Meta-Programming in KDE

The technology behind KConfig XT and friends

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The KDE Project

Overview

- What is Meta-Programmig?
- Flavors of Meta-Programming
- Code Generators in KDE
  - libkabc
  - KConfig XT
  - kxml_compiler
- libkode
- Other Code Generators
  - Torque
  - gSOAP
- Conclusion

What is Meta-Programming?

Definitions:

- The art of programming programs that read, transform, or write other programs
- Automated Programming
- Creating program code automatically from meta descriptions rather than programming directly in a a programming language

Flavors of Meta-Programming

- Assemblers, Compilers -
  High-level language code is transformed into lower-level language code
- C++ Templates -
  Generic programming by describing repeating C++ code in generalized form.
- Aspect Weavers -
  Additional code described by aspects is injected into code (Aspect-oriented programming).
- Code Generators -
  Generating source code based on specific input data or commands.

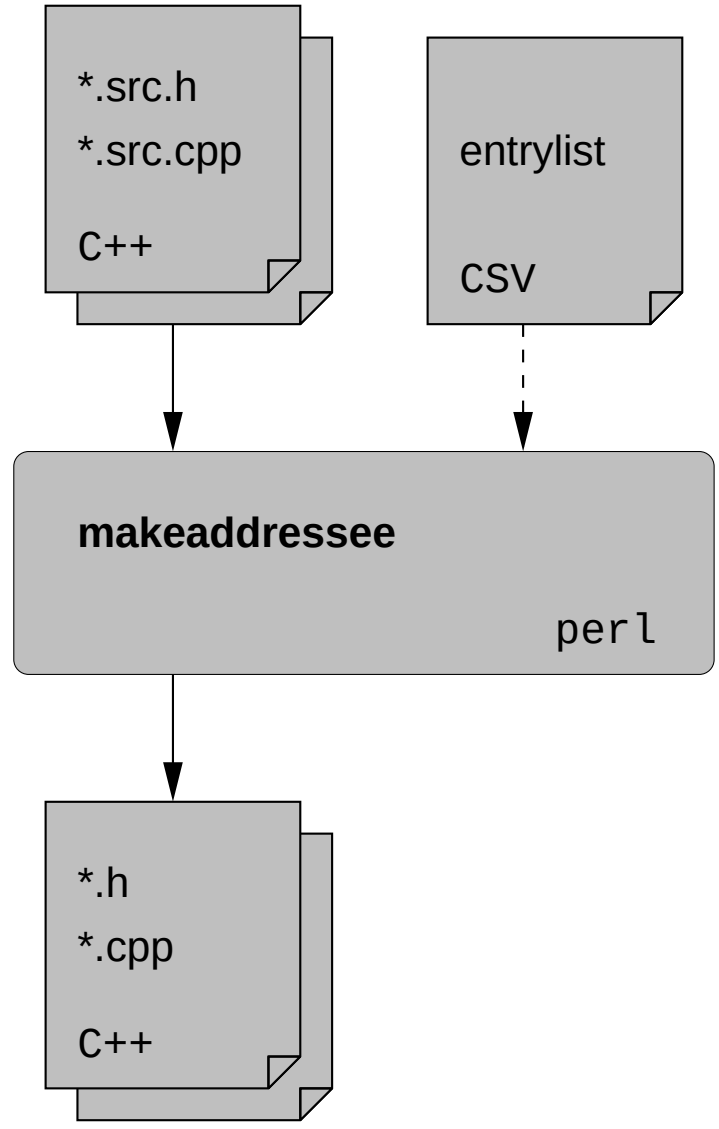
Code Generators used in KDE

- moc (Qt Meta Object Compiler)
- uic (Qt Designer)
- dcopidl (DCOP stubs and skeletons)
- kdewidgets (KDE plugins for Qt Designer)
- kapptemplate (kdesdk)
- umbrello (Code Generation from UML)
- kdebindings (Language bindings)
- makeaddressee (libkabc)
- kconfig_compiler (KConfig XT)
- kxml_compiler

libkabc Code Generation

Generation of Addressee class which provides access to all fields of a contact.

- C++ Template Files
- Text file describing fields
- Generator script "makeaddressee" (Perl)
- Output: Addressee class



libkabc Meta Sources

C++ Template (addressee.src.h)

```
/**
  Return translated label for uid field.
 */
static QString uidLabel();

--DECLARATIONS--
/**
  Set name fields by parsing the given string and trying to associate the
  parts of the string with according fields. This function should probably
  be a bit more clever.
 */
void setNameFromString( const QString & );
```

Control File (entrylist)

```
# This file describes the fields of an address book entry.
#
# The following comma-separated fields are used:
#
#          Control: A generates accessor functions.
#                   L generates a static function for returning a tranlsated label
#                   F generates a Field id and object for generic field handling
#                   E generate an equality test in Addressee::operator==().
#      Field Name : A descriptive name which is shown to the user.
#            Type : C++ type of field.
#      Identifier : A string used in code as variable name etc.
#  Field Category : Categories the field belongs to (see Field::FieldCategory).
#  Output function: Function used to convert type to string for debug output (optional)

ALE,name,QString,name

ALFE,formatted name,QString,formattedName,Frequent
```

libkabc Generated Code

Generated C++ code (addressee.h)

```
/**
  Return translated label for uid field.
 */
static QString uidLabel();
```

```
/**
  Set name.
 */
void setName( const QString &name );
/**
  Return name.
 */
QString name() const;
/**
  Return translated label for name field.
 */
static QString nameLabel();

/**
  Set formatted name.
 */
void setFormattedName( const QString &formattedName );
/**
  Return formatted name.
 */
QString formattedName() const;
/**
  Return translated label for formattedName field.
 */
static QString formattedNameLabel();

(...)
```

libkabc Discussion

Benefits:

- No more need to write error-prone repetitive code
- Type-safe API for all fields
- Strong typing, errors can be found at compile-time, not at run-time
- Consistency is enforced (field names, labels, API docs, etc.)
- Field list easily extendable

Problems:

- Increased complexity of build process
- People change generated code instead of sources.
- API docs are not at usual place

Lessons from libkabc approach

- Saves work and improves quality of code.
- Works around limitations of C++ (type-safety can’t be ensured in generic way, C++ identifier aren’t accessible to program at run-time).
- Crude ad-hoc approach for special case.
- Increased complexity and non-standard meta descriptions might confuse developers
- Template approach could be done by more generic system.

