Runtime Polymorphic Generic Programming—Mixing Objects and Concepts in ConceptC++

Mat Marcus[1] Jaakko Järvi[2] Sean Parent[1]

[1]Adobe Systems Inc. ({*mmarcus*|*sparent*}*@adobe.com*)

[2]Texas A&M University (*jarvi@cs.tamu.edu*)

2007-07-31

Setting

- Generic programming (in the style of STL) is a proven paradigm for developing reusable libraries
  - Non-intrusive
  - Static polymorphism (only)
- Object-oriented programming
  - Intrusive
  - Runtime polymorphism (only)
- This work: combination of both leads to non-intrusive runtime polymorphism (good thing)
  - Presented techniques achieve modularity of components in Adobe source libraries: succesfully integrated into several Adobe applications
- Novel idioms for library design and implementation in ConceptC++

Outline

- Static polymorphism in generic programming
- Dynamic polymorphism in object-oriented programming
- Basics of ConceptC++
- Approach to combine best of both worlds by instantiating generic components with non-intrusive run-time polymorphic types
- Implementation details of the approach (very little)
- Conclusions

Static polymorphism of generic programming

```
template <typename P>
struct layout_engine {
  void append(P placeable);
  void solve() {

    ... measure(placeables_m[i], extents_m[i]);

    // solve layout constraints and update place_data_m

    ... place(placeables_m[i], place_data_m[i]); ...
  }

  vector<extents_t> extents_m;
  vector<P> placeables_m;
  vector<place_data_t> place_data_m;
}
```

- `measure` and `place` must be overloaded for `P` (with the right signature and semantics)

Using the layout engine with a specific widget type

```
template <typename P> struct layout_engine { ... };

void measure(HIViewRef& t, extents_t& result) { ... };
void place(HIViewRef& t,
           const place_data_t& place_data) { ... };

layout_engine<HIViewRef> le;
HIViewRef w;
...
le.append(w);
...
le.solve();
```

Polymorphism via indirection

```
struct layout_engine {
  void append(PlaceableBase* placeable);
  void solve() {

    ... placeables_m[i]->measure(extents_m[i]);

    // solve layout constraints and update place_data_m

    ... placeables_m[i]->place(place_data_m[i]); ...
  }

  vector<extents_t> extents_m;
  vector<PlaceableBase*> placeables_m;
  vector<place_data_t> place_data_m;
}
```

Using the layout engine with many widget types — Reference semantics

```
struct MyWidget : PlaceableBase {
  virtual void measure(extents_t&) { ... };
  virtual void place(const place_data_t&) { ... };
};

struct YourWidget : PlaceableBase {
  virtual void measure(extents_t&) { ... };
  virtual void place(const place_data_t&) { ... };
  ...
};

layout_engine le;
MyWidget* m = new MyWidget();
YourWidget* y = new YourWidget();
...
le.append(m); le.append(y);
...
le.solve();
```

OO reference semantics

- Intrusive, widget types must inherit from common base
- Ownership unclear

Our approach

- Idioms in ConceptC++ to realize run-time polymorphism in a transparent way
  - We also provide emulations in C++ 2003
- Generic components instantiated with wrappers that provide run-time polymorphism
- Non-intrusive, no changes needed to wrapped types
- ConceptC++'s adaptation mechanism (concept maps) hide wrapping from clients
- Retain "value semantics"
- Minimize overhead (small object optimization, move semantics)

Our approach: example use

- A generic layout engine, oblivious of whether it is used polymorphically or not

```
template <Placeable P> struct layout_engine { ... }
```

- Static use

```
layout_engine<HIViewRef> le;
HIViewRef w;
le.append(w); ...; le.solve();
```

- Transparent non-intrusive polymorphic use

```
layout_engine<poly<placeable>> le2;
HIViewRef w; MyWidget x; YourWidget y;
le2.append(w); le2.append(x); le2.append(y)
```

- `HIViewRef`, `MyWidget`, `YourWidget` can come from arbitrary libraries, no need for a common base class or conformance to certain function signatures

