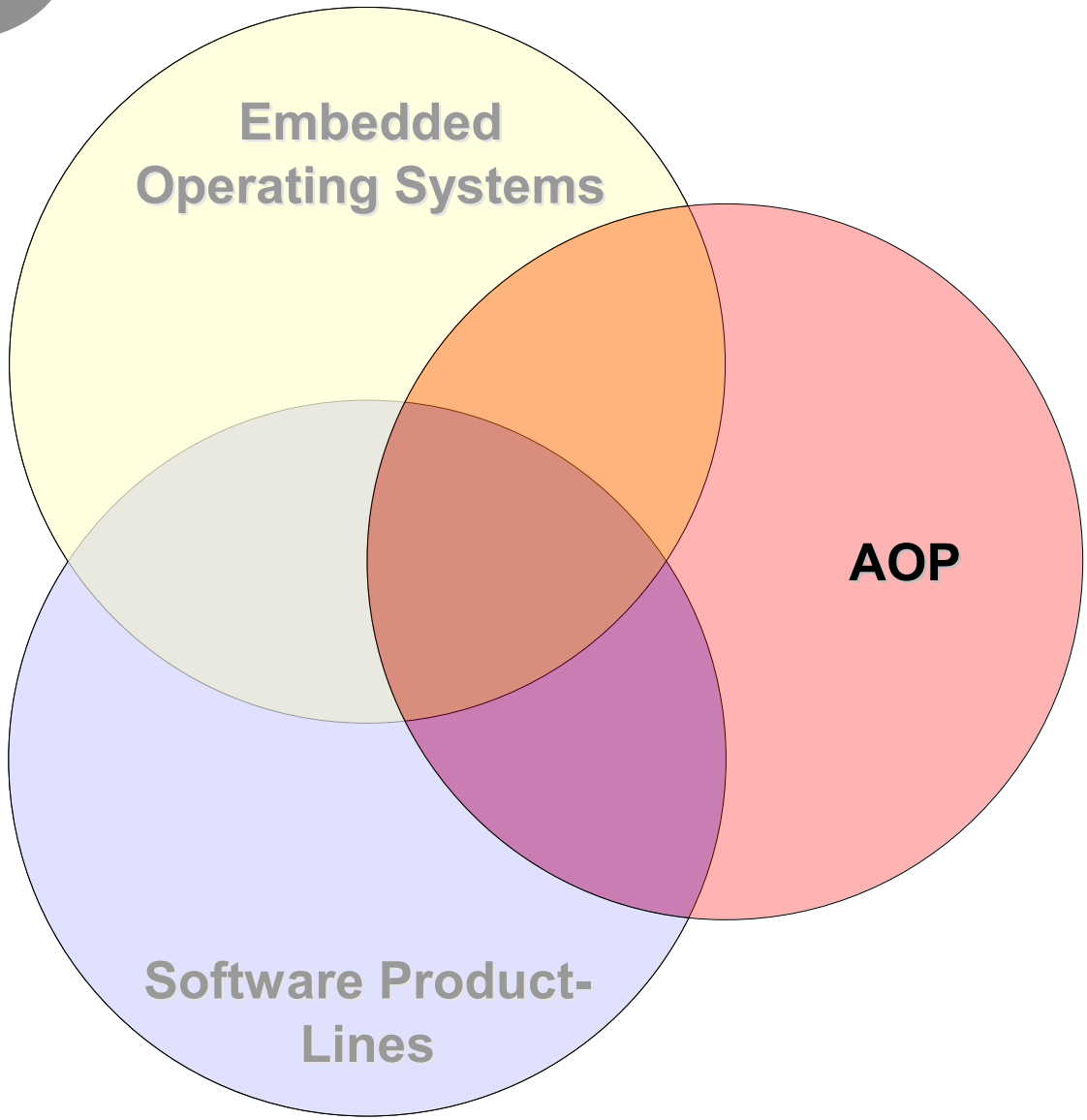
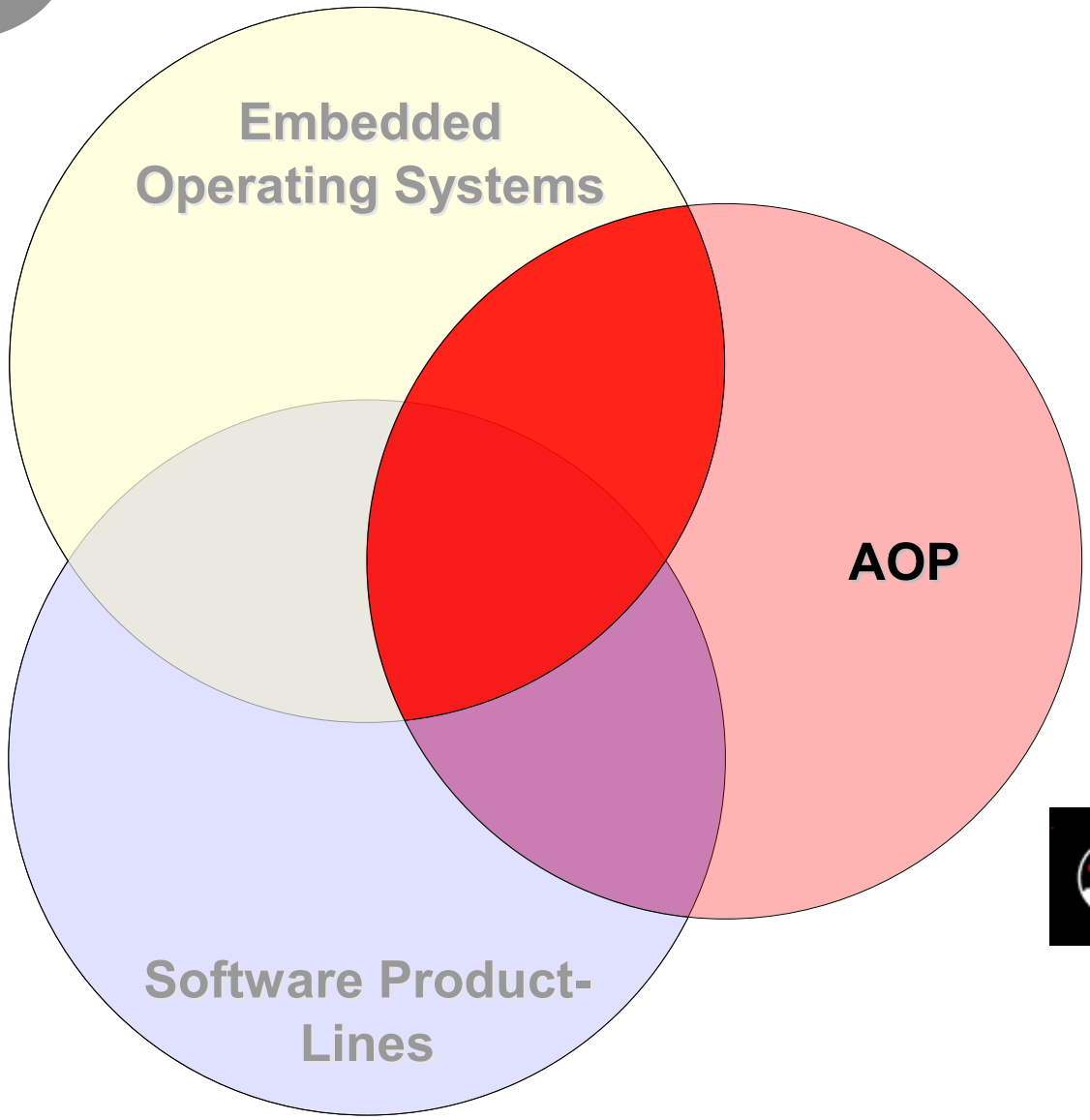


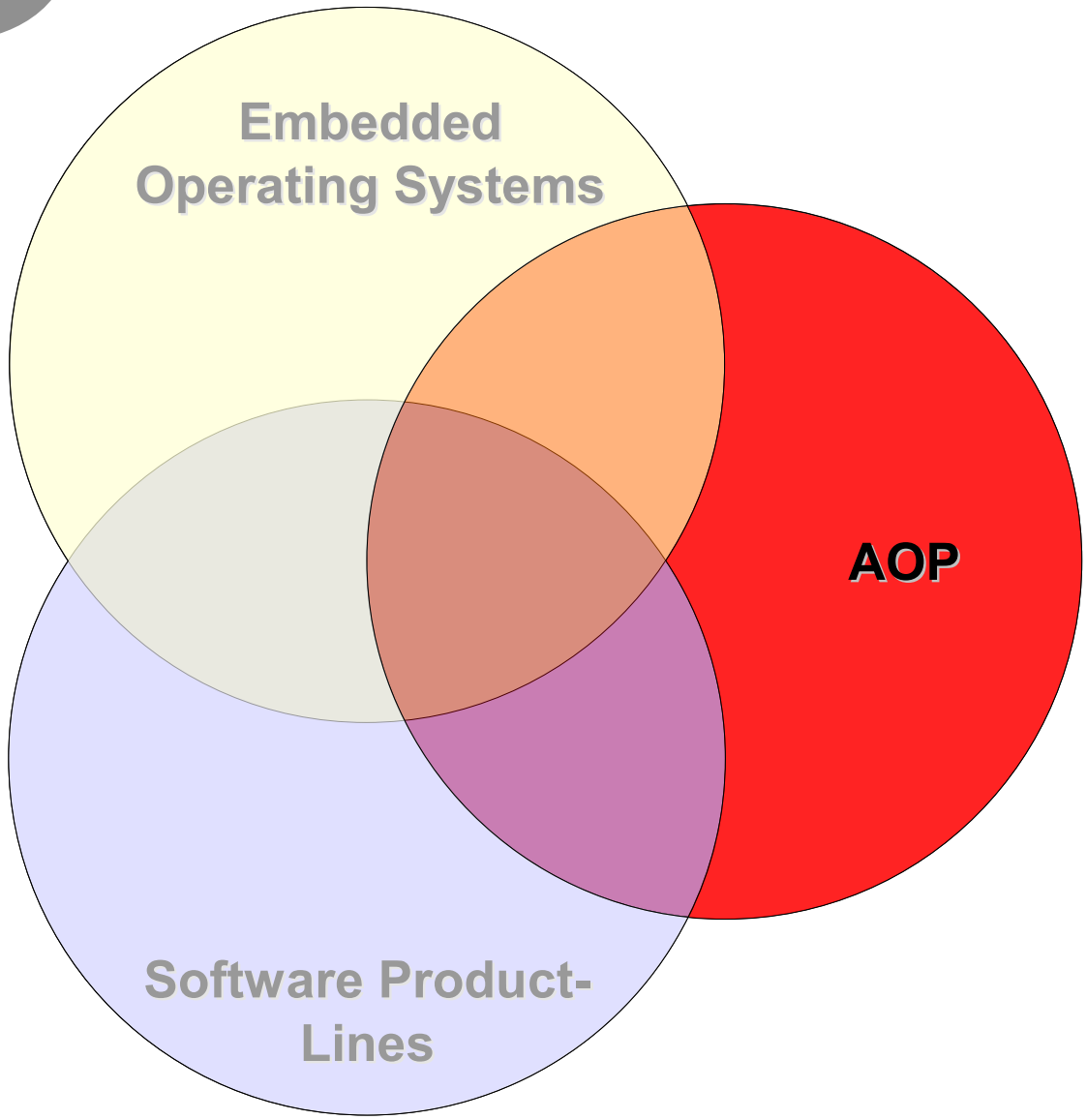
Inhalt dieses Vortrags



Motivation:
Fallstudie eCos

- Das Problem
  - tangled code
  - scattered code
- AOP als Lösungsansatz

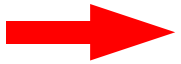
Inhalt dieses Vortrags



Hauptteil:
AspectC++

- Die Sprache
  - Grundbegriffe
  - Besonderheiten
- Beispiele
  - Win32 Fehlerbehandlung
  - Observer Pattern

