

Some tidbits about functional interfaces

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The key example is `Iterator::map`.

`Iterator::map`

```
1 fn map<B, F>(self, f: F) -> Map<Self, F>
2 where
3     Self: Sized,
4     F: FnMut(Self::Item) -> B,
5 { //... }
```

1. Prototypical implementation
2. Specializations
3. Ownership and borrowing
4. Object safety and type erasure

Toy example: Curves

Let's use something simpler than Iterator for the sake of illustration.
Here is a trait that describes one-parameter families of values of type T:

```
1 pub trait Curve<S> {  
2     fn sample(&self, t: f64) -> S;  
3 }
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The only required method is `sample`, but we might also expose something that transforms `Curve<S>` into `Curve<T>` given a function `S -> T`:

Curve::map

```
1 fn map<T>(self, f: impl Fn(S) -> T) -> impl Curve<T> {  
2     //...  
3 }
```


Concrete implementation

```
1 struct MapCurve<S, T, C, F>
2 where
3     C: Curve<S>,
4     F: Fn(S) -> T,
5 {
6     inner: C,
7     function: F,
8     _phantom: PhantomData<(S, T)>,
9 }
10
11 impl<S, T, C, F> Curve<T> for MapCurve<S, T, C, F>
12 where //... same as above
13 {
14     fn sample(&self, t: f64) -> T {
15         (self.function)(self.inner.sample(t))
16     }
17 }
```

Curve::map

MapCurve provides a basis for our functional interface method:

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```
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2 where Self: Sized {
3     MapCurve {
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- It's lazy — i.e. `f` is never invoked until `sample` is called on its output.
- It moves `self` into its output.
- It requires `Self: Sized`.

Some problems with laziness:

Loss of concreteness

It might be hard, for example, to serialize/deserialize a `MapCurve` even if the input curve can easily be serialized/deserialized, since it holds an arbitrary `Fn` closure (and we only have an `impl Curve<T>` too).

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Struct nesting

Since we're embedding the entire input into the `MapCurve` output, repeated calls will continue to increase the depth of struct nesting.

Some specialized implementations

Example: SampleCurve

Underlying data implementation of map need not actually be lazy:

```
1 struct SampleCurve<S> {
2     samples: Vec<S>,
3 }
4
5 impl<S> Curve<S> for SampleCurve<S> {
6     fn sample(&self, t: f64) -> S {
7         //... interpolated from self.samples
8     }
9
10    fn map<T>(self, f: impl Fn(S) -> T) -> impl Curve<T> {
11        let mapped_samples: Vec<T> = self.samples.into_iter()
12            .map(f)
13            .collect();
14        SampleCurve { samples: mapped_samples }
15    }
16 }
```

Some specialized implementations

One can imagine making a subtrait for types where some functional operations preserve the relevant form of concreteness, as in the preceding example; e.g.:

```
1 pub trait ConcreteCurve<S>: Curve<S> + Serialize + //...
2 {
3     fn map_concrete<T>(self, f: Fn(S) -> T)
4         -> impl ConcreteCurve<T>;
5 }
```

Some specialized implementations

Example: MapCurve itself

Repeated calls to `Curve::map` can reuse the same inner data:

```
1  impl<S, T, C, F> Curve<T> for MapCurve<S, T, C, F> {  
2      //... sample implementation...  
3      fn map<U>(self, f: Fn(T) -> U) -> impl Curve<U> {  
4          let new_func = move |x| f((self.function)(x));  
5          MapCurve {  
6              inner: self.inner,  
7              function: new_func,  
8              _phantom: PhantomData,  
9          }  
10     }  
11 }
```

Another idea: GATs

Another approach is to specify the output type in the trait:

Example: concrete map output type

```
1 pub trait Curve<S> {  
2     //... sample method etc.  
3     type MapOutput<T, F: Fn(S) -> T>: Curve<T>;  
4  
5     fn map<T, F: impl Fn(S) -> T>(self, f: F)  
6         -> Self::MapOutput<T, F>  
7     where Self: Sized;  
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Caveats:

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```

Caveats:

- `Curve<S>` is no longer object-safe.
- Associated type defaults are unstable.
- Implementation of `map` cannot be defaulted.

