Coccinelle for Rust
https://gitlab.inria.fr/coccinelle/coccinelleforrust.git

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- Perform repetitive transformations at a large scale.
  - Rust is 1.6 MLOC.
  - The Linux kernel is 23 MLOC.
  - Collateral evolutions: a change in an API requires changes in all clients.
- Provide a transformation language that builds on developer expertise.
- Changes + developer familiarity = (semantic) patches

An example change (Rust repository)

```
commit d822b97a27e50f5a091d2918f6ff0ffd2d2827f5
Author: Kyle Matsuda <kyle.yoshio.matsuda@gmail.com>
Date:   Mon Feb 6 17:48:12 2023 -0700

    change usages of type_of to bound_type_of

diff --git a/compiler/rustc_borrowck/src/diagnostics/conflict_errors.rs b/compiler/.../conflict_errors.rs
@@ -2592,4 +2592,4 @@ fn annotate_argument_and_return_for_borrow(
             } else {
-                let ty = self.infcx.tcx.type_of(self.mir_def_id());
+                let ty = self.infcx.tcx.bound_type_of(self.mir_def_id()).subst_identity();
                 match ty.kind() {
                     ty::FnDef(_, _) | ty::FnPtr(_) => self.annotate_fn_sig(
diff --git a/compiler/rustc_borrowck/src/diagnostics/mod.rs b/compiler/.../mod.rs
@@ -1185,4 +1185,4 @@ fn explain_captures(
                         matches!(tcx.def_kind(parent_did), rustc_hir::def::DefKind::Impl { .. })
                             .then_some(parent_did)
-                            .and_then(|did| match tcx.type_of(did).kind() {
+                            .and_then(|did| match tcx.bound_type_of(did).subst_identity().kind() {
                                 ty::Adt(def, ..) => Some(def.did()),
...
```

136 files changed, 385 insertions(+), 262 deletions(-)

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Creating a semantic patch: Step 1: remove irrelevant code

```
-                 let ty = self.infcx.tcx.type_of(self.mir_def_id())
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```

```
-                     .and_then(|did| match tcx.type_of(did).kind() {
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```

Creating a semantic patch: Step 2: pick a typical example

```
@@

@@

- self.infcx.tcx.type_of(self.mir_def_id())
+ self.infcx.tcx.bound_type_of(self.mir_def_id()).subst_identity()
```

Creating a semantic patch: Step 3: abstract over subterms using metavariables

```
@@
expression tcx, arg;
@@

- tcx.type_of(arg)
+ tcx.bound_type_of(arg).subst_identity()
```

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```

Updates over 200 call sites.

An outlier

```
            let (shim_size, shim_align, _kind) = ecx.get_alloc_info(alloc_id);
+           let def_ty = ecx.tcx.bound_type_of(def_id).subst_identity();
            let extern_decl_layout =
-               ecx.tcx.layout_of(ty::ParamEnv::empty().and(ecx.tcx.type_of(def_id))).unwrap();
+               ecx.tcx.layout_of(ty::ParamEnv::empty().and(def_ty)).unwrap();
            if extern_decl_layout.size != shim_size || extern_decl_layout.align.abi != shim_align {
                throw_unsup_format!(
                    "`extern` static `{name}` from crate `{krate}` has been declared \
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```

The developer has created a new name to avoid a long line.

- Could address it manually.
- Could create a rule for the special case of nested function call contexts (probably not worth it for one case).

An alternate semantic patch

```
@@
expression tcx, arg;
@@


  tcx.
-     type_of(arg)
+     bound_type_of(arg).subst_identity()
```

Putting tcx in the context ensures any comments will be preserved.

A refinement