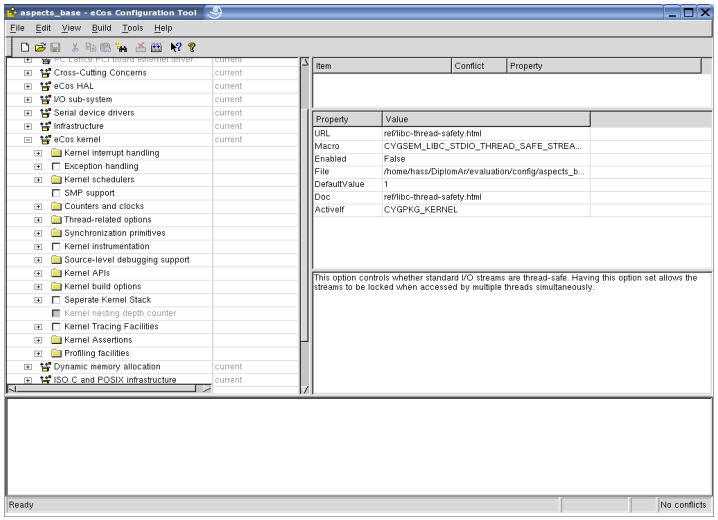
Überblick



- **Querschneidende Belange in eCos**
  - Das Problem
- Aspektorientierte Programmierung
  - Der Lösungsansatz
- AspectC++
  - Grundlagen
  - Ergebnisse der eCos-Lösung
  - Erweiterte Sprachmerkmale am Beispiel
    - Vererbung und Wiederverwendung: *Observer Pattern*
    - Generische Programmierung: *Win32 Fehlerbehandlung*
- Zusammenfassung

eCos: An OS Product Line

- Open source OS product line for embedded systems
  - developed and maintained by RedHat
  - supports a high number of 16/32 bit architectures
  - kernel written in C++
- Goal: static configurability
  - 63 selectable packages
  - 761 selectable configuration options
- Configuration approach
  - package selection (coarse-grained configuration)
  - **conditional compilation** (fine-grained configuration)

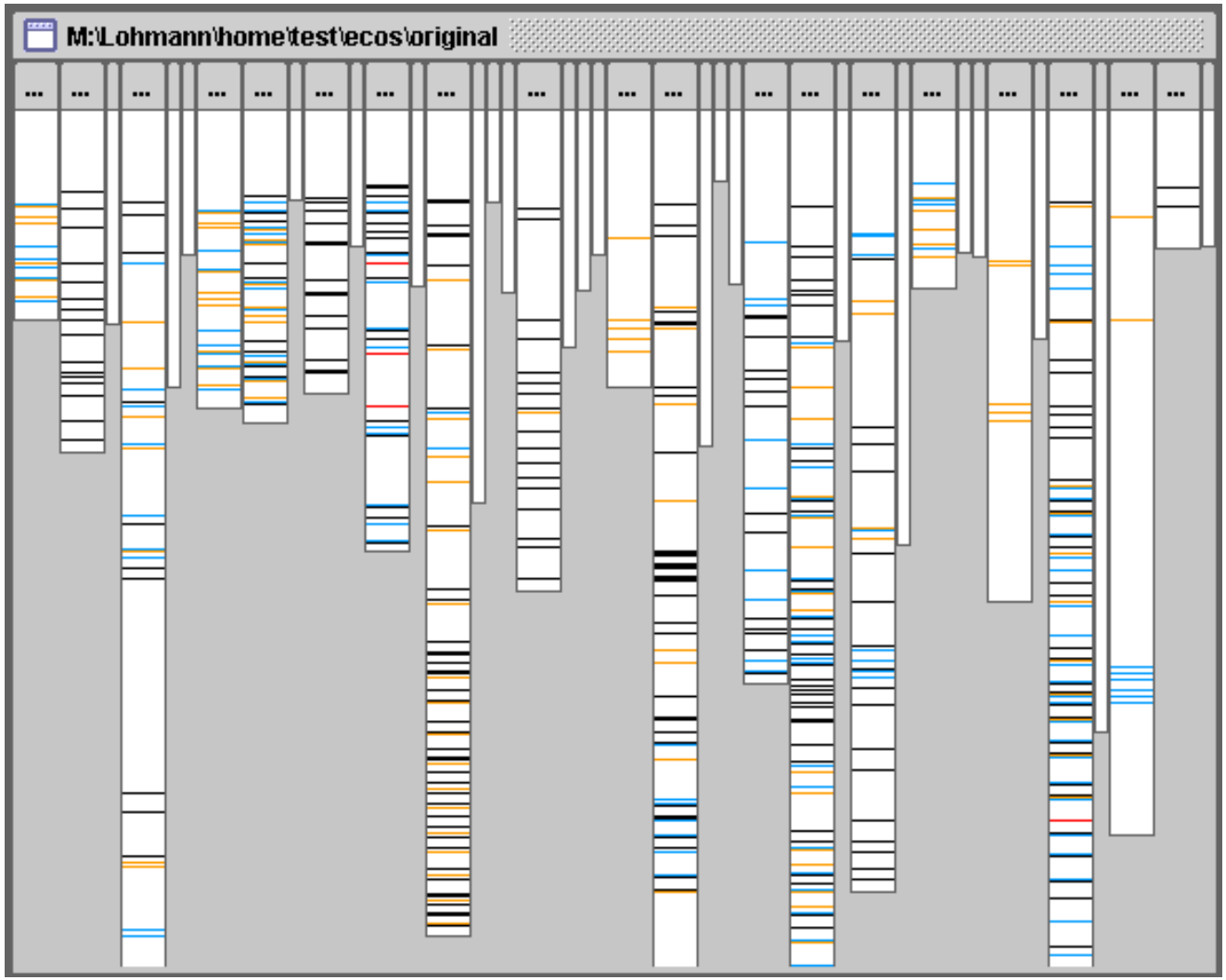


eCos: Global Policies in the Code

synchronization

instrumentation

tracing



eCos: Configuration Options

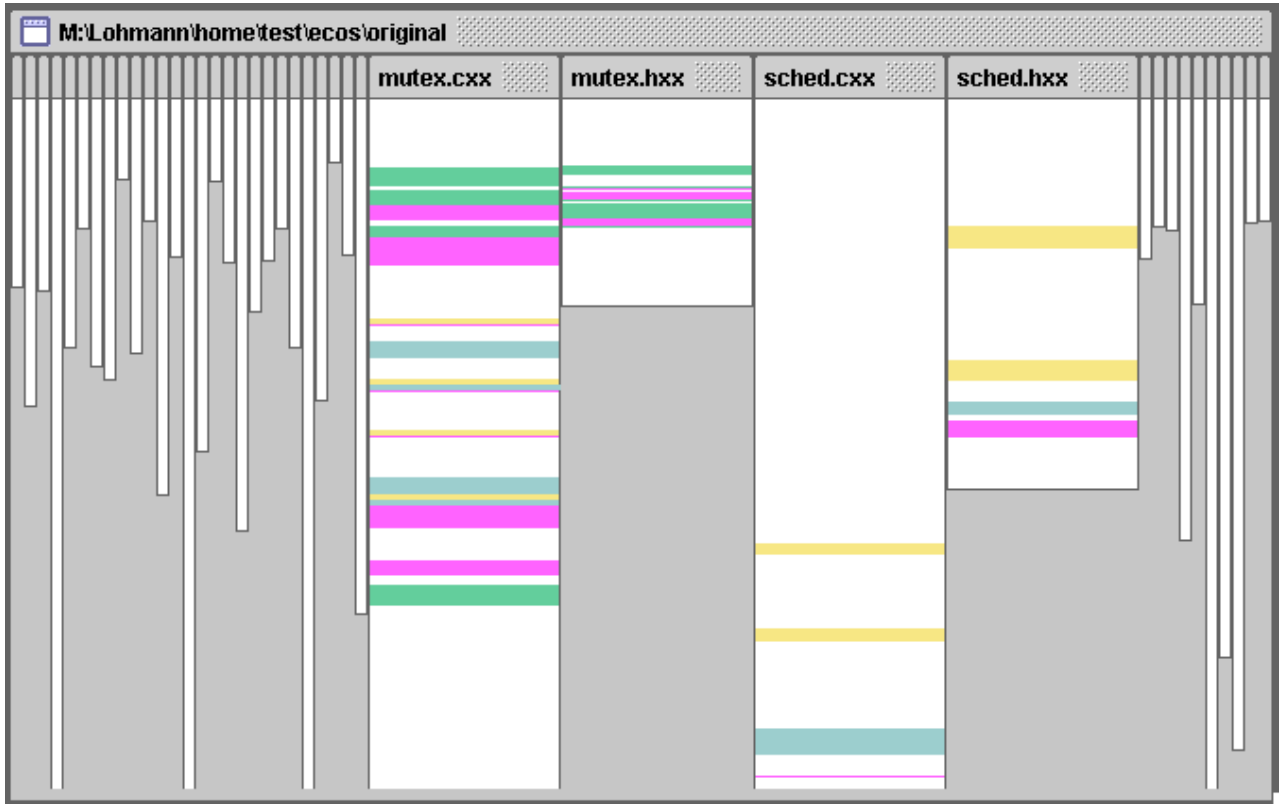
Variants of the optional mutex priority inversion protocol