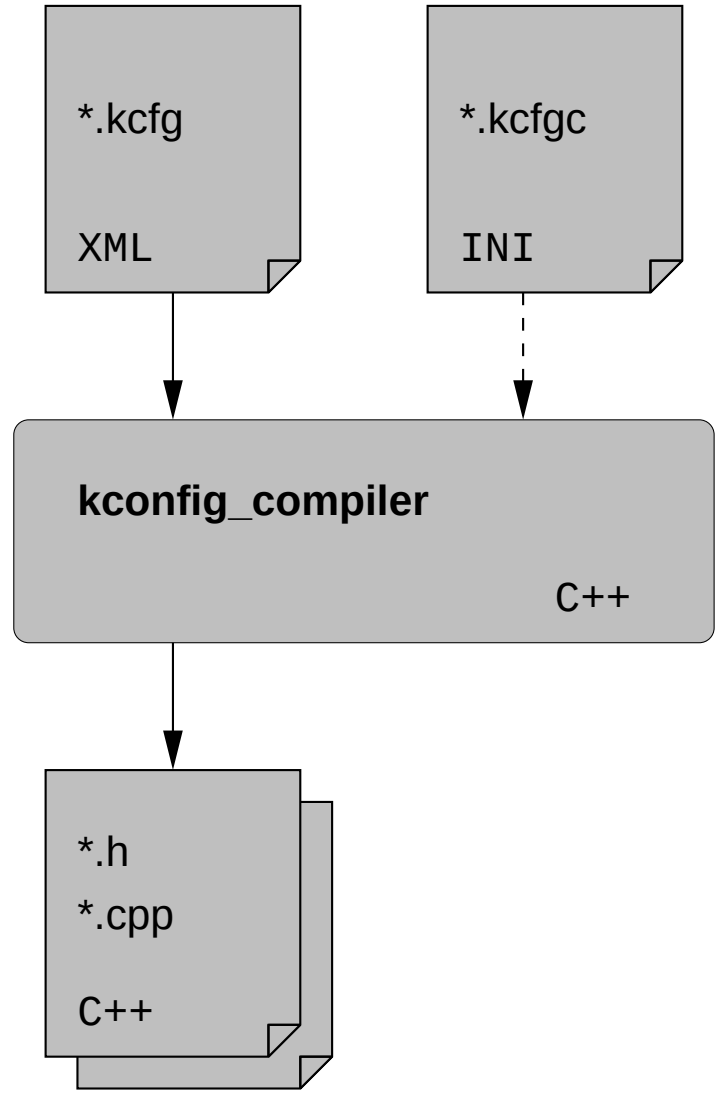
KConfig XT

KDE 3.2 introduced KConfig XT (extended technology)

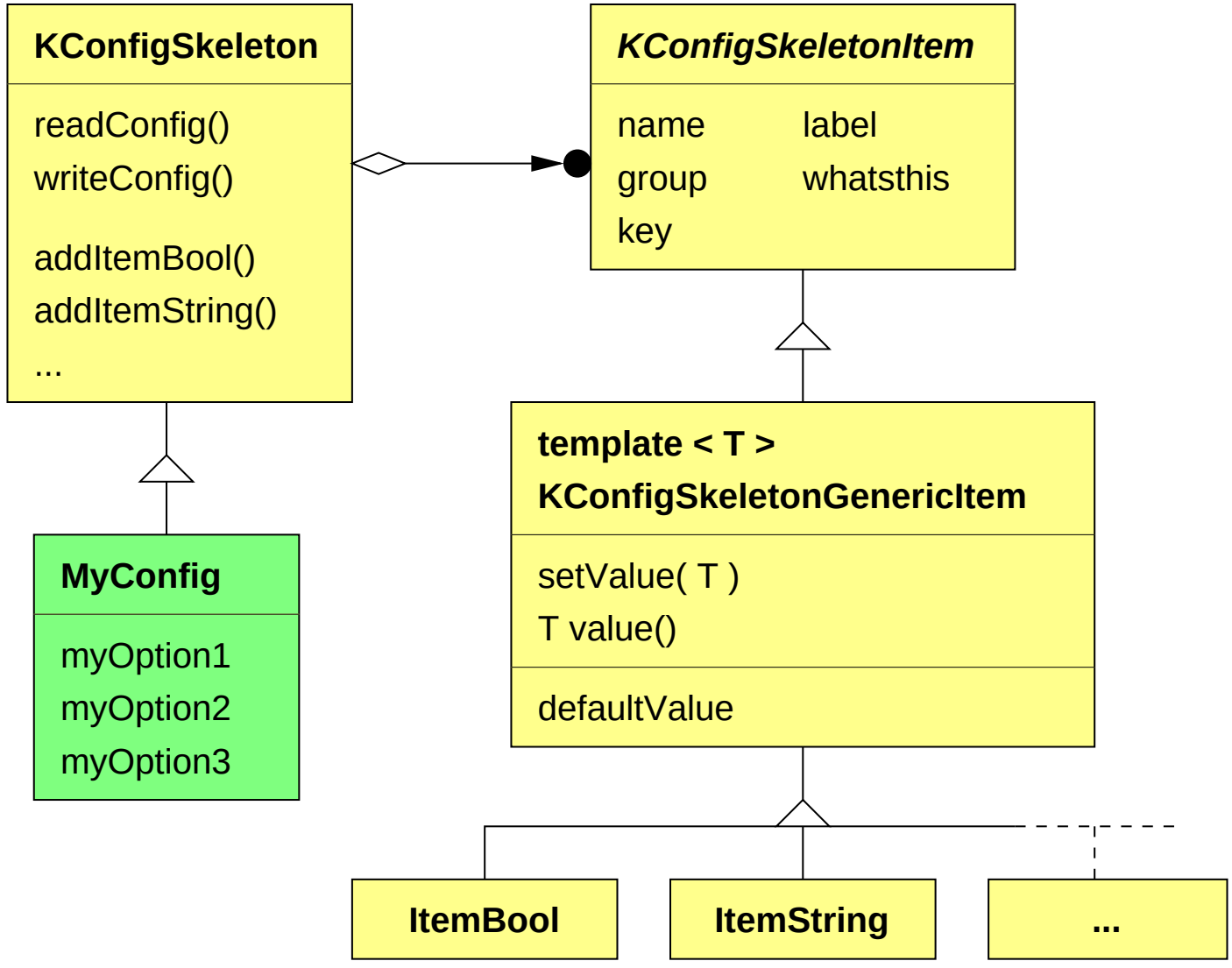
- Abstract description of configuration options in XML
- Code generator for translating XML files to C++ code
- Application has convenient and type-safe access to configuration options
- Loading and saving is handled in the background
- Generic access to configuration options including meta information
- Automatic connection of GUI designer generated dialogs to configuration backend

