CMPT 373
Software Development Methods

Design Patterns

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Recall: Managing Complexity

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is *managing complexity*

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Strive for components that:
- interact minimally
- know minimal information

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Your problems will usually be slightly different

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- Design patterns…
  - have clear formulations of the problems they attack
  - enable efficient communication
  - have well understood strengths & weaknesses
  - provide *anchor points* in the design space that you can *explore*

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Start simple and adopt or move toward design patterns as their utility becomes clear.

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  - Using a common interface for many types
- 4(ish) common types of polymorphism:

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- Design patterns are largely built around exploiting
  - composition
  - polymorphism
- ***Polymorphism***
  - Using a common interface for many types
- 4 common types of polymorphism:
  - Inheritance / Subtyping (at runtime)
  - Parametric polymorphism (at compile time)
  - Overloading / type classes
  - Coercion / casting

Choosing one form of polymorphism over another yields trade-offs

3 classical categories

- ***Creational***
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Other categories exist for specific domains.
These are general.

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- We will derive a handful of patterns in these categories
- I want us to try to construct them from first principles
  - Identify goals
  - Understand the constraints of a scenario
  - Derive a design that does what you want
- I expect the patterns to be obvious in retrospect….

Problem: Flexibly creating objects

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Note, there are also temporal constraints!
When are the arguments & types known?

Problem: Flexibly creating objects

- How would you normally create an instance of an object?
- What are the coupled constraints in this approach?
- What if you want to allow the user to define their own kinds of objects to create? (custom paintbrush for objects)

```
Animal animal{"Zebra", RunPolicy, WinnyPolicy};
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Animal animal = maker.makeOne();
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```
class ThingMaker{
  //info about
  //thing to make
  Animal makeOne();
} maker;
```

```
Animal animal = maker.makeOne();
```

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How would you attack this?

```
class ThingMaker{
   Animal toCopy;
public:
   Animal makeOne();
} maker;
```

```
Animal animal = maker.makeOne();
```

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- Register an instance as a template & make clones

e.g. Creational Pattern: Prototype

- Goal: Create new objects based on a configuration.

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An inheritance version:

interface

```
class Clonable
   std::unique_ptr<Clonable>
   clone() = 0;
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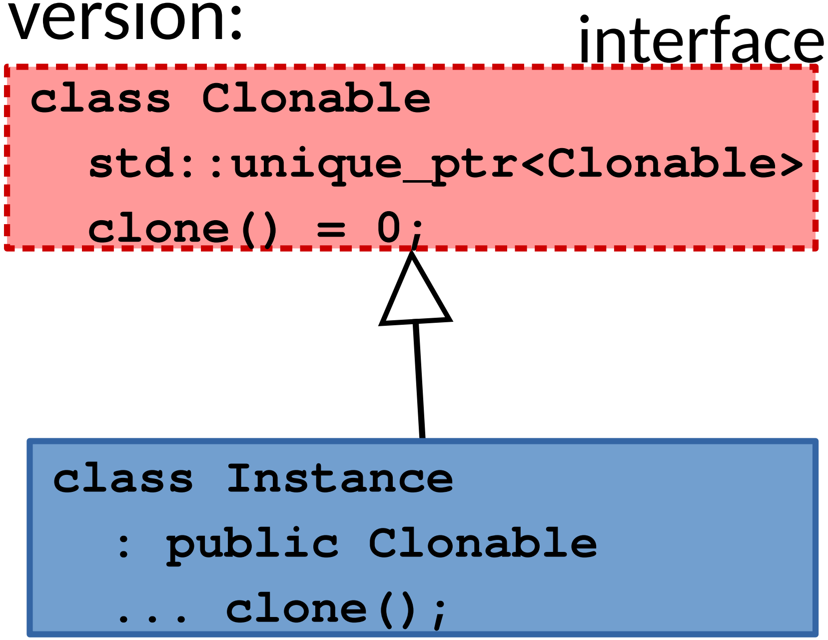

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class Instance
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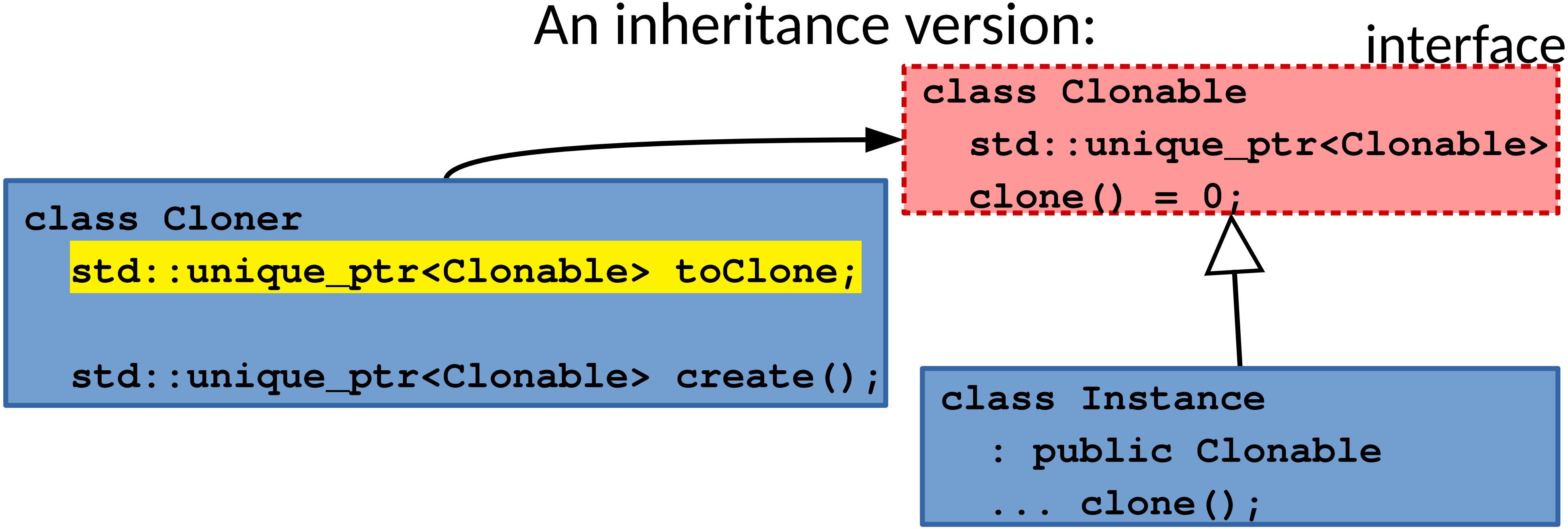

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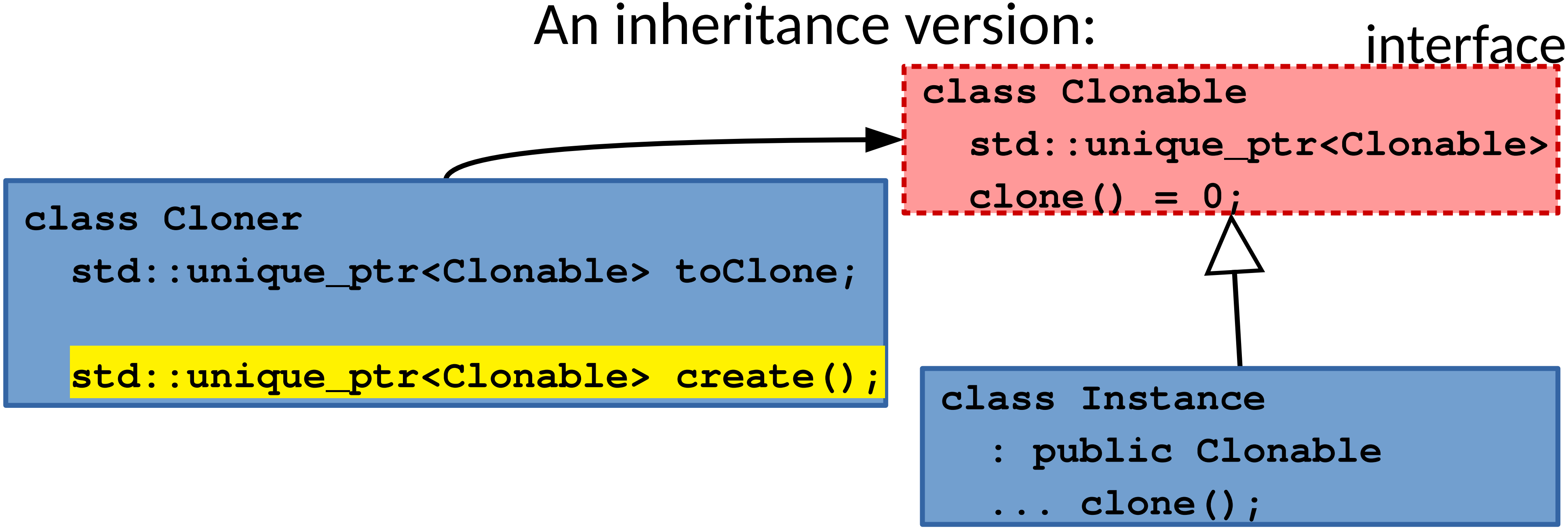