simple

ceiling

inheritance

dynamic



eCos: Implementation Example

27 lines of code

```
Cyg_Mutex::Cyg_Mutex() {
    CYG_REPORT_FUNCTION();
    locked   = false;
    owner    = NULL;
#if defined(CYGSEM_KERNEL_SYNCH_MUTEX_PRIORITY_INVERSION_PROTOCOL_DEFAULT) && \
    defined(CYGSEM_KERNEL_SYNCH_MUTEX_PRIORITY_INVERSION_PROTOCOL_DYNAMIC)
#ifdef CYGSEM_KERNEL_SYNCH_MUTEX_PRIORITY_INVERSION_PROTOCOL_DEFAULT_INHERIT
    protocol = INHERIT;
#endif
#ifdef CYGSEM_KERNEL_SYNCH_MUTEX_PRIORITY_INVERSION_PROTOCOL_DEFAULT_CEILING
    protocol = CEILING;
    ceiling  = CYGSEM_KERNEL_SYNCH_MUTEX_PRIORITY_INVERSION_PROTOCOL_DEFAULT_PRI;
#endif
#ifdef CYGSEM_KERNEL_SYNCH_MUTEX_PRIORITY_INVERSION_PROTOCOL_DEFAULT_NONE
    protocol = NONE;
#endif
#else // not (DYNAMIC and DEFAULT defined)
#ifdef CYGSEM_KERNEL_SYNCH_MUTEX_PRIORITY_INVERSION_PROTOCOL_CEILING
#ifdef CYGSEM_KERNEL_SYNCH_MUTEX_PRIORITY_INVERSION_PROTOCOL_DEFAULT_PRIORITY
    // if there is a default priority ceiling defined, use that to initialize
    // the ceiling.
    ceiling = CYGSEM_KERNEL_SYNCH_MUTEX_PRIORITY_INVERSION_PROTOCOL_DEFAULT_PRIORITY;
#else
    ceiling = 0; // Otherwise set it to zero.
#endif
#endif
#endif // DYNAMIC and DEFAULT defined
     CYG_REPORT_RETURN();
}
```

eCos: Implementation Example

2 lines for the **tracing policy**

```
Cyg_Mutex::Cyg_Mutex() {
    CYG_REPORT_FUNCTION();
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    owner    = NULL;
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#else
    ceiling = 0; // Otherwise set it to zero.
#endif
#endif
#endif // DYNAMIC and DEFAULT defined
    CYG_REPORT_RETURN();
}
```

eCos: Implementation Example

21 (almost unreadable) lines for **optional features**

```
Cyg_Mutex::Cyg_Mutex() {
    CYG_REPORT_FUNCTION();
    locked   = false;
    owner    = NULL;
#if defined(CYGSEM_KERNEL_SYNCH_MUTEX_PRIORITY_INVERSION_PROTOCOL_DEFAULT) && \
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#ifdef CYGSEM_KERNEL_SYNCH_MUTEX_PRIORITY_INVERSION_PROTOCOL_DEFAULT_INHERIT
    protocol = INHERIT;
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#ifdef CYGSEM_KERNEL_SYNCH_MUTEX_PRIORITY_INVERSION_PROTOCOL_DEFAULT_CEILING
    protocol = CEILING;
    ceiling  = CYGSEM_KERNEL_SYNCH_MUTEX_PRIORITY_INVERSION_PROTOCOL_DEFAULT_PRI;
#endif
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    protocol = NONE;
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#else
    ceiling = 0; // Otherwise set it to zero.
#endif
#endif
#endif // DYNAMIC and DEFAULT defined
    CYG_REPORT_RETURN();
}
```

eCos: Implementation Example

```
Cyg_Mutex::Cyg_Mutex() {
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    protocol = INHERIT;
#endif
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    protocol = CEILING;
    ceiling  = CYGSEM_KERNEL_SYNCH_MUTEX_PRIORITY_INVERSION_PROTOCOL_DEFAULT_PRI;
#endif
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    ceiling = CYGSEM_KERNEL_SYNCH_MUTEX_PRIORITY_INVERSION_PROTOCOL_DEFAULT_PRIORITY;
#else
    ceiling = 0; // Otherwise set it to zero.
#endif
#endif
#endif // DYNAMIC and DEFAULT defined
    CYG_REPORT_RETURN();
}
```

4 lines for the
basic implementation

eCos: Implementation Example

```
Cyg_Mutex::Cyg_Mutex() {
    CYG_REPORT_FUNCTION();
    locked   = false;
    owner    = NULL;
#if defined(CYGSEM_KERNEL_SYNCH_MUTEX_PRIORITY_INVERSION_PROTOCOL_DEFAULT) && \
    defined(CYGSEM_KERNEL_SYNCH_MUTEX_PRIORITY_INVERSION_PROTOCOL_DYNAMIC)
#ifdef CYGSEM_KERNEL_SYNCH_MUTEX_PRIORITY_INVERSION_PROTOCOL_DEFAULT_INHERIT
    protocol = INHERIT;
#endif
#ifdef CYGSEM_KERNE                                                  LING
    protocol = CEIL
    ceiling  = CYGS                                                  FAULT_PRI;
#endif
#ifdef CYGSEM_KERNE                                                  E
    protocol = NONE
#endif
#else // not (DYNAM
#ifdef CYGSEM_KERNE
#ifdef CYGSEM_KERNE                                                  ORITY
    // if there is                                                   alize
    // the ceiling.
    ceiling = CYGSE                                                  AULT_PRIORITY;
#else
    ceiling = 0; //
#endif
#endif
#endif // DYNAMIC and DEFAULT defined
    CYG_REPORT_RETURN();
}
```

Well, ...

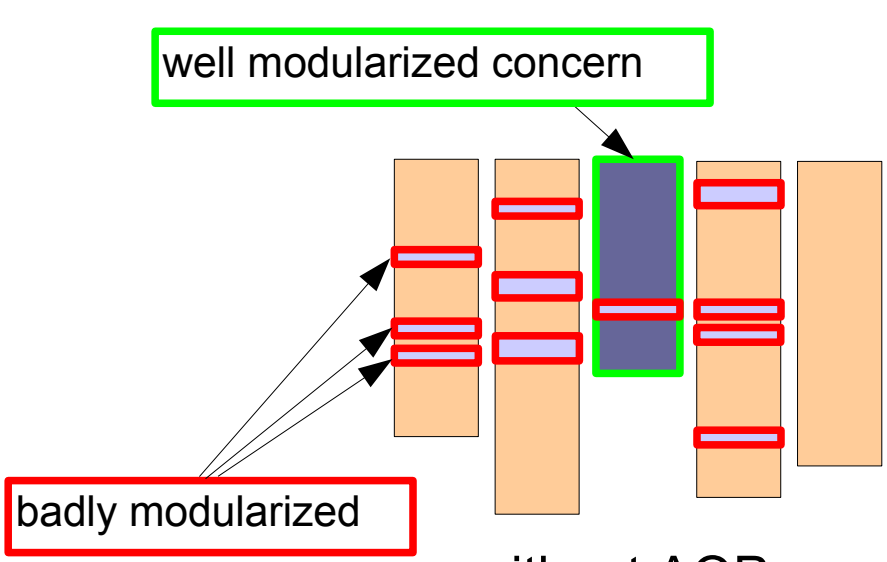
- comprehensability ?
- extensability ?
- reuseability ?
- maintainability ?

Überblick

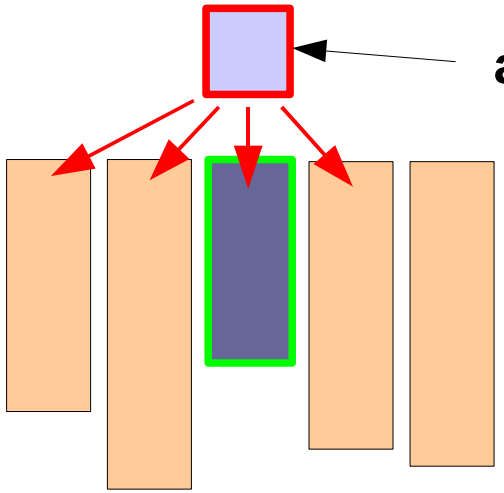
- Querschneidende Belange in eCos
  - Das Problem
- **Aspektorientierte Programmierung**
  - Der Lösungsansatz
- AspectC++
  - Grundlagen
  - Ergebnisse der eCos-Lösung
  - Erweiterte Sprachmerkmale am Beispiel
    - Vererbung und Wiederverwendung: *Observer Pattern*
    - Generische Programmierung: *Win32 Fehlerbehandlung*
- Zusammenfassung

Aspekt-Orientierte Programmierung

AOP bietet Sprachmittel zur Trennung und Kapselung von querschneidenden Belangen



without AOP



with AOP

AOP: Trennung von *Was* und *Wo*

- **Join-Points**
  - bezeichnen Stellen in der **Programmstruktur** (name join-points) oder Ereignisse im laufenden **Kontrollfluss** (code join-points)
  - werden **deklaritiv** spezifiziert durch **pointcut expressions**

- **Advice**
  - zusätzliche **Elemente** (Methoden, Daten, ...), werden in bestimmte Klassen oder Strukturen eingefügt (statisch)
  - zusätzliches **Verhalten** (Code), das
    - **before**, **after**
    - **around** (anstelle von)

    bestimmten Ereignissen im Kontrollfluss aktiviert wird

Überblick

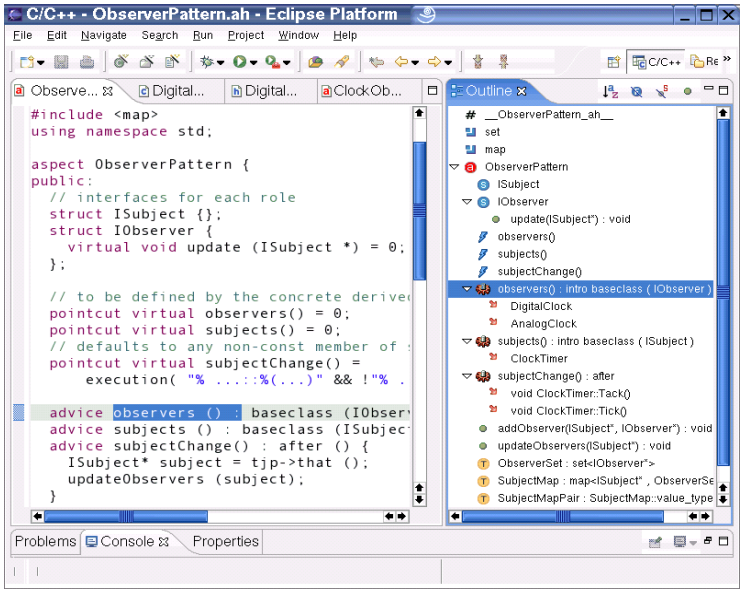
- Querschneidende Belange in eCos
  - Das Problem
- Aspektorientierte Programmierung
  - Der Lösungsansatz
- **AspectC++**
  - Grundlagen
  - Ergebnisse der eCos-Lösung
  - Erweiterte Sprachmerkmale am Beispiel
    - Vererbung und Wiederverwendung: *Observer Pattern*
    - Generische Programmierung: *Win32 Fehlerbehandlung*
- Zusammenfassung