KConfig XT Code Generation

- XML description of configuration options (.kcfg)
- Code generation options from separate file (.desktop-style)
- kconfig_compiler creates C++ code for classes encapsulating configuration information



KConfig XT Generated Code



KConfig XT: XML -> C++

Control File (kontact.kcfgc):

```
# Code generation options for kconfig_compiler
File=kontact.kcfg
NameSpace=Kontact
Singleton=true
Mutators=true
ItemAccessors=true
ClassName=Prefs
```

XML description (kontact.kcfg):

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE kcfg SYSTEM "http://www.kde.org/
  standards/kcfg/1.0/kcfg.dtd">
<kcfg>
  <kcfgfile name="kontactrc"/>

  <group name="View">
    <entry type="String" name="ActivePlugin">
      <default>kontact_summaryplugin</default>
      <label>Active Plugin</label>
      <whatsthis>This option specifies the
      plugin which is activated on start-up.
      </whatsthis>
    </entry>
  </group>

</kcfg>
```

Generate C++ code (prefs.h):

```
namespace Kontact {

class Prefs : public KConfigSkeleton
{
  private:
    Prefs() : KConfigSkeleton( "kontactrc" ) { ... }

    QString mActivePlugin;

  public:
    static Prefs *self();
    ~Prefs();

    /** Set ActivePlugin */
    static void setActivePlugin( const QString &v )
    {
      if ( !self()->isImmutable( "ActivePlugin" ) )
        self()->mActivePlugin = v;
    }

    /** Get ActivePlugin */
    static QString activePlugin()
    {
      return self()->mActivePlugin;
    }

    /** Get Item object for ActivePlugin */
    ItemString *activePluginItem()
    {
      return mActivePluginItem;
    }
};