Ownership and borrowing

Onto the next problem: `Curve::map` takes ownership of `self`. This can be bad for ergonomics; for example, we might imagine that there is some other `Curve<S>` method which only needs to immutably borrow `self`:

```
1 fn extract_data(&self, impl IntoIterator<Item = f64>)  
2     -> impl Iterator<Item = S> { //... }
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```
1 fn extract_data(&self, impl IntoIterator<Item = f64>)  
2     -> impl Iterator<Item = S> { //... }
```

Then we run into issues with patterns like this:

```
1 // my_curve is something which implements Curve<f64>  
2 let my_curve = function_curve(|t| t * t + 2.0);  
3 let some_data = my_curve  
4     .map(|x| x * x)  
5     .extract_data(some_iterator);  
6 // Here, we can no longer use my_curve, even though  
7 // we did no mutation
```

Ownership and borrowing

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```
1 impl<S, C> Curve<S> for &C
2 where C: Curve<S> {
3     fn sample(&self, t: f64) -> S {
4         <C as Curve<S>>::sample(self, t)
5     }
6 }
```

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3     fn sample(&self, t: f64) -> S {
4         <C as Curve<S>>::sample(self, t)
5     }
6 }
```

With this in hand, the problem is easily avoided:

```
1 let my_curve = function_curve(|t| t * t + 2.0);
2 let some_data = (&my_curve)
3     .map(|x| x * x)
4     .extract_data(some_iterator);
5 // Now we can still use my_curve after the borrow
```

Ownership and borrowing

In fact, Iterator does something exactly like this:

Example: Iterator

```
1 impl<I: Iterator + ?Sized> Iterator for &mut I {  
2     type Item = I::Item;  
3     //... other methods  
4 }
```

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1 impl<I: Iterator + ?Sized> Iterator for &mut I {  
2     type Item = I::Item;  
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4 }
```

It also provides the convenience method `by_ref`, which makes syntax for this situation more convenient:

Example: Iterator::by_ref

```
1 fn by_ref(&mut self) -> &mut Self  
2 where Self: Sized {  
3     self  
4 }
```

This lets you write things like `iter.by_ref()` instead of `(&mut iter)`.

Object safety and type erasure

Finally, `Curve::map` requires a `Sized` bound on `Self` since it must generally embed the `Curve` implementor into a field of `MapCurve`.

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The primary consequence is:

Exclusion from vtables

A trait method requiring `Self` to be `Sized` is considered *explicitly non-dispatchable*, so it is excluded from the trait object completely.

Unavailability of method on unsized types

(Obviously.) This most prominently applies to `dyn Curve<S>` (see above). Note that this means that code like the following simply doesn't work, since the `Box` gets dereferenced:

```
1 let boxed_curve: Box<dyn Curve<f64>> = Box::new(my_curve);
2 // The following will fail to compile:
3 let mapped_curve = boxed_curve.map(|x| x * 2.0);
```


Object safety and type erasure

Solutions for this kind of situation give implementations of `Curve<S>` for things like `Box<dyn Curve<S>>` explicitly:

```
1 impl<S, C, D> Curve<S> for D
2 where
3     C: Curve<S> + ?Sized,
4     D: Deref<Target = C>,
5 {
6     fn sample(&self, t: f64) -> S {
7         <C as Curve<S>>::sample(self, t)
8     }
9 }
```

The practical implication is that calling `Curve::map` on a `Box<dyn Curve<S>>` uses the generic implementation of `map` based on the implementation of `sample` which is dispatched dynamically.

&T

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Caveat emptor

There is something sneakily problematic here: a specialized implementation of `map` can be passed through to a `&T`, but in the `Deref` version that is impossible because of the required `?Sized` bound which must therefore exclude `map`.

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(Always be suspicious of trait-based blanket implementations.)

That's all!

Thanks for listening! This talk should be available on my GitHub profile if you want to see any of the slides again:

<https://github.com/mweatherley/talks>