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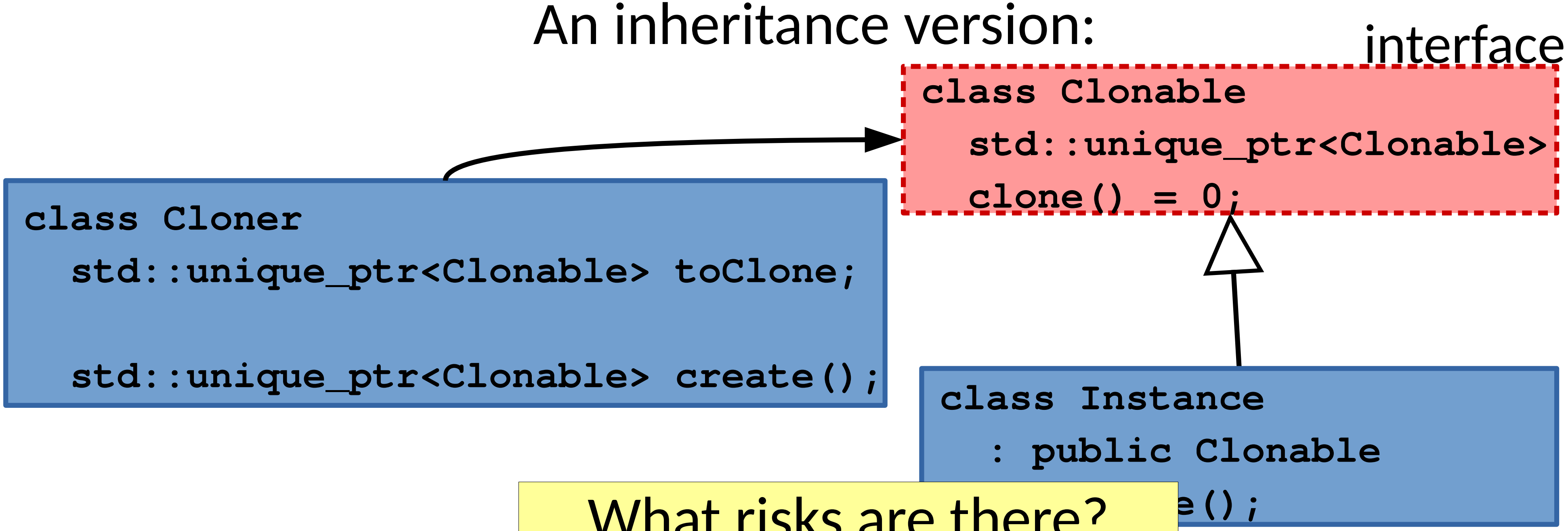

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What risks are there?
Can you see better ways?

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  - Deep copy vs shallow copy?

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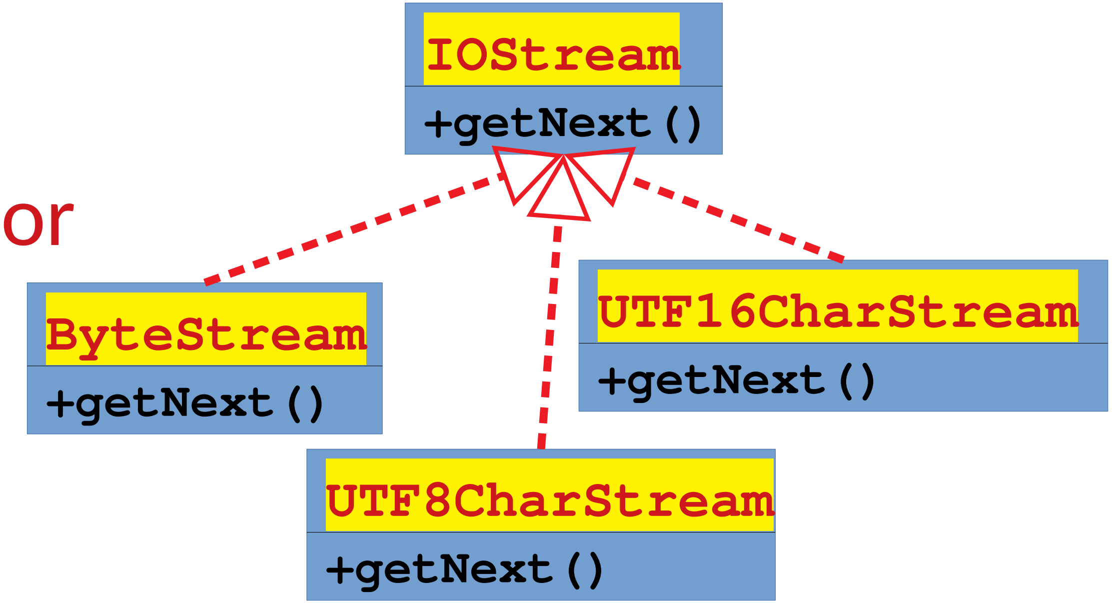

