Cake: a tool for adaptation of object code

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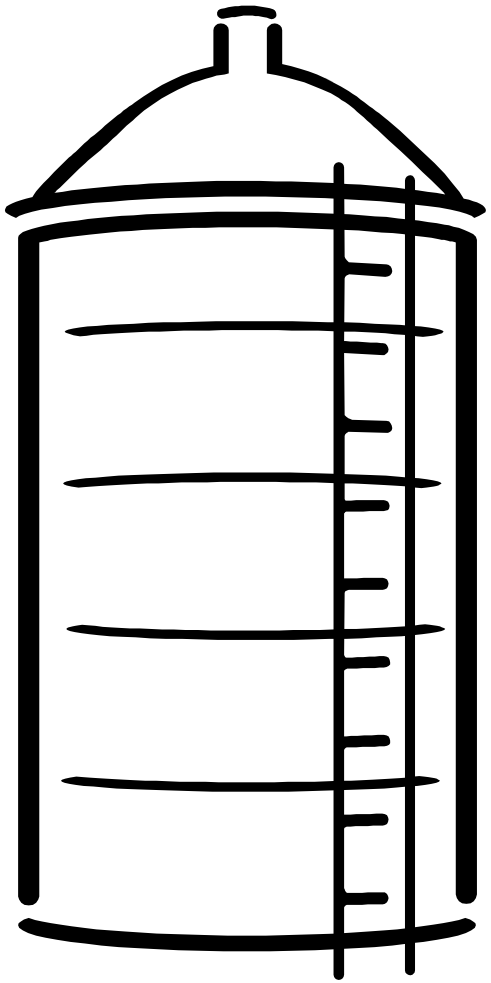
Some familiar problems