AspectC++

- AOP Spracherweiterung für C++
  - Syntax und Semantik angelehnt an AspectJ

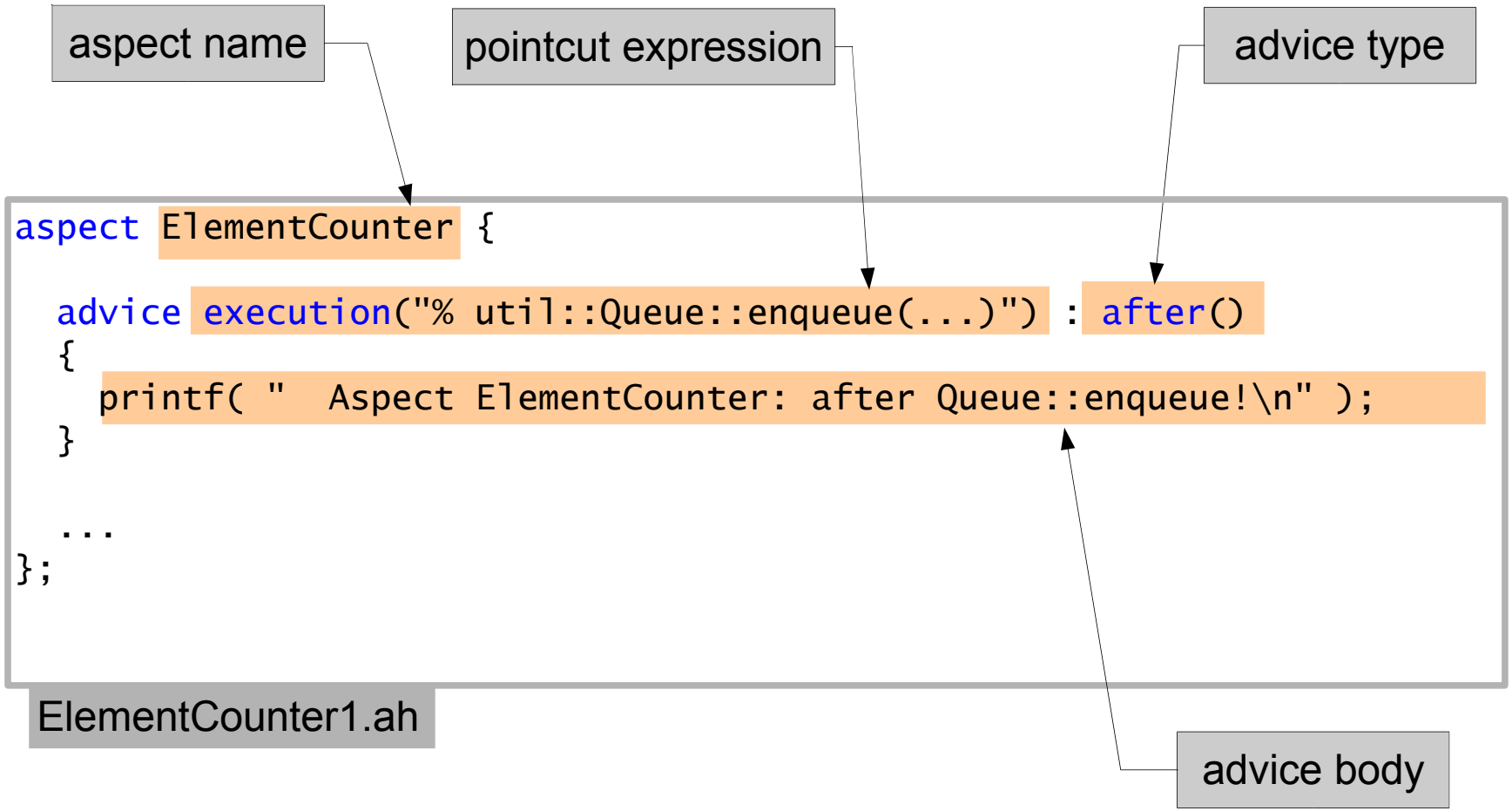
http://www.aspectc.org

- Werkzeugunterstützung
  - Source-Level Weber ac++
  - IDE Integration in Eclipse und (kommerziell) VisualStudio
  - OpenSource Projekt
  - Kommerzieller Support durch pure::systems GmbH



- Aktive Nutzer-Community

Syntactic Elements



Pointcut Expressions

- Pointcut expressions are made from ...
  - **match expressions**, e.g. "% util::queue::enqueue(...)"
    - are matched against C++ programm entities → name join-points
    - support wildcards
  - **pointcut functions**, e.g execution(...), call(...), that(...)
    - **execution:** all points in the control flow, where a function is about to be executed → code join-points
    - **call:** all points in the control flow, where a function is about to be called → code join-points
- Pointcut functions can be combined into expressions
  - using logical connectors: &&, ||, !
  - Example: call("% util::Queue::enqueue(...)") && within("% main(...)")

c++ aspect

Advice

advice for code join-points (runtime events)

- **before advice**
  - advice code runs **before** the original code
  - may read and modify function paramerter (call + execution)
- **after advice**
  - advice runs **after** the original code
  - may read and modify function result values (call + execution)
- **around advice**
  - advice code run **instead of** the original code
  - original code can be explicitely invoked by `tjp->proceed()`

introductions

- further methods, attributes, ... are inserted into classes
- extension of interfaces and class implementations

Before / After Advice

advice execution(“void ClassA::foo()”) : **before**()

advice execution(“void ClassA::foo()”) : **after**()

```
class ClassA {
public:
  void foo(){
    printf(“ClassA::foo()”\n);
  }
}
```

advice call (“void ClassA::foo()”) : **before**()

advice call (“void ClassA::foo()”) : **after**()

```
int main(){
  printf(“main()\n”);
  ClassA a;
  a.foo();
}
```

Around Advice

```
advice execution("void ClassA::foo()") :
around()
    before code

    tjp->proceed()

    after code
```

```
class ClassA {
public:
  void foo(){
    printf("ClassA::foo()"\n);
  }
}
```

```
advice call("void ClassA::foo()") : around()
    before code

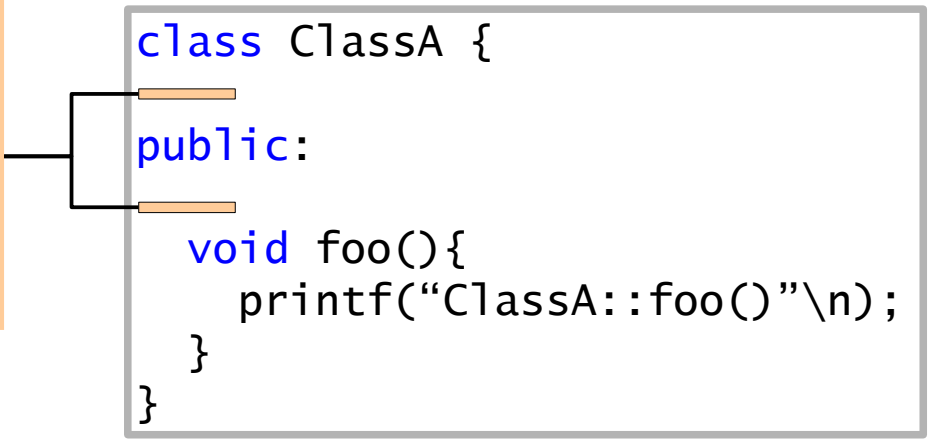
    tjp->proceed()

    after code
```

```
int main(){
  printf("main()\n");
  ClassA a;
  a.foo();
}
```

Introductions

```
advice "ClassA" : slice class {
  private element to introduce
public:
  public element to introduce
};
```



Beispiel: eCos Priority Ceiling Protocol

```
aspect priority_ceiling {

  void call_clear_ceiling(Cyg_Thread*);
  ...

  advice “Cyg_Mutex” : cyg_priority ceiling;
  ...

  advice construction(“Cyg_Mutex”) : after() {
    tjp->that()->ceiling = CYGSEM_DEFAULT_PRIORITY;
  }


  advice call("% Cyg_Mutex::lock_inner(...)")
      && within("% Cyg_Mutex::lock(...)")
      && args(self)
    : after(Cyg_Thread* self)
  {
    if(!(*tjp->result())) {
      call_clear_ceiling(self);
    }
  }
  ...
};
```

Was **Wo**

Beispiel: eCos Priority Ceiling Protocol

```
aspect priority_ceiling {

  void call_clear_ceiling(Cyg_Thread*);
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  advice "Cyg_Mutex" : cyg_priority ceiling;
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    : after(Cyg_Thread* self)
  {
    if(!(*tjp->result())) {
      call_clear_ceiling(self);
    }
  }
  ...

};
```

Was **Wo**

Einfügung einer Variable *ceiling* in alle Klassen mit dem Namen *Cyg_Mutex*

Beispiel: eCos Priority Ceiling Protocol

```
aspect priority_ceiling {

  void call_clear_ceiling(Cyg_Thread*);
  ...

  advice “Cyg_Mutex” : cyg_priority ceiling;
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    : after(Cyg_Thread* self)
  {
    if(!(*tjp->result())) {
      call_clear_ceiling(self);
    }
  }
  ...

};
```

Was **Wo**

Ausführen der *Initialisierung* **nach** dem **Erstellen** einer *Cyg_Mutex* Instanz

Beispiel: eCos Priority Ceiling Protocol

```
aspect priority_ceiling {

  void call_clear_ceiling(Cyg_Thread*);
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  advice “Cyg_Mutex” : cyg_priority ceiling;
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  {
    if(!(*tjp->result())) {
      call_clear_ceiling(self);
    }
  }
  ...

};
```

Was **Wo**

Nach einem **Aufruf** von *Cyg_Mutex::lock_inner*, der stattfindet...