```
@@
TyCtxt tcx;
expression arg;
@@

  tcx.
-     type_of(arg)
+     bound_type_of(arg).subst_identity()
```

Specifying the type of `tcx` protects against changing other uses of `type_of`.

Some Coccinelle internals

Input: Parsing provided by Rust Analyzer.

- Used both for Rust code and for semantic patch code.
- Will provide type inference, when needed (currently, loses concurrency).

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Output: Pretty printing provided by `rustfmt`.

- To avoid problems with code not originally formatted with `rustfmt` (or formatted with a different version), the `rustfmt`ed changes are dropped back into the original code.
- Preserves comments and whitespace in the unchanged part of the code.

Some Coccinelle internals

In the middle:

- Wrap Rust code and semantic patch code, eg to indicate metavariables.
- Match semantic patch code against Rust code, to collect change sites and metavariable bindings.
- On a successful match, apply the changes, instantiated according to the metavariable bindings, reparse, and repeat with the next rule.

A case study

Software: stratisd

- https://github.com/stratis-storage/stratisd
- Easy to use local storage management for Linux.
- Over 2000 commits, and over 10K lines of Rust code.

Commit selection:

- Patchparse: https://gitlab.inria.fr/lawall/patchparse4
- Collect change patterns that occur at least 40 times.
- 13 commits selected, affecting 10-94 files, and up to 3000 $+/-$ lines.

Some successes

Commits:

- 39b925b0: Remove EngineError alias
- c3918972: Replace EngineResult usage with StratisResult

Semantic patch:

```
@type@
@@
- EngineError
+ StratisError
```

```
@type@
@@
- EngineResult
+ StratisResult
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Some successes

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- 39b925b0: Remove EngineError alias
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Semantic patch:

```
@type@
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- EngineError
+ StratisError
```

```
@type@
@@
- EngineResult
+ StratisResult
```

Results:

- Typical changes: `use`, method signatures, method calls.
- Benefits from recent improvements in pretty printing.

Some successes

fe7df6a9: Remove unnecessary pub modifier on stratisd tests

Semantic patch:

```
@@
identifier f;
expression e;
@@
#[test]
- pub
  fn f() { e; }
```

Results:

- 69 changes across 9 files.
- 1 case has an additional attribute and thus is omitted.

Some successes

9c60ad44: Remove ErrorEnum and add error chaining

```
@@
expression return_message, e1;
@@
  return_message.append3(e1,
-   msg_code_ok(), msg_string_ok(),
+   DbusErrorEnum::OK as u16, OK_STRING.to_string(),
  )

@@
@@
- DbusErrorEnum::INTERNAL_ERROR
+ DbusErrorEnum::ERROR
```

```
@@
expression e;
@@
- StratisError::Error
+ StratisError::Msg
    (e,)

@@
expression e1, e2;
@@
- StratisError::Engine(e1,
+ StratisError::Msg(
    e2,)
```

Results:

- Covers 290/417 changes. Omits uses and some less common patterns.
- Trailing commas lead to a lot of rule duplication.

Some successes

d4ac5d89: Switch from trait objects to type parameters and associated types

```
@r1@
identifier mthd, f;
identifier t;
@@
pub fn
- mthd(f: &Factory<MTSync<TData>, TData>,) -> t<MTSync<TData>, TData>
+ mthd<E>(f: &Factory<MTSync<TData<E>>, TData<E>>,) -> t<MTSync<TData<E>>, TData
<E>>
+where E: 'static + Engine,
  {
  ...
  }
```

Results:

- Covers ??? changes.
- Trailing commas issues.
- New feature: ... for method bodies.
  - Matches both simple expressions and block expressions.

Some failures

Commits:

- aeed4b7c: Use inline format arguments
- ea33caf4: Conform to snake_case naming style

Some failures

Commits:

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Issues:

- Require changes inside identifier names and strings.
- Such changes require scripting, as found in Coccinelle for C.

Some failures

2569545c: Add anonymous lifetime parameters.

Semantic patch extract:

```
@type@
lifetime l1,l2;
@@
(
App <l1,l2>
|
App
+ <'_,'_>
)
```

Disjunctions on types not currently supported.

Some failures

f00fb860: Allow disabling actions when stratisd detects unresolvable failures

Semantic patch extract:

```
@@
identifier mthd;
@@
- log_action!(
+ handle_action!(
    pool.mthd(
              ...
              )
+   ,dbus_context, pool_path.get_name()
    )
```

Issues:

- This covers a few changes, but the commit has more variety.
- New feature: ... for argument lists and parameter lists.
- Future feature: ... to connect the definitions of pool_path to the call site.

Conclusion

- Pattern-based transformation language.
  - Changes can be expressed in all parts of the code: expressions, signatures, lifetimes, etc.
  - Changes can be sensitive to expression types.
- Works well for frequent atomic changes.
  - Recent updates to improve pretty printing, handling of macros, genericity (…), etc.
- Future work: … for control-flow paths, nesting.
  - Connect variable definitions to uses.
  - Connect method definitions to the containing type implementation.

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