Software is

- expensive to develop
- expensive to maintain
- inflexible

Some common ideas, all entailing mismatch

Better programming languages

- great for new codebases
- mismatch: inevitably *many* languages

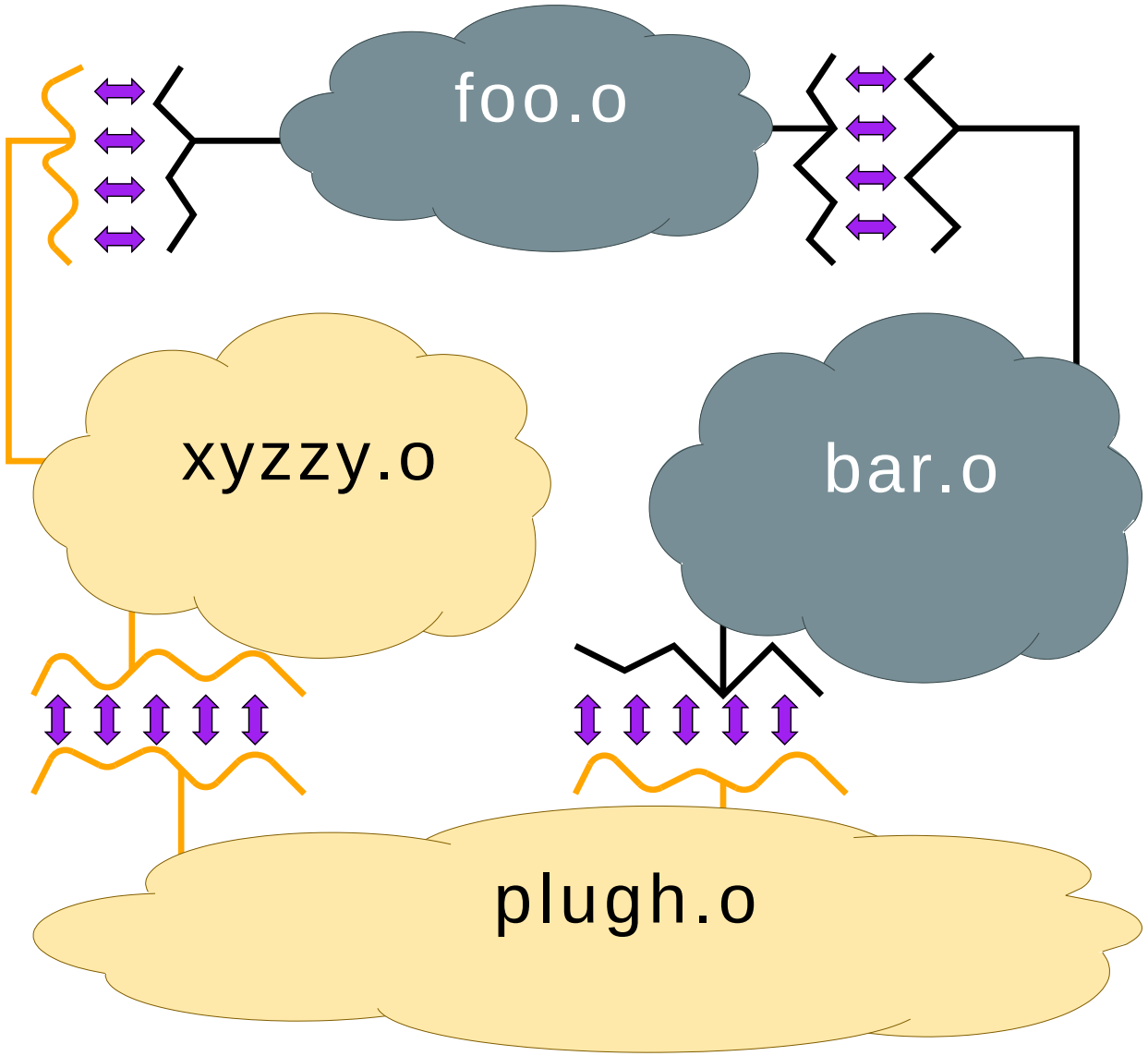
Decentralised development

- many variant codebases evolving in parallel
- mismatch: no more interface consensus

Unanticipated composition

- mismatch: no *a priori* agreement on interfaces

Starting point: Cake's big picture



Cake in one slide

Cake is

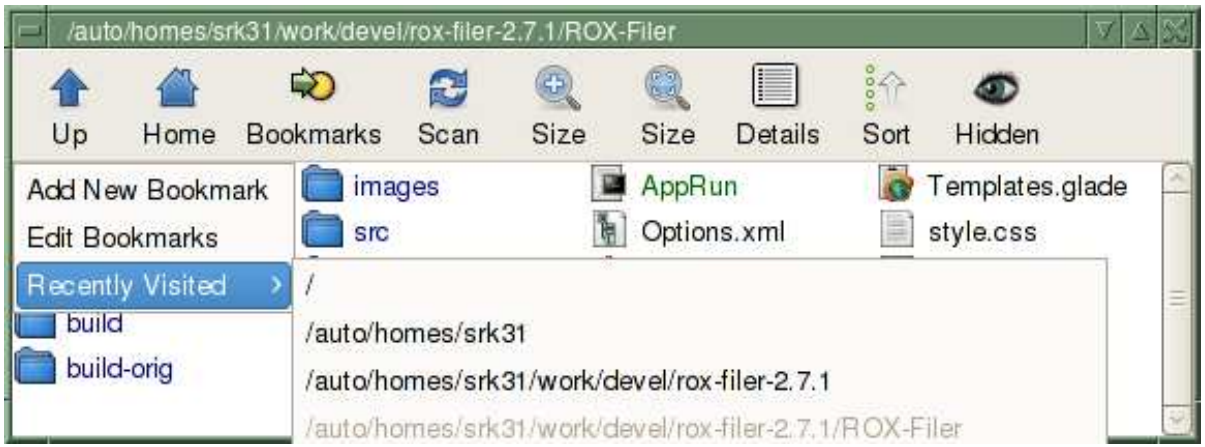
- a language expressing *compositions* of software
- a productive tool for overcoming *mismatch*
- operating on *binaries*
- designed around practical experience
- ongoing work

In this talk, I'll cover

- two motivational case-studies
- the Cake language design
- some implementation and status

Wanted: a tool for helping with tasks like...

Unanticipated composition: port feature P from app X to Y



Case study: Konqueror + ROX-Filer

Evolution: link client version 1 against library version 2

Case study: gtk-theme-switch

Outline of the rest of this talk

- **Design and first case study**
- Second case study: object exchange
- The Cake language: core
- The Cake language: practicalities
- Status and questions

Experiment 1: a simple exercise in glue

I like program X, but it lacks feature P found in program Y.