}
```

Benefits of Code Generation

- All definitions are at one place
- Type-safe interface to config options
- Eliminates potential errors caused by inconsistent config keys or default values.
- Less code to be written.
- Meta-data for config options at run-time (labels, whatsthis, info for kconfigeditor)
- Cleaner config files (default values aren’t written)
- More extensible
- Better KIOSK integration (immutability etc.)
- Easier to add GUIs.

Discussion of kconfig_compiler

- Increases complexity of build system
- Designer for .kcfg files (kcfgcreator), XML code is easy to create
- kconfig_compiler internally is an ugly piece of software
- kconfig_compiler itself is easy to test.
- Interesting experience to work on kconfig_compiler. Thinking very abstract. Simple changes can have big effects.

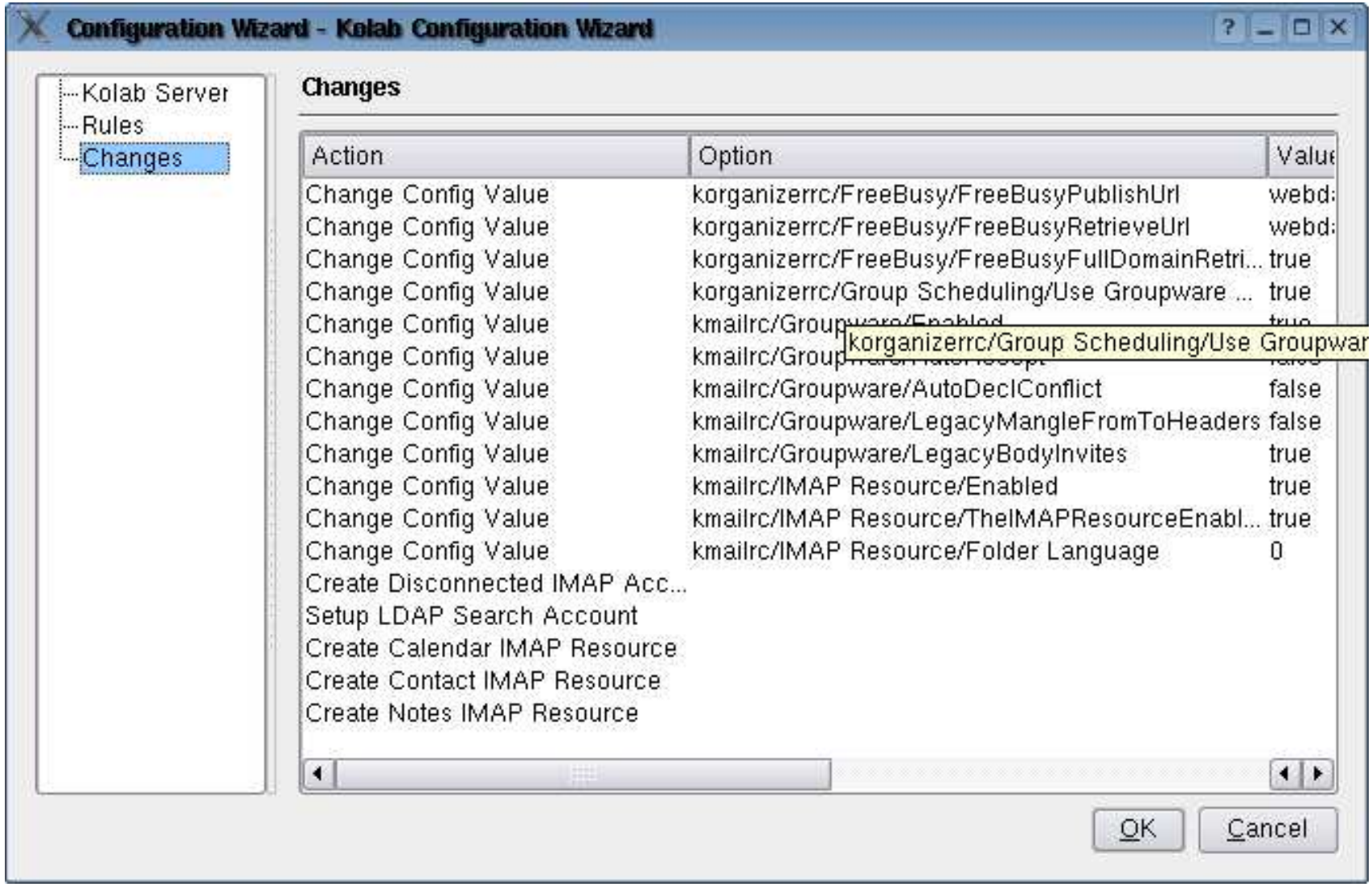
Configuration Wizards

- Based on KConfig XT XML meta data
- Additional rules for propagation of configuration values
- Extendable by custom code
- Dialog for setting options to propagate, optionally including views for the rules and preview of changes
- Used for setting up groupware access etc.

Config Propagation Example

```
<kcfg>

  <kcfgfile name="kolabrc"/>

  <group name="General">
    <entry name="User" type="String">
      <label>Kolab user name</label>
      <default></default>
    </entry>
  </group>

  <group name="Constants">
    <entry name="EnableFreeBusy">
      <default>true</default>
    </entry>
  </group>

  <propagation source="kolabrc/Constants/EnableFreeBusy"
               target="korganizerrc/FreeBusy/FreeBusyPublishAuto" />

  <propagation source="kolabrc/General/User"
               target="korganizerrc/FreeBusy/FreeBusyPublishUser" />