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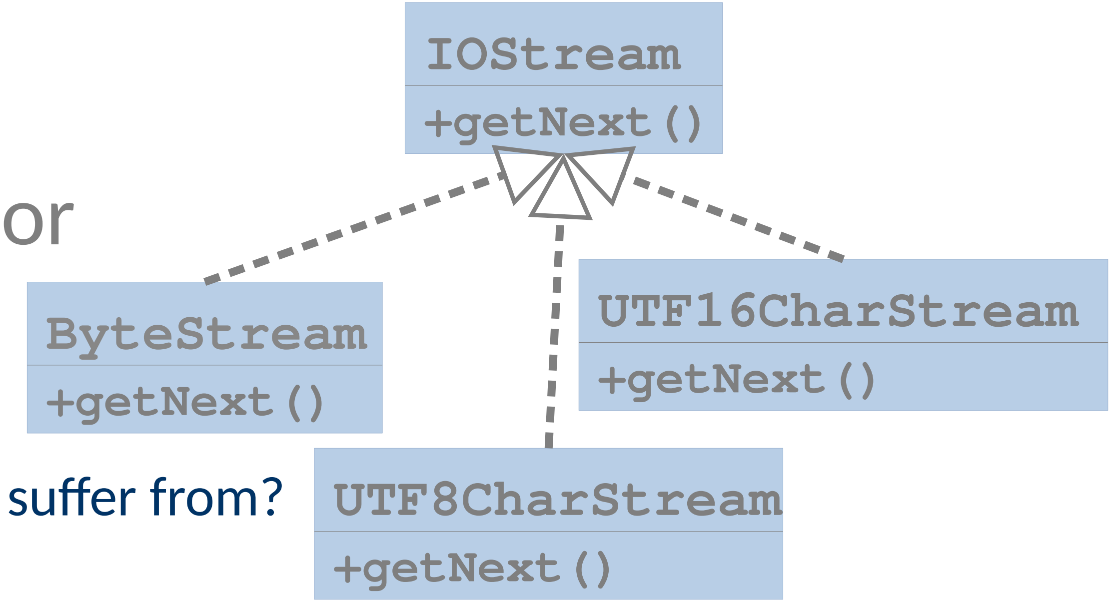

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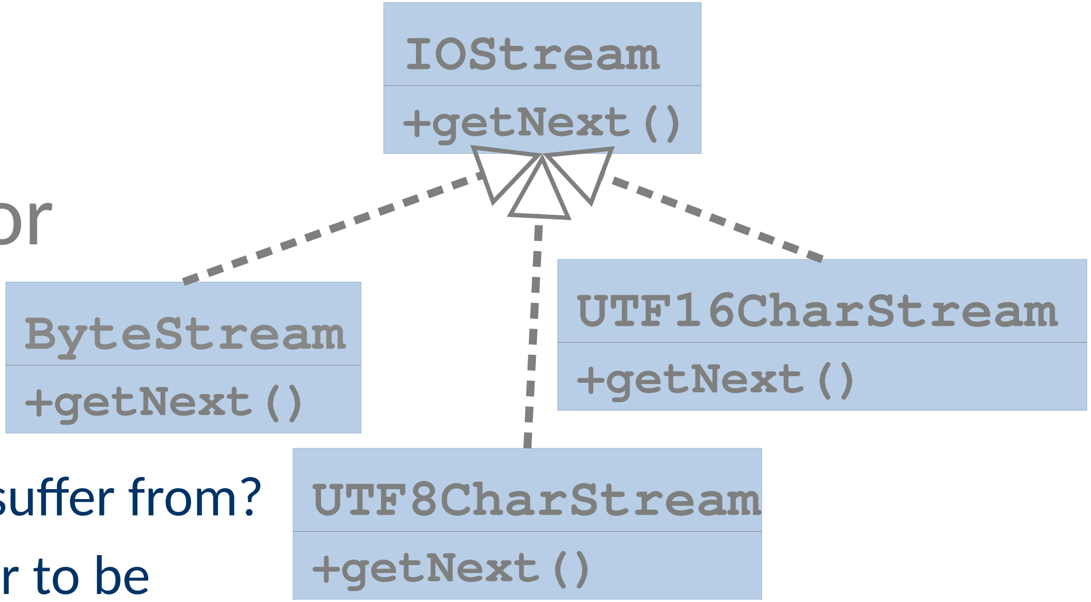
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  - What issues do these solutions suffer from?
  - What if you wanted the behavior to be dynamic?

Problem: Adding Behavior/State