- let $X =$ ROX-Filer, $P =$ history and $Y =$ Konqueror

```
static GList *history = NULL;          /* Most recent first */
static GList * history_tail = NULL;    /* Oldest item */
void bookmarks_add_history(const gchar *path);
GtkWidget *build_history_menu(FilerWindow *filer_window);
```

```
class LIBKONQ_EXPORT KonqHistoryManager : public KParts::HistoryProvider,
        public KonqHistoryComm { // ...
        void addToHistory( bool pending, const KURL& url,
                const QString& typedURL = QString::null,
                const QString& title = QString :: null );
        virtual QStringList allURLs() const;
        /* ... */ };
```

Decision: black-box approach

Why not hack source?

- must understand source language
- must understand code internals
- poor compositionality
- poor maintainability
- time sink?

Instead choose *black-box* approach; but possibly

- less powerful?
- performance? …

Decision: work with *binaries*

Why binaries?

- unify many source languages
- convenience
- no source code?
- debugging analogue: use DWARF metadata

But oblivious to

- *cross-module* macro expansion
- *cross-module* inlining
- template metaprogramming, . . .

(. . . at compile time. First two are bad ideas anyway.)

Konqueror + ROX case-study: findings

Easy:

- converting and transferring data
- interposing on control flow

Hard:

- extricating the history feature from libkonq
- altering embedded policy
- bypassing language quirks (protected)
- manual set-up of infrastructure state
- understanding infrastructure (binding convention, . . .)

Interesting: difficulties were *infrastructure*, not *application*

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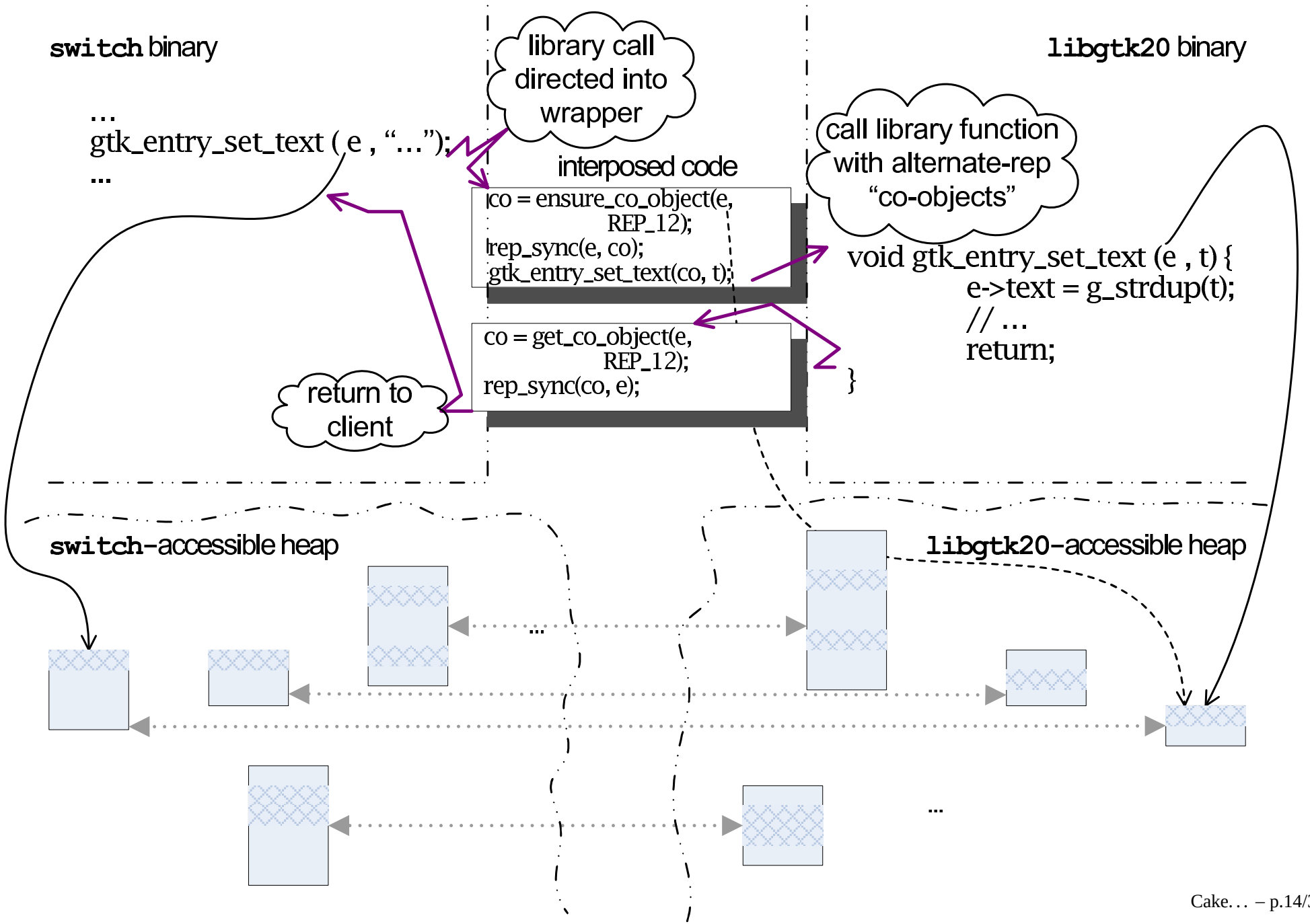
A second case study: evolution