Non-intrusive adaptation with concept maps in ConceptC++

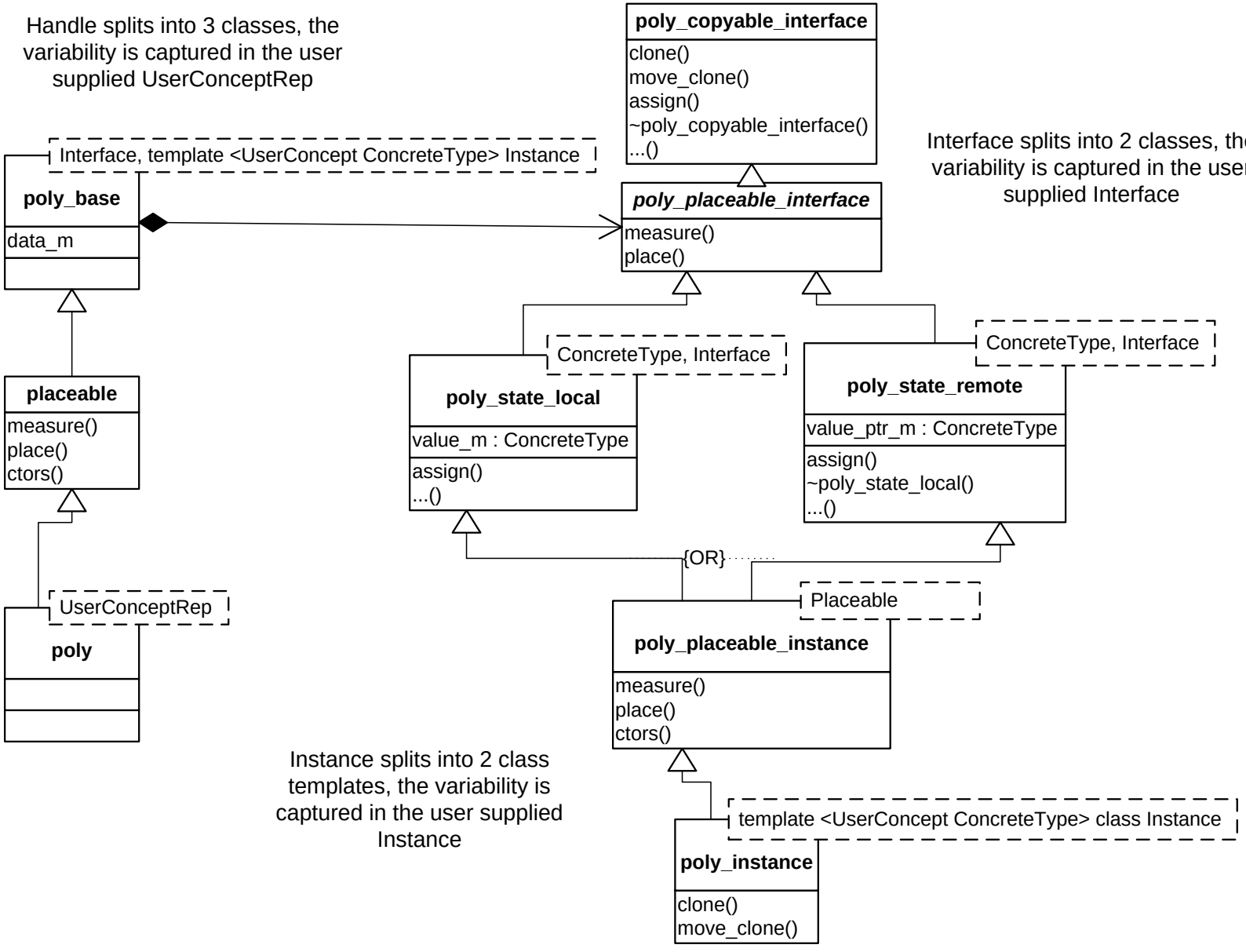
- The language we use is C++ extended with "concepts"
- Concepts are on their way to the next revision of standard C++
- Key features:
  - **`requires`** clause — specify constraints on type parameters
  - **`concept`** — a collection of requirements on a type or types
  - **`concept_map`** — a non-intrusive adaptation mechanism that establishes "type models a concept"
- Provides constrained templates for C++ — concept maps and overloading on constraints $\Rightarrow$ expressive adaptation mechanism

Concepts and concept maps

```
concept Placeable <typename T> : Copyable<T> {
  void measure(T& t, extents_t& result);
  void place(T& t, const place_data_t& place_data);
}

template <Placeable P> struct layout_engine { ... }

concept_map Placeable<MyWidget> {
  void measure(MyWidget& t, extents_t& result) { ... };
  void place(MyWidget& t, const place_data_t& place_data) { ... };
}

concept_map Placeable<poly<placeable>> {
  void measure(poly<placeable>& t, extents_t& result) {
    t.measure(result);
  }
  void place(poly<placeable>& t, const place_data_t& place_data) {
    t.place(place_data);
  }
}

layout_engine<MyWidget>;
layout_engine<poly<placeable>>;
```

Detailed contents of the paper

- How to define wrapper types to provide non-intrusive run-time polymorphic value types in ConceptC++
  1. Implement the concept (`Placeable`) as an abstract base class
  2. Derive a generic implementation class (`PlaceableImpl<P>`) where each member function delegates to `P`, which models `Placeable`.
  3. Define a concept map `Placeable<MyWidget>` for a particular concrete type `MyWidget`
  4. Implement a handle over over the abstract base class. Make it constructible from any `Placeable` type, to be wrapped to `PlaceableImpl`
- A commonality/variability analysis that captures reusable parts to framework/library "poly." In `poly<placeable>`
  - `poly` template provides regularity, small object optimization, move semantics
  - `placeable` provides the interface specific to the `Placeable` concept
- Concept refinement dynamically


Handle splits into 3 classes, the variability is captured in the user supplied UserConceptRep
poly_copyable_interface
clone()
move_clone()
assign()
~poly_copyable_interface()
...()
Interface splits into 2 classes, the variability is captured in the user supplied Interface
Interface, template <UserConcept ConcreteType> Instance
poly_base
data_m
poly_placeable_interface
measure()
place()
placeable
measure()
place()
ctors()
ConcreteType, Interface
poly_state_local
value_m : ConcreteType
assign()
...()
ConcreteType, Interface
poly_state_remote
value_ptr_m : ConcreteType
assign()
~poly_state_local()
...()
{OR}
UserConceptRep
poly
Placeable
poly_placeable_instance
measure()
place()
ctors()
Instance splits into 2 class templates, the variability is captured in the user supplied Instance
template <UserConcept ConcreteType> class Instance
poly_instance
clone()
move_clone()

Related work

- Boost.Any (Henney)
- Dynamic any (Nasonov)
- Polymorphic wrappers share similarities with existential types

Conclusions

- Mixed paradigm for genuinely composable components
  - Non-intrusive
  - run-time polymorphic if so wanted: the kind of polymorphism (static, dynamic) becomes property of client of a library, not hard-coded to the interface
- Foundation of APIs of many components in Adobe Source libraries that have proven to be highly composable
  - Layout library, layout parser, property model library, property model parser
- Future directions: parameterization over concepts would be useful