</kcfg>
```

Screenshot Configuration Wizard

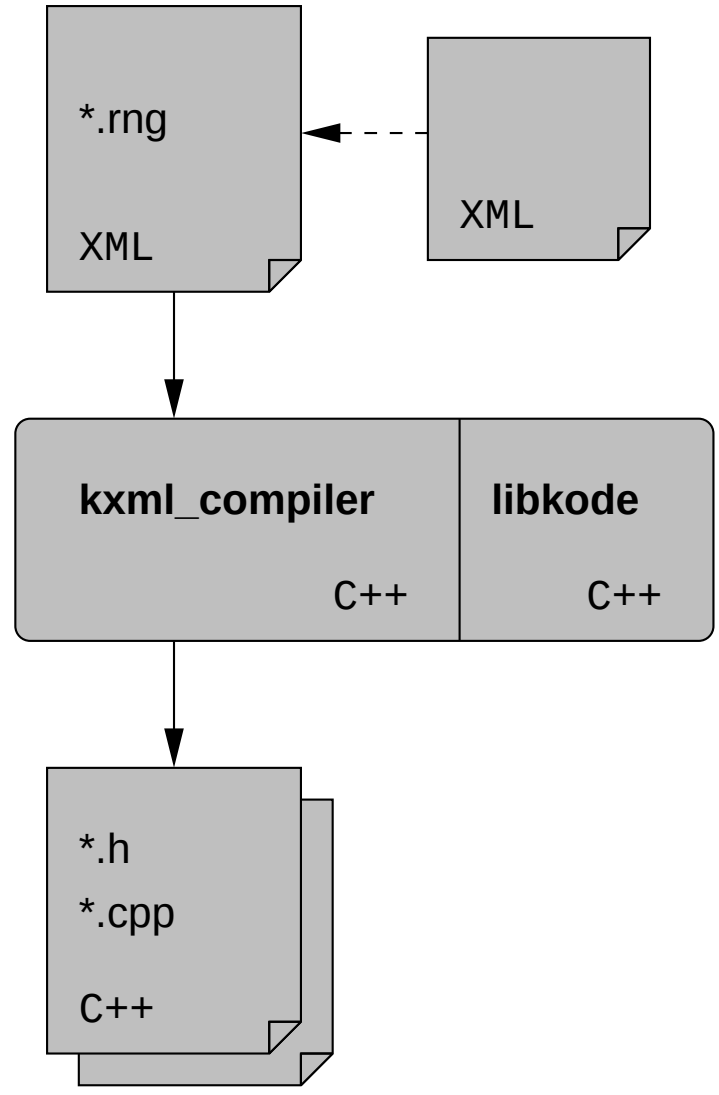


Config Propagation Potential

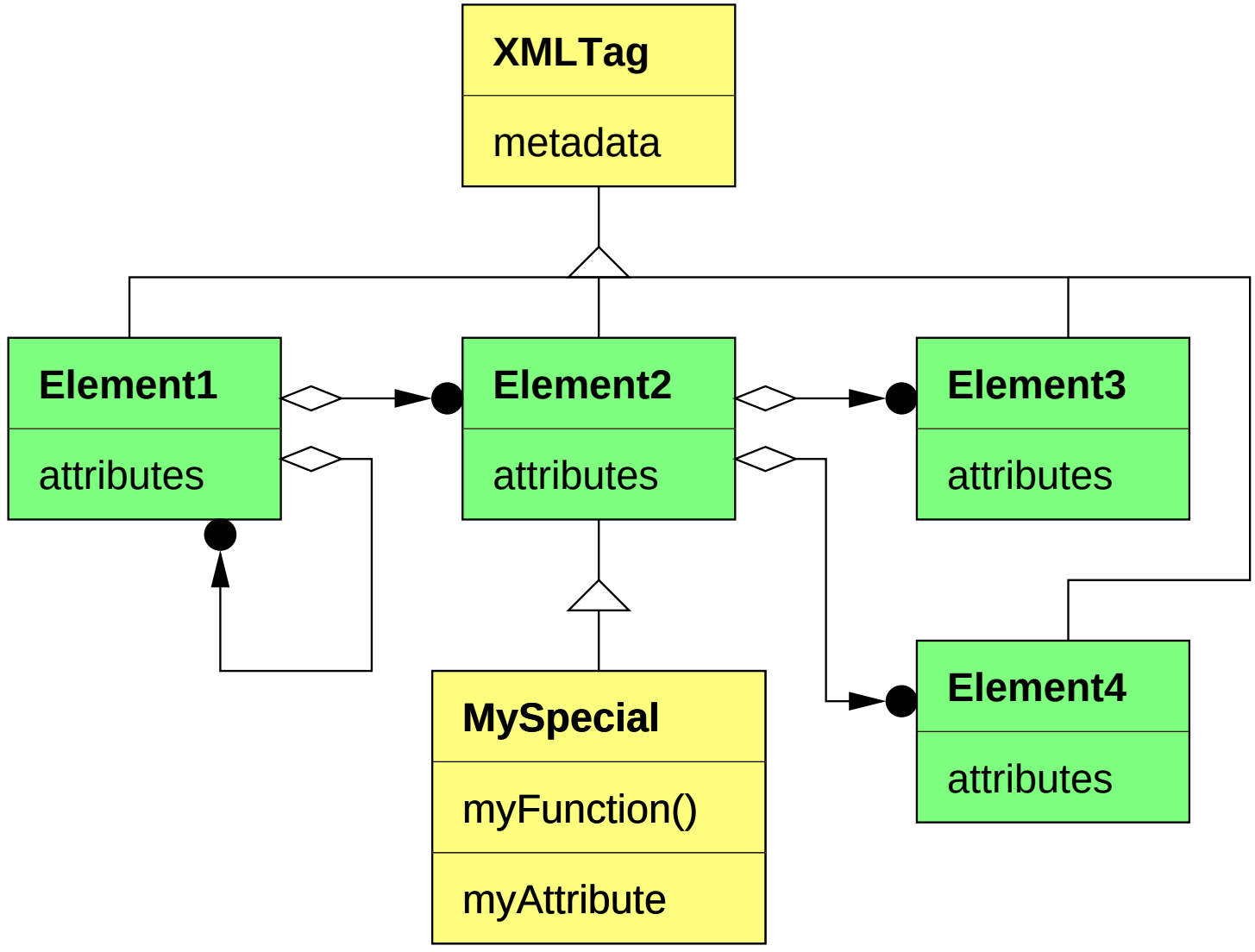
- Simple configuration for specific purposes including logic and know-how of configuration options
- Fine-grained configuration is unaffected
- User levels (home users, former Windows users, enterprise users)
- Meta information is available
  - Show changes (overview page)
  - Record changes as transactions
  - Undo of configuration changes
  - Indicate in GUI which options are set by wizards

kxml_compiler

- Generate C++ classes representing XML data
- Source: RelaxNG scheme (maybe converted from DTD)
- Generator: kxml_compiler (C++ program using code generation library libkode)
- Output: Classes representing XML data, including parser for corresponding XML data files and output as XML (serializing/deserializing)



Generated Classes



Discussion

Benefits:

- No hand-written code necessary for parsing XML.
- Parsing code can be optimized for specific scheme.
- Validating parser.
- Enable persistence or streaming of objects.
- Meta data can be used for example to create editor or viewer GUIs.

Problems:

- Not all XML schemes can easily be transfered to class representations.
- Working on kxml_comiler itself is challenging because it introduces an additional level of abstraction.

Feature Plan - DTD

kde-features.dtd - /build/kde/cvs/head/kdepim/kresources/featureplan/

File Edit Search Preferences Shell Macro Windows Help

/build/kde/cvs/head/kdepim/kresources/featureplan/kde-features.dtd 638 bytes L: 26 C: 0

```
<!ELEMENT features (category+)>

<!ELEMENT category (feature|category)*>
<!ATTLIST category name CDATA #REQUIRED >

<!ELEMENT feature (summary?,responsible*)>
<!ATTLIST feature status (inprogress|todo|done) "todo"
                 target CDATA #REQUIRED>

<!ELEMENT responsible EMPTY>
<!ATTLIST responsible name CDATA #IMPLIED
                      email CDATA #IMPLIED>