Beispiel: eCos Priority Ceiling Protocol

```
aspect priority_ceiling {

  void call_clear_ceiling(Cyg_Thread*);
  ...

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      && args(self)
    : after(Cyg_Thread* self)
  {
    if(!(*tjp->result())) {
      call_clear_ceiling(self);
    }
  }
  ...

};
```

Was **Wo**

Nach einem **Aufruf** von *Cyg_Mutex::lock_inner*, der stattfindet...

...**innerhalb** der Ausführung von *Cyg_Mutex::lock* und außerdem...

Beispiel: eCos Priority Ceiling Protocol

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aspect priority_ceiling {

  void call_clear_ceiling(Cyg_Thread*);
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    }
  }
  ...

};
```

Was **Wo**

Nach einem **Aufruf** von *Cyg_Mutex::lock_inner*, der stattfindet...

...**innerhalb** der Ausführung von *Cyg_Mutex::lock* und außerdem...

...ein **Argument** vom Typ *Cyg_Thread** übergibt...

Beispiel: eCos Priority Ceiling Protocol

```
aspect priority_ceiling {

  void call_clear_ceiling(Cyg_Thread*);
  ...

  advice "Cyg_Mutex" : cyg_priority ceiling;
  ...

  advice construction("Cyg_Mutex") : after() {
    tjp->that()->ceiling = CYGSEM_DEFAULT_PRIORITY;
  }


  advice call("% Cyg_Mutex::lock_inner(...)")
      && within("% Cyg_Mutex::lock(...)")
      && args(self)
    : after(Cyg_Thread* self)
  {
    if(!(*tjp->result())) {
      call_clear_ceiling(self);
    }
  }
  ...