gtk-theme-switch

- one version for Gtk+ 1.2, another for Gtk+ 2.0
- forked codebase (maintenance)
- . . . diff (`-U3`) is ∼500 lines
- can one *binary* work with both libraries?

Main challenge: exchange of mismatched objects.

Object exchange in action



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Introducing the Cake language

Cake is a *configuration language*

- i.e. expresses *inter-component relationships*
- specifically: mismatch resolutions

Cake complements existing languages:

- accommodates heterogeneity
- accommodates plug-incompatibility

Cake language: basics

Two main kinds of statement:

- exists—describes existing binaries
- derive—derives new ones

A simple Cake module:

```
exists   elf_reloc ("switch2.o") switch2;
exists    elf_external_sharedlib  ("gtk-x11-2.0") gtk-x11-2.0;
exists    elf_external_sharedlib  ("gdk-x11-2.0") gdk-x11-2.0;
//   ...   more follow
derive   elf_executable ("switch2") switch-exec = make_exec(
           link [switch2, gtk-x11-2.0, gdk-x11-2.0, /*  ...  */]
           );
```

A simple mismatch, using C++

```
struct foo {
        int a;
        float b;
};

int manipulate_foo(struct foo *f);
```

```
struct foo {
        float b;
        int a;
        char pad_ignored[42];
};
int manipulate_foo(struct foo *f);
```

In C++, you might write

```
int __wrap_manipulate_foo( first::foo *f) {
        second::foo obj;  obj.a = f->a; obj.b = f->b;
        int retval = second::manipulate_foo(&obj);
        f->a = obj.a; f->b = obj.b;
        return retval ;
}
```

A simple mismatch, in Cake

In Cake, you'd write…

…nothing! (Assuming sufficient debug information…)

Function correspondences (1)

Consider these two mismatched functions.

```
guint     gtk_signal_connect   (GtkObject          *o,
                                const gchar        *name,
                                GtkSignalFunc       f,
                                gpointer            f_data );
```

```
gulong      g_signal_connect_data    ( gpointer             inst ,
                                       const gchar         * detail ,
                                       GCallback             c_h ,
                                       gpointer              data ,
                                       GClosureNotify        destroy_data ,
                                       GConnectFlags         flags );
```

How would you manually code around this mismatch?

Function correspondences (2)

In Cake:

```
derive /* ... */ switch_exec = link[switch12, libgtk20]
{
  // ...
  switch12 ↔ libgtk20 {
    gtk_signal_connect (i, d, c_h, data)
      → g_signal_connect_data (i, d, c_h, data, null, {});
    // more correspondences ...
  }
  // more pairwise blocks...
};
```

- pattern-matching + “dual scoping”
- primitive values (e.g. guint ↔ guint) for free

Value correspondences

Name-matching gets so far. Further: *value correspondences*.

```
struct _GtkWindow {
  GtkBin bin; gchar * title ; //  ...
  GtkWindowType type;
  guint window_has_focus:1;
};
```

```
struct _GtkWindow {
  GtkBin bin; gchar * title ; //  ...
  gchar *wm_role;
  guint type :4; /* GtkWindowType */
  guint has_focus :1;
};
```

Value correspondences

Name-matching gets so far. Further: *value correspondences*.

```
struct _GtkWindow {
  GtkBin bin; gchar * title ; // ...
  GtkWindowType type;
  guint window_has_focus:1;
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```
struct _GtkWindow {
  GtkBin bin; gchar * title ; // ...
  gchar *wm_role;
  guint type :4; /* GtkWindowType */
  guint has_focus :1;
};
```

```
switch12 ↔ libgtk20 {
  values GtkWindow ↔ GtkWindow {
```