<!ELEMENT summary (#PCDATA|i|a|b|em|strong|br)*>

<!ELEMENT i (#PCDATA)>
<!ELEMENT b (#PCDATA)>
<!ELEMENT em (#PCDATA)>
<!ELEMENT strong (#PCDATA)>
<!ELEMENT br EMPTY>

<!ELEMENT a (#PCDATA)>
<!ATTLIST a href CDATA #IMPLIED>
<!ATTLIST a title CDATA #IMPLIED>
```

Feature Plan - Relax NG Scheme

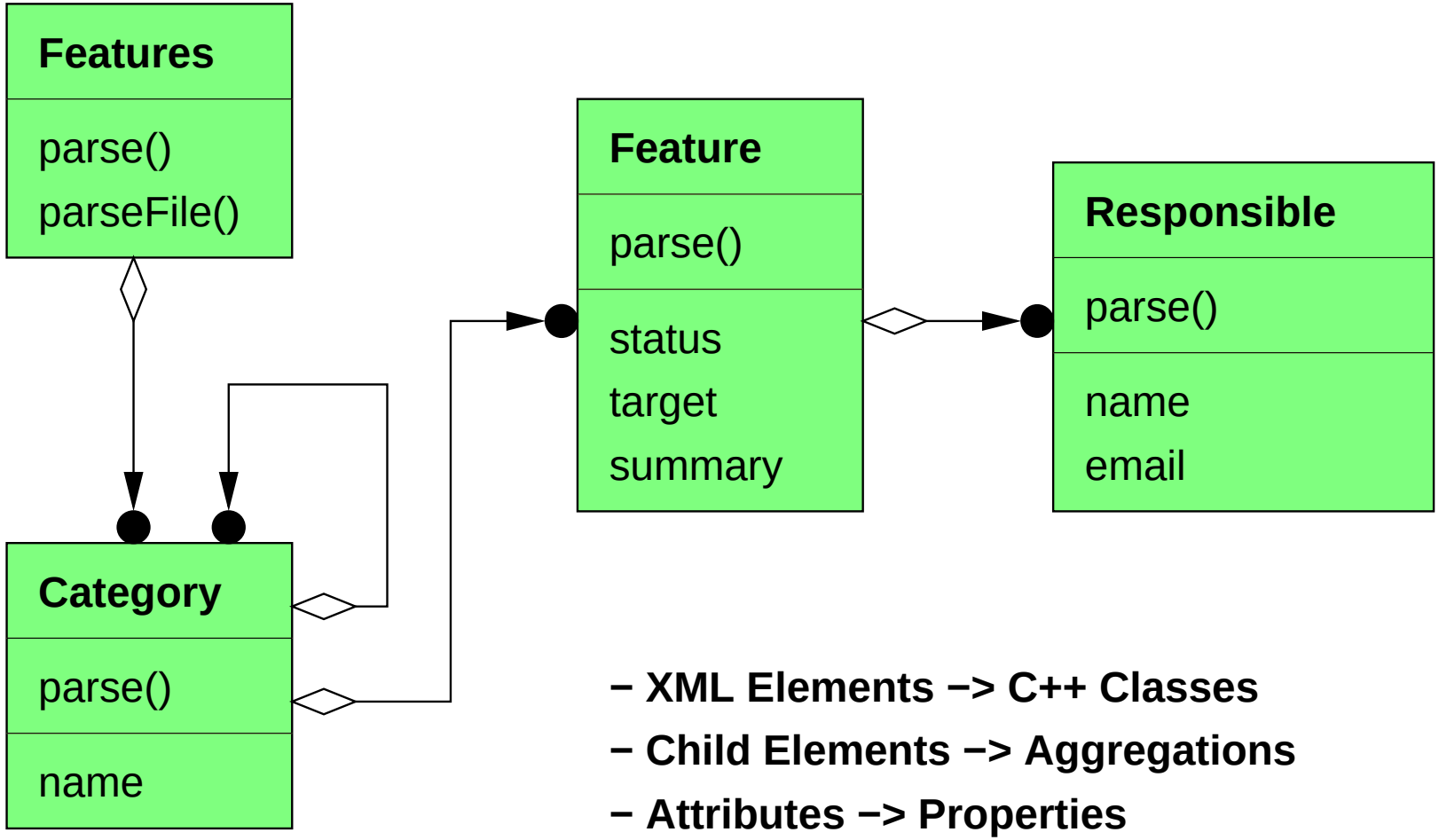
kde-features.rng - /build/kde/cvs/head/kdepim/kresources/featureplan/

File Edit Search Preferences Shell Macro Windows Help

/build/kde/cvs/head/kdepim/kresources/featureplan/kde-features.rng 3592 bytes L: 1 C: 0