};
```

Was **Wo**

Nach einem **Aufruf** von *Cyg_Mutex::lock_inner*, der stattfindet...

...**innerhalb** der Ausführung von *Cyg_Mutex::lock* und außerdem...

...ein **Argument** vom Typ *Cyg_Thread** übergibt...

...überprüfe, ob der Mutex verlassen wurde und passe ggfs. die Priorität an

Results with eCos

- **Refactored: *original kernel* → *aspectized kernel***
  - **3 cross-cutting policies**
    - interrupt synchronization 187 invocations → 160 code join-points
    - kernel instrumentation 162 invocations → 139 code join-points
    - tracing 336 invocations → 632 code join-points
  - **12 configuration options**
    - mutex features
    - thread features
- **Compared: *original kernel* ↔ *aspectized kernel***
  - scattering, performance, memory footprint

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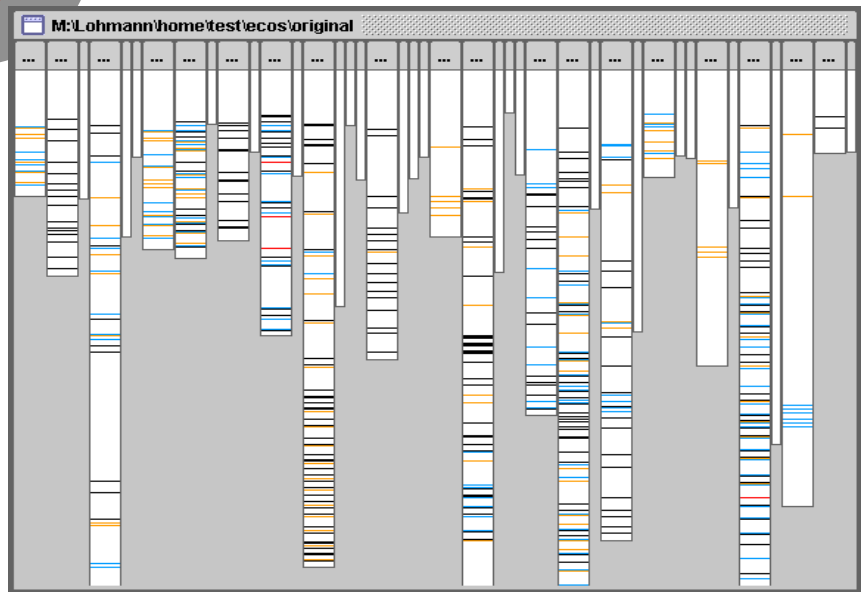
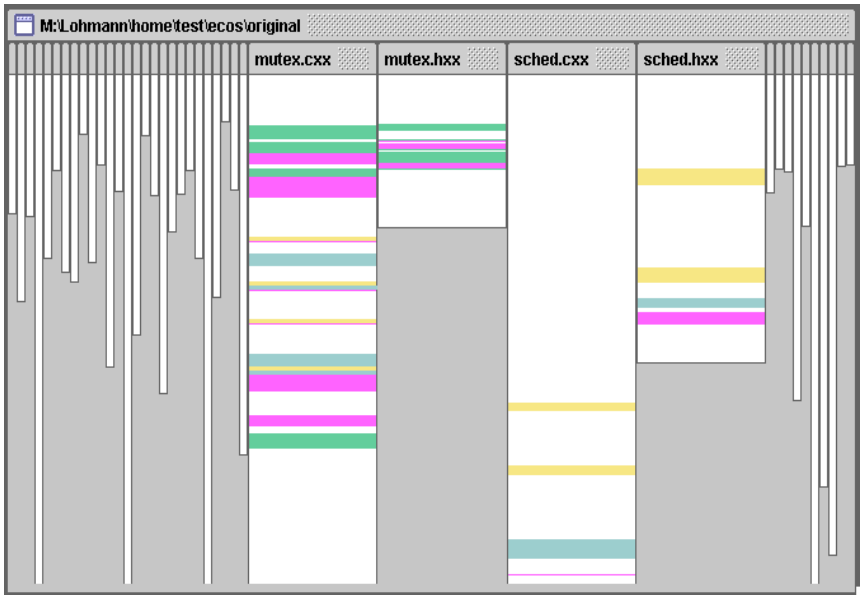
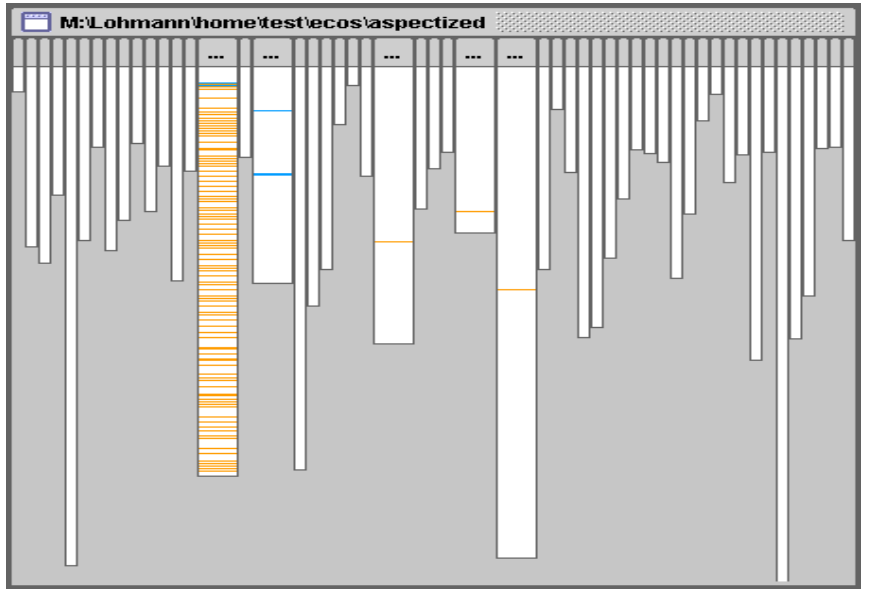
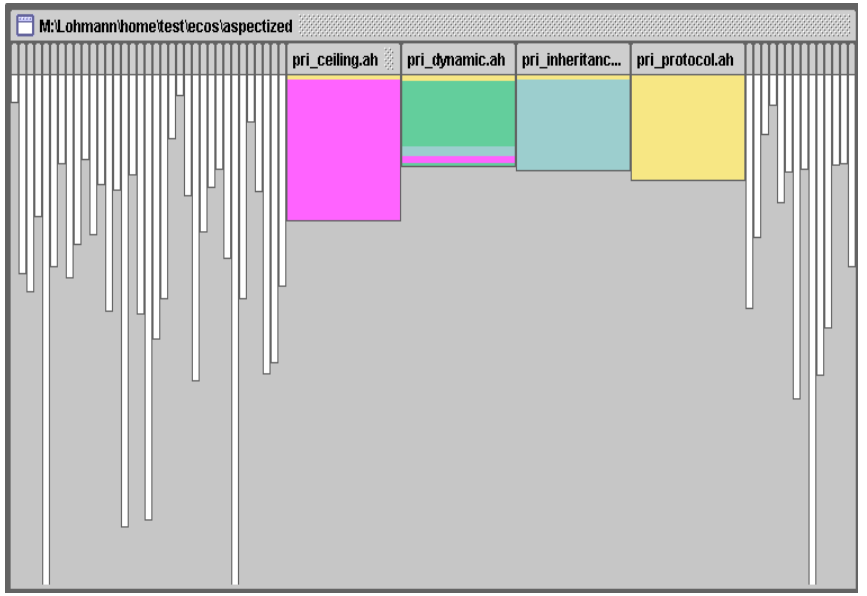
original kernel





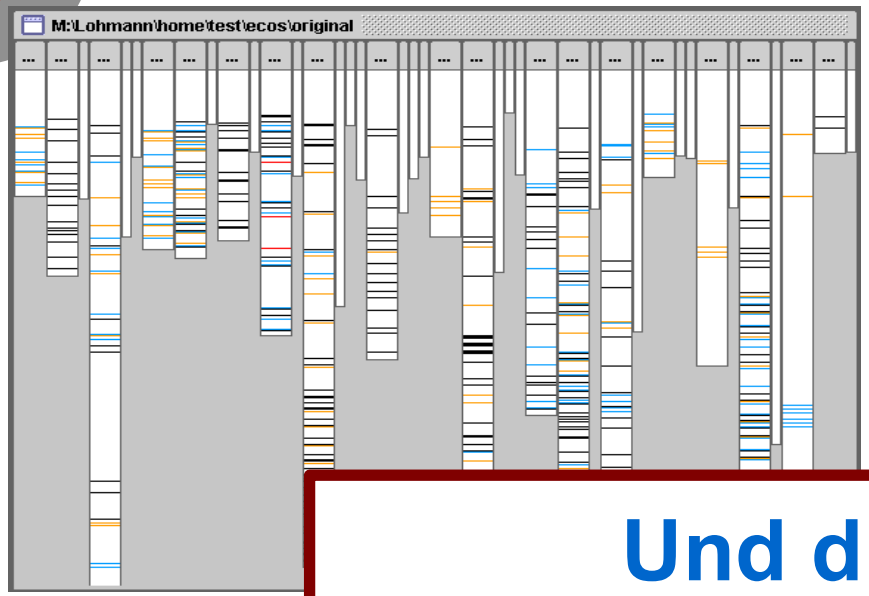
aspectized kernel

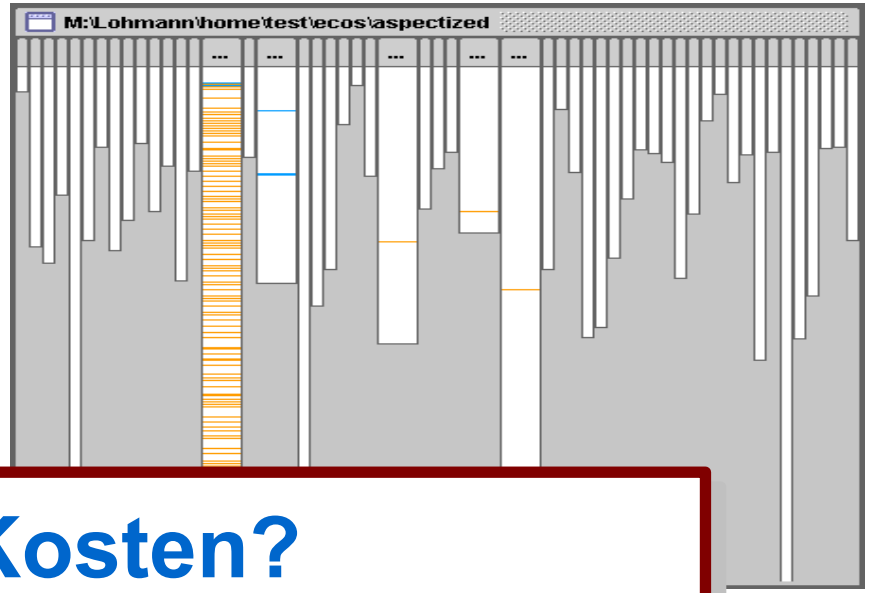




original kernel

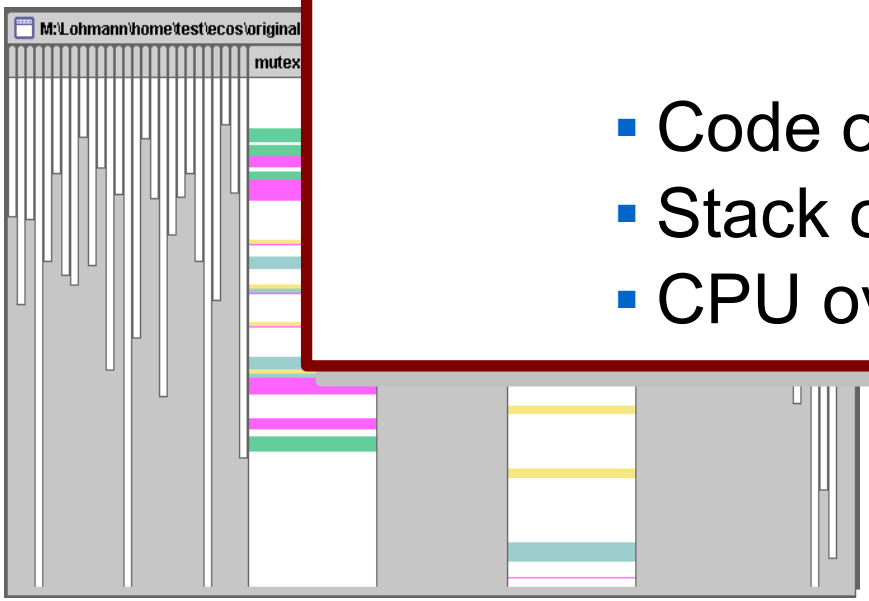
aspectized kernel

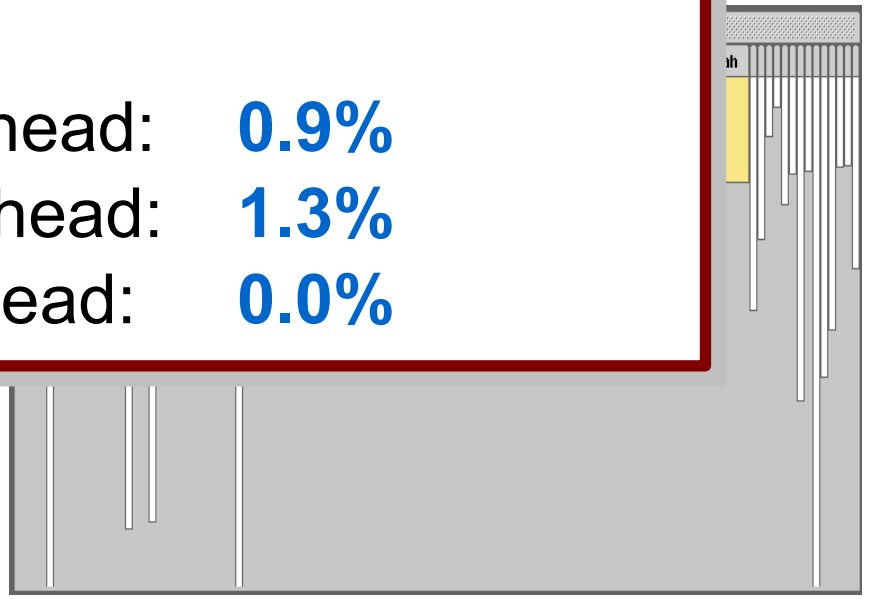




Und die Kosten?

- Code overhead: **0.9%**
- Stack overhead: **1.3%**
- CPU overhead: **0.0%**

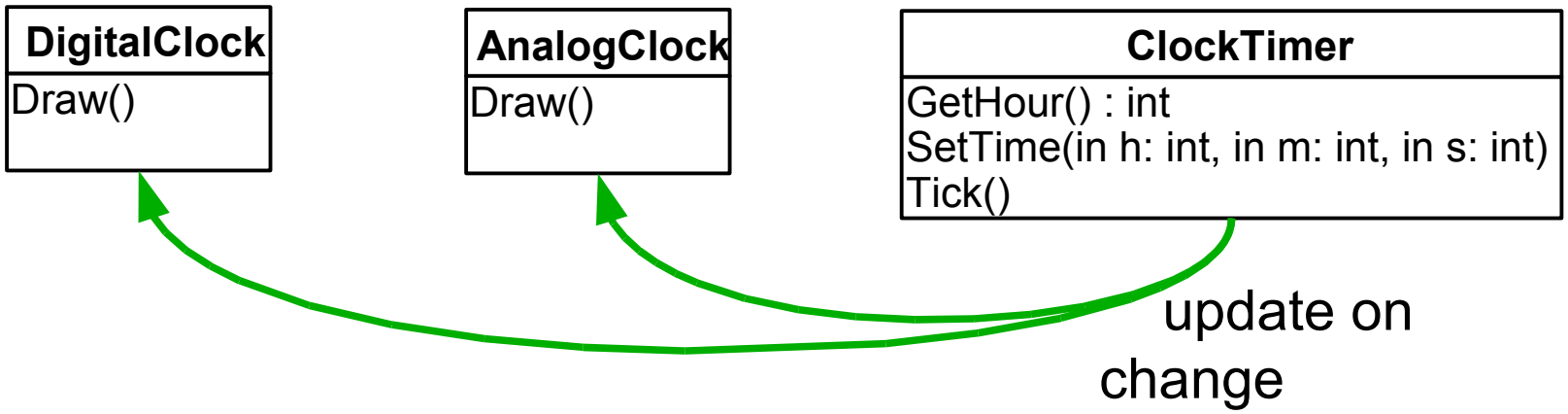




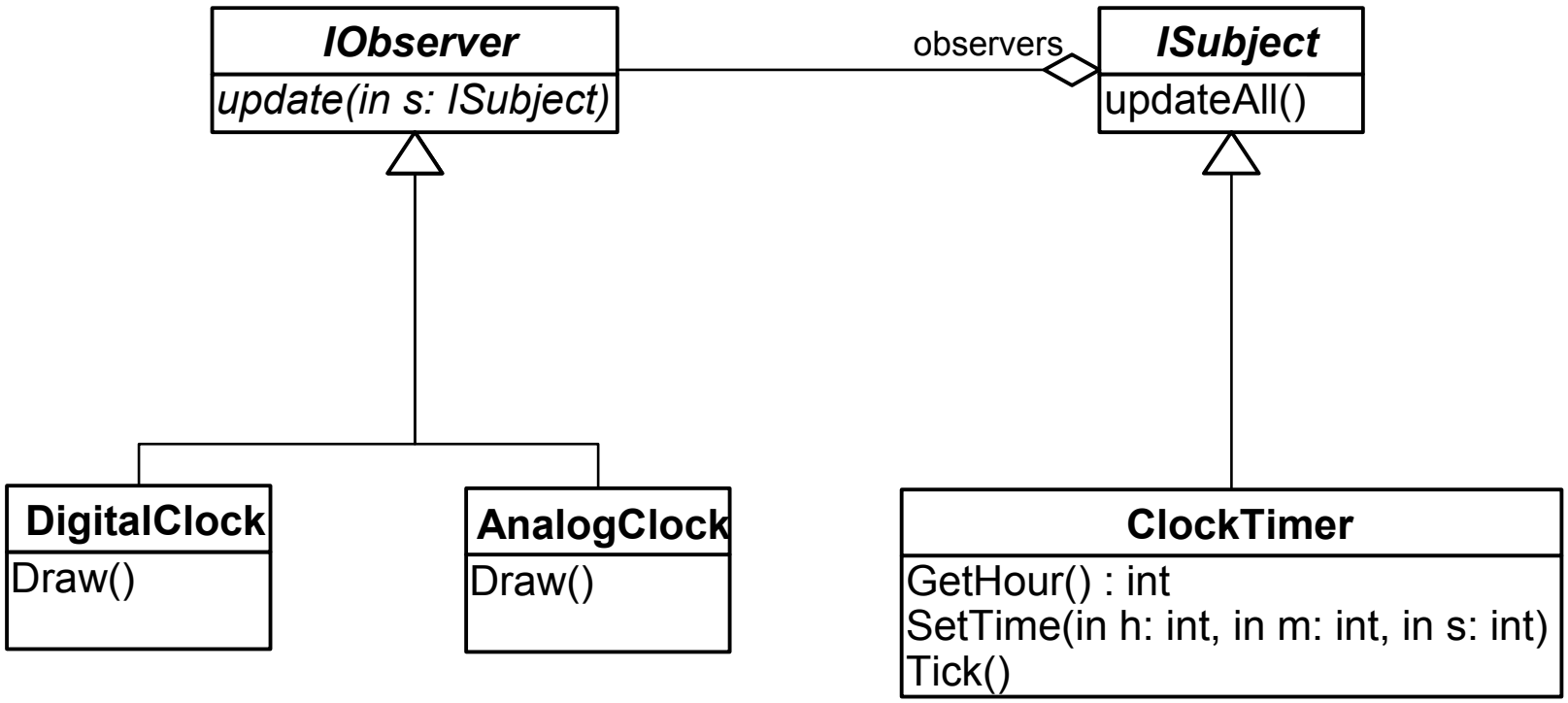
Überblick

- Querschneidende Belange in eCos
  - Das Problem
- Aspektorientierte Programmierung
  - Der Lösungsansatz
- AspectC++
  - Grundlagen
  - Ergebnisse der eCos-Lösung
  - Erweiterte Sprachmerkmale am Beispiel
    - **Vererbung und Wiederverwendung: *Observer Pattern***
    - Generische Programmierung: *Win32 Fehlerbehandlung*
- Zusammenfassung

Observer Pattern: Scenario

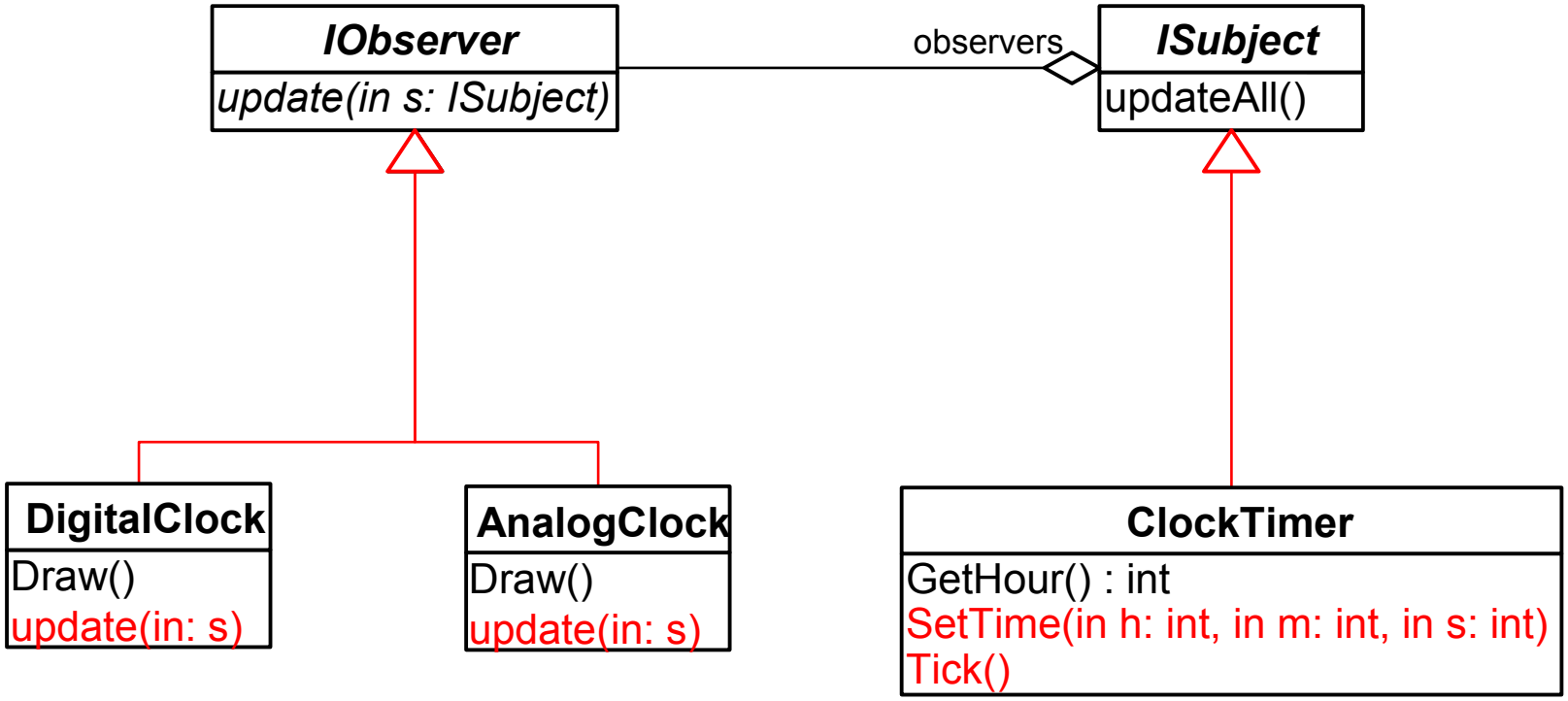


Observer Pattern: Implementation



Observer Pattern: Implementation

The 'Observer Protocol' concern...



...crosscuts the module structure

Aspects and Inheritance

- Aspects can inherit from other aspects...
  - Reuse aspect definitions
  - Override methods and pointcuts
- Pointcuts can be pure virtual
  - Postpone the concrete definition to derived aspects
  - An aspect with a pure virtual pointcut is called **abstract aspect**
- Common usage: Reusable aspect implementations
  - Abstract aspect defines advice code, but pure virtual pointcuts
  - Aspect code uses the join-point API to expose context
  - Concrete aspect inherits the advice code and overrides pointcuts

Solution: Generic Observer Aspect