Value correspondences

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  guint has_focus:1;
};
```

```
switch12 ↔ libgtk20 {
  values GtkWindow ↔ GtkWindow {
    void → wm_role;
```

Value correspondences

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  guint has_focus :1;
};
```

```
switch12 ↔ libgtk20 {
  values GtkWindow ↔ GtkWindow {
    void → wm_role;
    type as .GtkWindowType <--> type as .GtkWindowType;
```

Value correspondences

Name-matching gets so far. Further: *value correspondences*.

```
struct _GtkWindow {
  GtkBin bin; gchar * title ; // ...
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};
```

```
struct _GtkWindow {
  GtkBin bin; gchar * title ; // ...
  gchar *wm_role;
  guint type:4; /* GtkWindowType */
  guint has_focus:1;
};
```

```
switch12 ↔ libgtk20 {
  values GtkWindow ↔ GtkWindow {
    void → wm_role;
    type as .GtkWindowType <--> type as .GtkWindowType;
    window_has_focus ↔ has_focus;
  }
}
```

More complex correspondence patterns

Function patterns may be predicated on call content:

```
// rule matched when using a particular argument value
gtk_type_check_object_cast (0, _) → ( true );
```

Simple stub language for defining sequences (on RHS):

```
gtk_window_set_policy (win, shrink , grow, _) →
  ( if shrink then gtk_window_set_size_request (win, 0, 0) else void;
    if grow then gtk_window_set_resizable (win, TRUE) else void );
```

- future: *context*-predicated patterns (stack; sequence. . .)

Future: interpretations of object files

In the first case study was a notion of component *style*.

```
dcop( // hide DCOP internals and enable introspection
    kde-3.x(”konqueror”, // KDE initialisation and self-binding
        qt-4.x( // import Qt initialisation constraints
            gcc-c++-4.x( // apply name-mangling rules etc.
                elf_reloc( // basic interpretation
                    ”konq_historymgr.o”
) // ...
```

Future work needed to work all this out:

- *define* these stackable interpretations
- code generation

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How Cake understands object files

Cake gets quite far using debugging info. But can also use:

- annotations in `exists` blocks
  - to supplement debugging info
  - to enable optimisations
- static analysis (none yet. . .)

Annotations enabling optimisations

```
exists elf_reloc ("switch.o") switch12 {
  declare { gtk_dialog_new : _ ⇒ object { // function returning a
                vbox: opaque ptr;       // pointer to an object, where
                _ : ignored;            // vbox is opaque to switch12,
              } ptr                     // and other fields are ignored
  } /* more annotations ... */ }
```

- opaque and ignored used during object exchange...
- ... to limit depth of deep copy

Choose your own adventurousness

Annotations can be made with varying strength.

- if check, annotation must be verifiable
  - from metadata or static analysis
- if declare, annotations must not contradict metadata
- if override, contradiction is allowed

Composition tasks naturally cover the spectrum...

```
exists elf_reloc ("switch.o") switch12 {
  override { gtk_dialog_new : _ ⇒ GtkDialog ptr; }
  /* static type in source code is imprecise (GtkWidget) */
}
```

Treatment of values

Cake describes treatment of *values*, not types

- there is no type system in Cake (but could be added)

But the Cake compiler consumes static metadata!

- necessary: can't assume RTTI, e.g. in C
- need stronger assumptions e.g. than C
- imprecise static types cause problems

Primitive "data types" (i.e. value forms) are defined by a pair

- DWARF *encoding* (e.g. unsigned, float, fixed, . . .)
- length in bytes

From these, get pointers, enums, structures, . . .

Summary: what Cake gives the programmer

Cake *relates* heterogeneous, mismatched components.

- zero-effort handling of simple binary incompatibilities
- expressive pattern-matching
- allow conservative or relaxed coding
- convenient pairwise correspondences (“dual scope”)
- flexible treatment of data encoding and identifiers
- (in future) abstraction over component styles

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Status

Case-studies implemented as hand-written glue code…

- *but* Gtk case study is partially automated
- stubs and conversion functions are generated by scripts

Cake compiler is ongoing right now

- parses, reads DWARF, merges annotations, complains
- more soon

Runtime library rep_man is most developed piece

- used in the Gtk case study
- completely generic

Thanks for your attention. Any questions?