- Let us consider another example:

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class VideoStream {
public:
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  - What if we want the ability to scale/resize frames?

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  - And the combined behavior is chosen at runtime.

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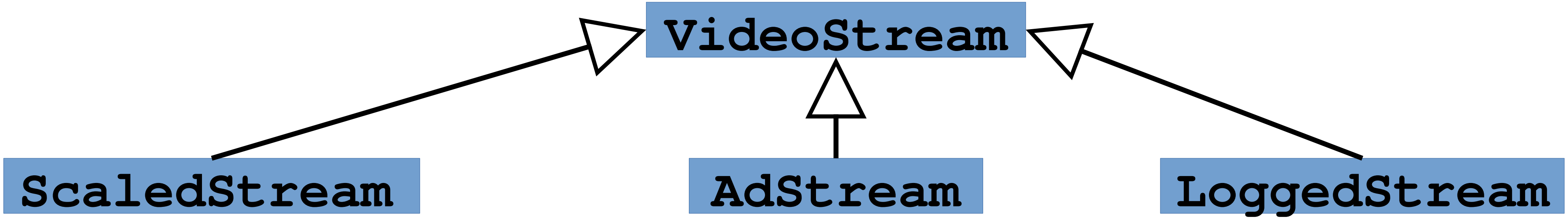