```
aspect ObserverPattern {
  ...
public:
  struct ISubject {};
  struct IObserver {
    virtual void update (ISubject *) = 0;
  };

  pointcut virtual observers() = 0;
  pointcut virtual subjects() = 0;

  pointcut virtual subjectChange() =  execution( "% ...::%(...)"
                  && !"% ...::%(...) const" ) && within( subjects() );

  advice observers () : slice class : public ObserverPattern::IObserver;
  advice subjects()   : slice class : public ObserverPattern::ISubject;

  advice subjectChange() : after () {
    ISubject* subject = tjp->that();
    updateObservers( subject );
  }

  void updateObservers( ISubject* subject ) { ... }
  void addObserver( ISubject* subject, IObserver* observer ) { ... }
  void remObserver( ISubject* subject, IObserver* observer ) { ... }
};
```

Solution: Generic Observer Aspect

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  void updateObservers( ISubject* subject ) { ... }
  void addObserver( ISubject* subject, IObserver* observer ) { ... }
  void remObserver( ISubject* subject, IObserver* observer ) { ... }
};
```

interfaces for the subject/observer roles

Solution: Generic Observer Aspect

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aspect ObserverPattern {
  ...
public:
  struct ISubject {};
  struct IObserver {
    virtual void update (ISubject *) = 0;
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  void updateObservers( ISubject* subject ) { ... }
  void addObserver( ISubject* subject, IObserver* observer ) { ... }
  void remObserver( ISubject* subject, IObserver* observer ) { ... }
};
```

abstract pointcuts that define subjects/observers

(need to be overridden by a derived aspect)

Solution: Generic Observer Aspect

```
aspect ObserverPattern {
  ...
public:
  struct ISubject {};
  struct IObserver {
    virtual void update (ISubject *) = 0;
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  pointcut virtual observers() = 0;
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  advice subjectChange() : after () {
    ISubject* subject = tjp->that();
    updateObservers( subject );
  }

  void updateObservers( ISubject* subject ) { ... }
  void addObserver( ISubject* subject, IObserver* observer ) { ... }
  void remObserver( ISubject* subject, IObserver* observer ) { ... }
};
```

virtual pointcut defining all state-changing methods.

(defaults to the execution of any non-const methods in subjects)

Solution: Generic Observer Aspect

```
aspect ObserverPattern {
  ...
public:
  struct ISubject {};
  struct IObserver {
    virtual void update (ISubject *) = 0;
  };

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  void addObserver( ISubject* subject, IObserver* observer ) { ... }
  void remObserver( ISubject* subject, IObserver* observer ) { ... }
};
```

introduction of the role interface as additional **baseclass** into subjects and observers

Solution: Generic Observer Aspect

```
aspect ObserverPattern {
  ...
public:
  struct ISubject {};
  struct IObserver {
    virtual void update (ISubject *) = 0;
  };

  pointcut virtual observers() = 0;
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    updateObservers( subject );
  }

  void updateObservers( ISubject* subject ) { ... }
  void addObserver( ISubject* subject, IObserver* observer ) { ... }
  void remObserver( ISubject* subject, IObserver* observer ) { ... }
};
```

after advice to update observers after the execution of state-changing methods

Putting Everything Together

Applying the Generic Observer Aspect to the clock example

```
aspect ClockObserver : public ObserverPattern {
  // define the participants
  pointcut subjects()   = "ClockTimer";
  pointcut observers()  = "DigitalClock"||"AnalogClock";

public:
  // define what to do in case of a notification
  advice observers() : slice class {
  public:
    void update( ObserverPattern::ISubject* s ) {
      Draw();
    }
  };
};
```

Observer Pattern: Conclusions

- Applying the observer protocol is now very easy!
  - all necessary transformations are performed by the generic aspect
  - programmer just needs to define participants and behaviour
  - multiple subject/observer relationships can be defined
- More reusable and less error-prone component code
  - observer no longer “hard coded” into the design and code
  - no more forgotten calls to update() in subject classes

Überblick

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  - Grundlagen
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    - Vererbung und Wiederverwendung: *Observer Pattern*
    - **Generische Programmierung: *Win32 Fehlerbehandlung***
- Zusammenfassung

Error Handling in Win32: Scenario

```
LRESULT WINAPI WndProc( HWND hWnd, UINT nMsg, WPARAM wParam, LPARAM lParam ) {
  HDC dc = NULL; PAINTSTRUCT ps = {0};

  switch( nMsg ) {
    case WM_PAINT:
      dc = BeginPaint( hWnd, &ps );
      ...
      EndPaint(hWnd, &ps);
      break;
    ...
}}

int WINAPI WinMain( ... ) {
  HANDLE hConfigFile = CreateFile( "app.config", GENERIC_READ, ... );