```
<?xml version="1.0" encoding="UTF-8"?>
<grammar xmlns:a="http://relaxng.org/ns/compatibility/annotations/1.0"
         xmlns="http://relaxng.org/ns/structure/1.0">
  <define name="features">
    <element name="features">
      <ref name="attlist.features"/>
      <oneOrMore>
        <ref name="category"/>
      </oneOrMore>
    </element>
  </define>
  <define name="attlist.features" combine="interleave">
    <empty/>
  </define>
  <define name="category">
    <element name="category">
      <ref name="attlist.category"/>
      <zeroOrMore>
        <choice>
          <ref name="feature"/>
          <ref name="category"/>
        </choice>
      </zeroOrMore>
    </element>
  </define>
  <define name="attlist.category" combine="interleave">
```

Feature Plan - Generated Code



- XML Elements –> C++ Classes
- Child Elements –> Aggregations
- Attributes –> Properties
- Parsing of XML files to C++ objects

Feature Plan - Hand-Written Code

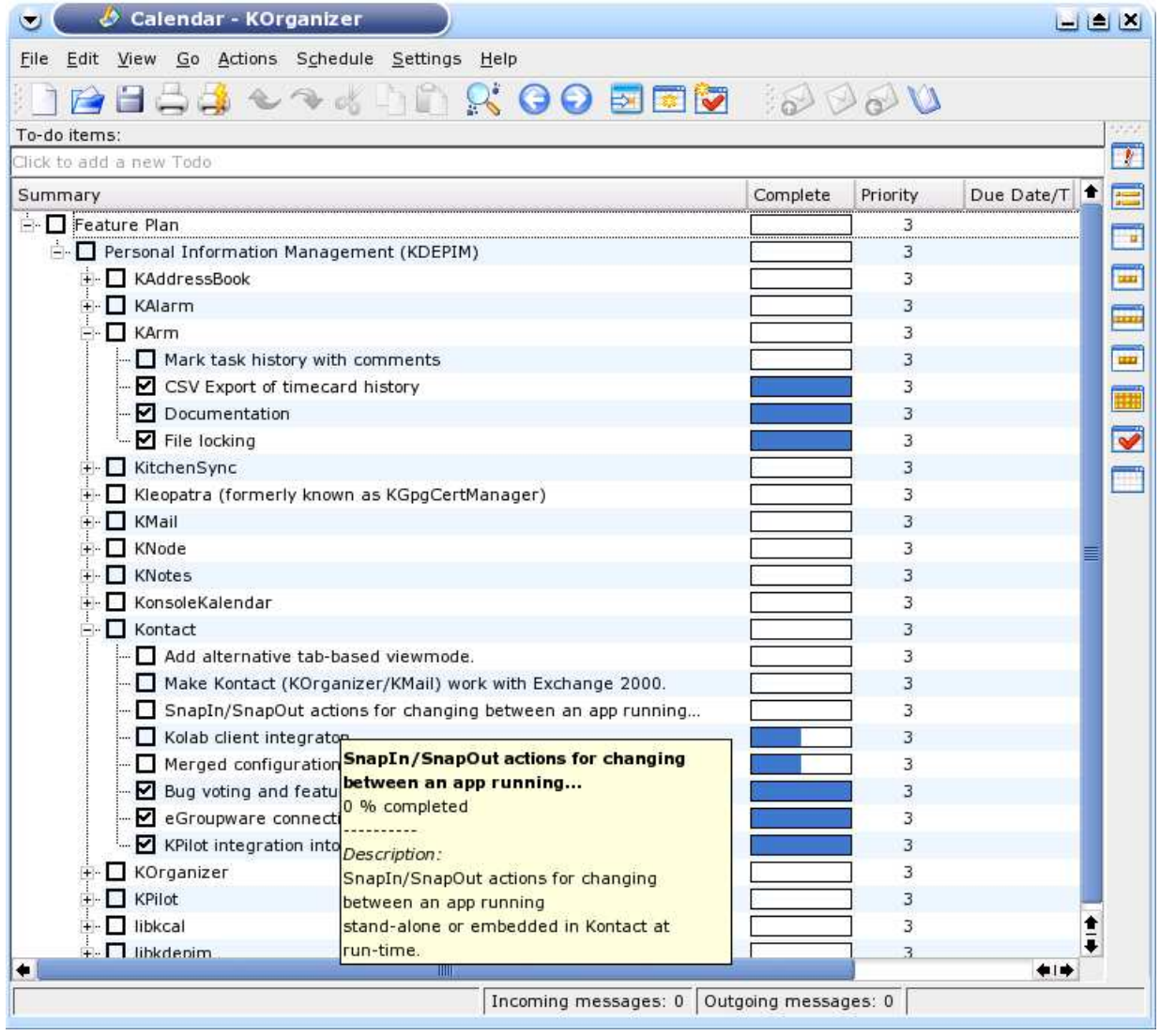
resourcefeatureplan.cpp - /build/kde/cvs/head/kdepim/kresources/featureplan/

File Edit Search Preferences Shell Macro Windows Help

/build/kde/cvs/head/kdepim/kresources/featureplan/resourcefeatureplan.cpp 3552 bytes L: 124 C: 1

```
bool ResourceFeaturePlan::doLoad()
{
  Features *features = Features::parseFile( mPrefs->filename() );

  if ( !features ) {
    return false;
  } else {
    Category::List categories = features->categoryList();
    KCal::Todo *masterTodo = new KCal::Todo;
    masterTodo->setSummary( "Feature Plan" );
    mCalendar.addTodo( masterTodo );
    insertCategories( categories, masterTodo );
  }

  return true;
}

void ResourceFeaturePlan::insertCategories( const Category::List &categories, Todo *parent )
{
  Category::List::ConstIterator it;
  for( it = categories.begin(); it != categories.end(); ++it ) {
    Category *c = *it;

    Todo *categoryTodo = new Todo;
    categoryTodo->setSummary( c->name() );
    categoryTodo->setRelatedTo( parent );

    insertCategories( c->categoryList(), categoryTodo );

    Feature::List features = (*it)->featureList();
    Feature::List::ConstIterator it2;
    for( it2 = features.begin(); it2 != features.end(); ++it2 ) {
      Feature *f = *it2;
      Todo *todo = new Todo;