  WNDCLASS wc = {0, WndProc, 0, 0, ... , "Example_Class"};
  RegisterClass( &wc );
  HWND hwndMain = CreateWindowEx( 0, "Example_Class", "Example", ... );
  UpdateWindow( hwndMain );

  MSG msg;
  while( GetMessage( &msg, NULL, 0, 0 ) ) {
    TranslateMessage( &msg );
    DispatchMessage( &msg );
  }
  return 0;
}
```

A typical Win32 application

Error Handling in Win32: Scenario

```
LRESULT WINAPI WndProc( HWND hWnd, UINT nMsg, WPARAM wParam, LPARAM lParam ) {
  HDC dc = NULL; PAINTSTRUCT ps = {0};

  switch( nMsg ) {
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      ...
      EndPaint(hWnd, &ps);
      break;
    ...
}}

int WINAPI WinMain( ... ) {
  HANDLE hConfigFile = CreateFile( "app.config", GENERIC_READ, ... );

  WNDCLASS wc = {0, WndProc, 0, 0, ... , "Example_Class"};
  RegisterClass( &wc );
  HWND hwndMain = CreateWindowEx( 0, "Example_Class", "Example", ... );
  UpdateWindow( hwndMain );

  MSG msg;
  while( GetMessage( &msg, NULL, 0, 0 ) ) {
    TranslateMessage( &msg );
    DispatchMessage( &msg );
  }
  return 0;
}
```

these Win32 API functions may fail

Win32 Error Handling: Goals

- Detect failed calls of Win32 API functions
  - by giving after advice for any call to a Win32 function
- Throw a *helpful* exception in case of a failure
  - describing the exact circumstances and reason of the failure
- Problem: Win32 failures are indicated by a "magic" return value
  - magic value to compare against depends on the ***return type*** of the function
  - error reason (`GetLastError()`) only valid in case of a failure

return type	magic value
BOOL	FALSE
ATOM	(ATOM) 0
HANDLE	INVALID_HANDLE_VALUE or NULL
HWND	NULL

The Join-Point API

- Inside an advice body, the current join-point context is available via the **implicitly passed tjp** variable:

```
advice ... {
  struct JoinPoint {
    ...
  } *tjp;      // implicitly available in advice code
  ...
}
```

- You have already seen how to use tjp, to ...
  - execute the original code in around advice with **tjp->proceed()**
- The join-point API provides a rich interface
  - to expose context **independently** of the aspect target
  - this is especially useful in writing **reusable aspect code**

The Join-Point API (Excerpt)

Types (compile-time)

```
// object type (initiator)
That

// object type (receiver)
Target

// result type of the affected function
Result

// type of the i'th argument of the affected
// function (with 0 <= i < ARGS)
Arg<i>::Type
Arg<i>::ReferredType
```

Consts (compile-time)

```
// number of arguments
ARGS

// unique numeric identifier for this join point
JPID

// numeric identifier for the type of this join
// point (AC::CALL, AC::EXECUTION, ...)
JPTYPE
```

Values (runtime)

```
// pointer to the object initiating a call
That* that()

// pointer to the object that is target of a call
Target* target()

// pointer to the result value
Result* result()

// typed pointer the i'th argument value of a
// function call (compile-time index)
Arg<i>::ReferredType* arg()

// pointer the i'th argument value of a
// function call (runtime index)
void* arg( int i )

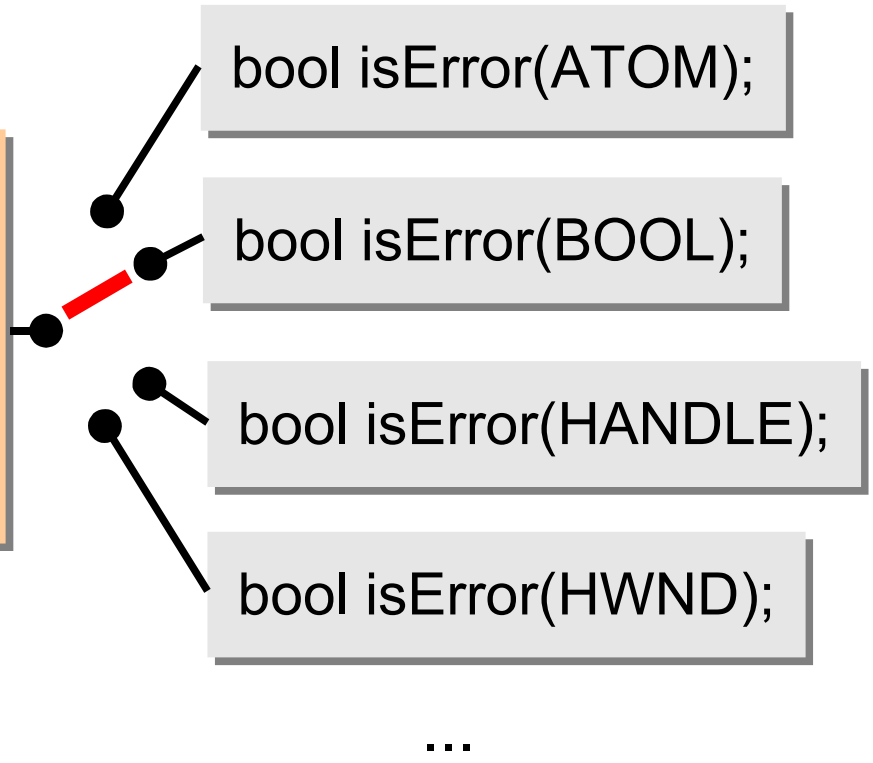
// textual representation of the join-point
// (function/class name, parameter types...)
static const char* signature()

// executes the original join-point code
// in an around advice
void proceed()

// returns the runtime action object
AC::Action& action()
```

Failure Detection: Generic Advice

```
advice call(win32API ()) :
after () {
  if (isError (*tjp->result()))
    // throw an exception
}
```



Error Report: Generative Advice

```
template <int I> struct ArgPrinter {
  template <class JP> static void work (JP &tjp, ostream &s) {
    ArgPrinter<I–1>::work (tjp, s);
    s << “, “ << *tjp. template arg<I-1>();
  }
};
```

```
advice call(win32API ()) : after () {
  // throw an exception
  ostringstream s;
  DWORD code = GetLastError();
  s << “WIN32 ERROR ” << code << ...
     << win32::GetErrorText( code ) << ... <<
     << tjp->signature() << “WITH: ” << ...;
     ArgPrinter<JoinPoint::ARGS>::work (*tjp, s);

  throw win32::Exception( s.str() );
}
```

Reporting the Error

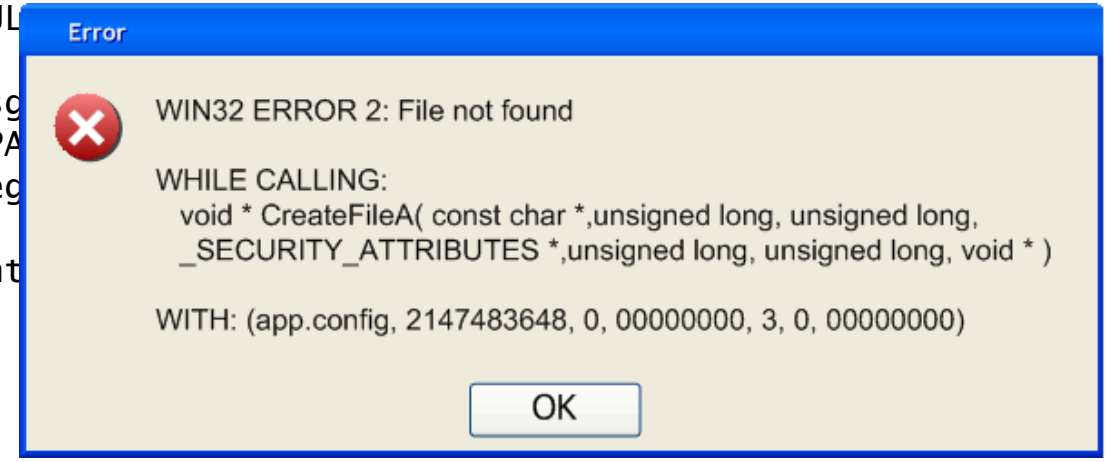
```
LRESULT WINAPI WndProc( HWND hWnd, UINT nMsg, WPARAM wParam, LPARAM lParam ) {
  HDC dc = NUL

  switch( nMsg
    case WM_PA
      dc = Beg
      ...
      EndPaint
      break;
    ...
}}

int WINAPI WinMain( ... ) {
  HANDLE hConfigFile = CreateFile( "app.config", GENERIC_READ, ... );

  WNDCLASS wc = {0, WndProc, 0, 0, ... , "Example_Class"};
  RegisterClass( &wc );
  HWND hwndMain = CreateWindowEx( 0, "Example_Class", "Example", ... );
  UpdateWindow( hwndMain );

  MSG msg;
  while( GetMessage( &msg, NULL, 0, 0 ) ) {
    TranslateMessage( &msg );
    DispatchMessage( &msg );
  }
  return 0;
}
```



Error Handling in Win32: Conclusions

- Easy to apply error handling for Win32 applications
  - previously undetected failures are reported by exceptions
  - rich context information is provided
- Uses advanced AspectC++ techniques
  - error detection by generic advice
  - context propagation by generative advice

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Zusammenfassung

Zusammenfassung

- AOP ...
  - versucht das Problem der querschneidenden Belange zu lösen: Vermeidung von *tangling* und *scattering*
  - modulare Implementierung durch Aspekte
  - Trennung von WO und WAS
- AspectC++ ...
  - erlaubt AOP mit C++
  - ähnelt AspectJ
  - wird durch IDEs unterstützt
- Beispiele zeigen beispielsweise, dass ...
  - viele Entwurfsmuster von Aspekten profitieren
  - redundanter Code vermieden werden kann

Weitere Informationen

- ***das*** Web Portal der Community: **www.aosd.net**
  - weitere AOP Sprachen/Werkzeuge
  - Konferenzen/Workshops
  - mailing lists
- AspectC++: **www.aspectc.org**
  - alle Infos zum AspectC++ Projekt
  - mailing list
- Literatur: "Aspect-Oriented Software Development"
  - von R. Filman, T. Elrad, S. Clarke, M. Aksit

Vielen Dank für's zuhören!