      QString summary = f->summary();
      int pos = summary.find( '\n' );
      if ( pos > 0 ) summary = summary.left( pos ) + "...";
      todo->setSummary( summary );
      todo->setDescription( f->summary() );
      todo->setRelatedTo( categoryTodo );
      int completed;
      if ( f->status() == "done" ) completed = 100;
      else if ( f->status() == "inprogress" ) completed = 50;
      else completed = 0;
      todo->setPercentComplete( completed );

      mCalendar.addTodo( todo );
    }
  }
}
```

Screenshot KOrganizer



Balance Sheet

	Lines of Code	
DTD	25	
Relax NG Scheme	151	
kcfg File	18	
Generated XML Handling Code	242	
Generated Configuration Code	101	
Boilerplate Code in KResource	330	
Functional Code in KResource	63	
Total Code	736	
Generated Code	343	(47 %)

libkode

- Library for supporting code generation driven by C++ programs.
- Representations for classes, functions, files, headers, code blocks etc.
- Classes for creating C++ files from the code representation
- Styles for customizing appearance code generation
- Semi-automatic handling of indentation, includes etc.
- Application "kode" for generation of program templates, e.g. header and implementation files including license header, optional singleton code, etc.

Torque

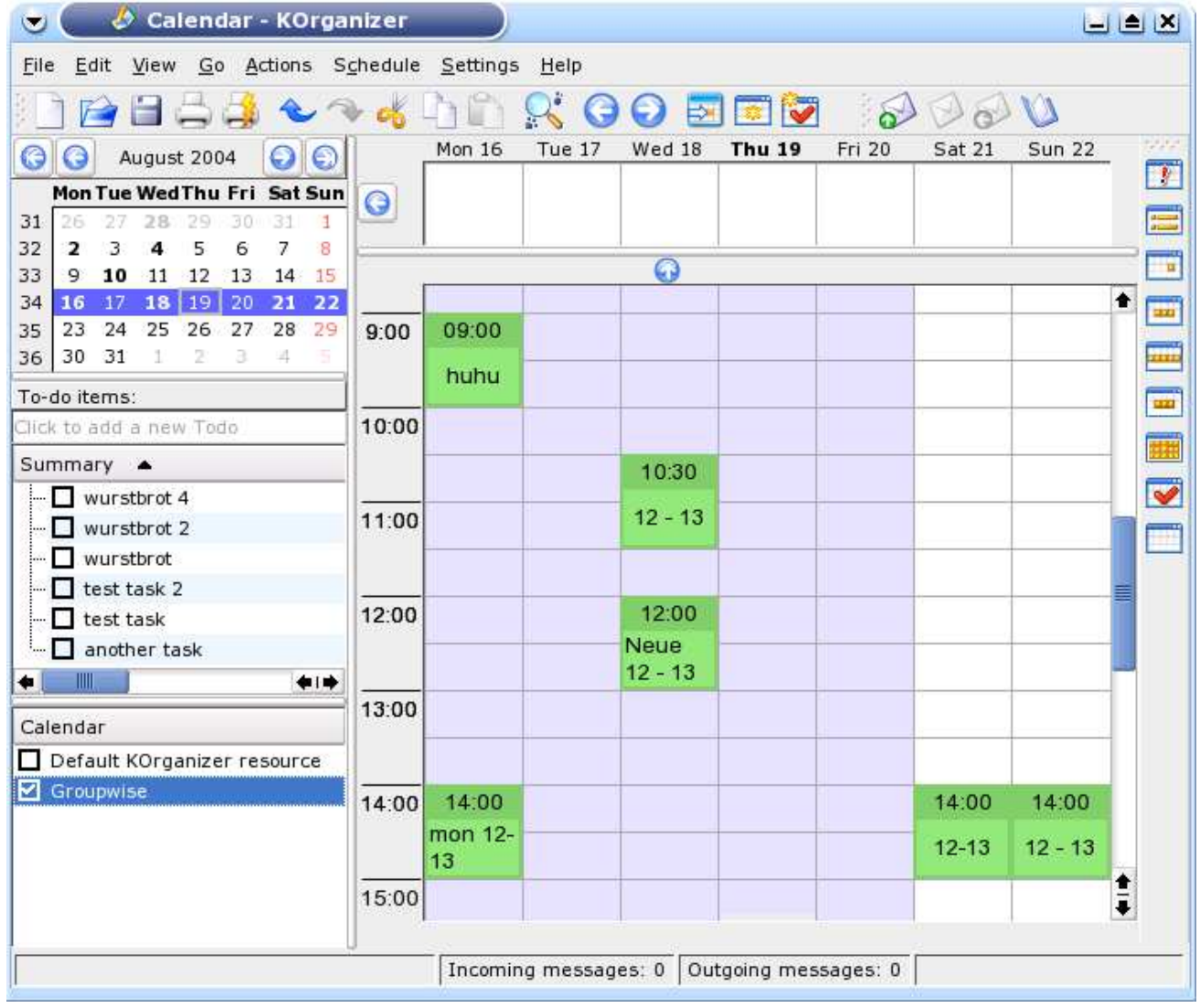
Example from another world

- Java library for generating object-relational mappings for database access
- Data-base scheme described in XML
- Generates classes representing data base elements of relational database
- Customizable by inheriting from generated base classes
- Automatic creation of data base tables

gSOAP

- Generator Tools for Coding SOAP/XML Web Services in C and C++
- Takes WSDL definitions and generates SOAP bindings from them
- Generates stubs and skeletons for convenient strong-typed client and server implementations
- Fast and efficient because gSOAP uses streaming XML parsing techniques
- Saves a lot of work when developing applications making use of SOAP
- Doesn’t seamlessly integrate in KDE code (strings and containers, event loop)

Novell Groupwise KResource



Conclusion

- Meta-Programming is a widely used technique.
- Code generation is a powerful tool.
- Central pieces of KDE like KConfig XT make heavy use of code generation
- New code generator ’kxml_compiler’ for generating C++ code from RelaxNG schemes representing XML data.
- Code generation helper library ’libkode’.
- Applications of meta-programming: KResources for XML feature plan and Novell Groupwise access.
- Think of meta-programming techniques like code-generation and use them where possible.