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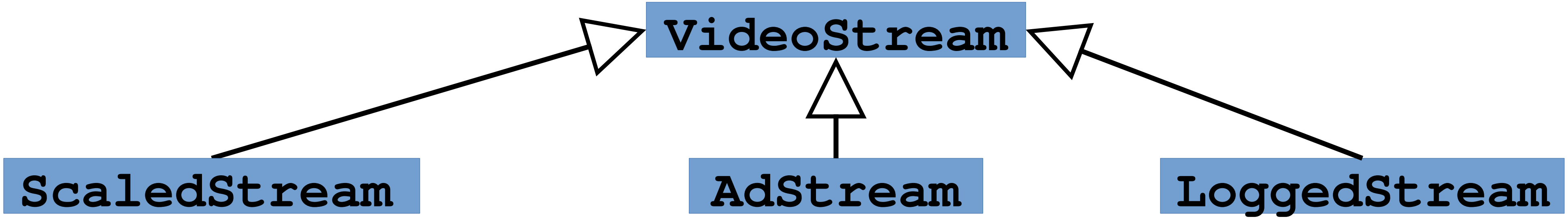

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Is this sufficient?

Problem: Adding Behavior/State

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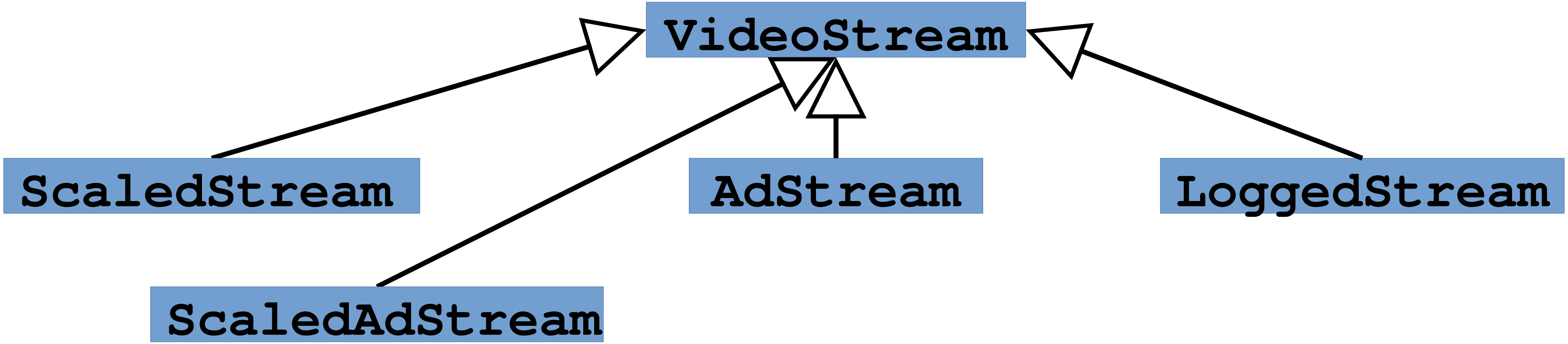

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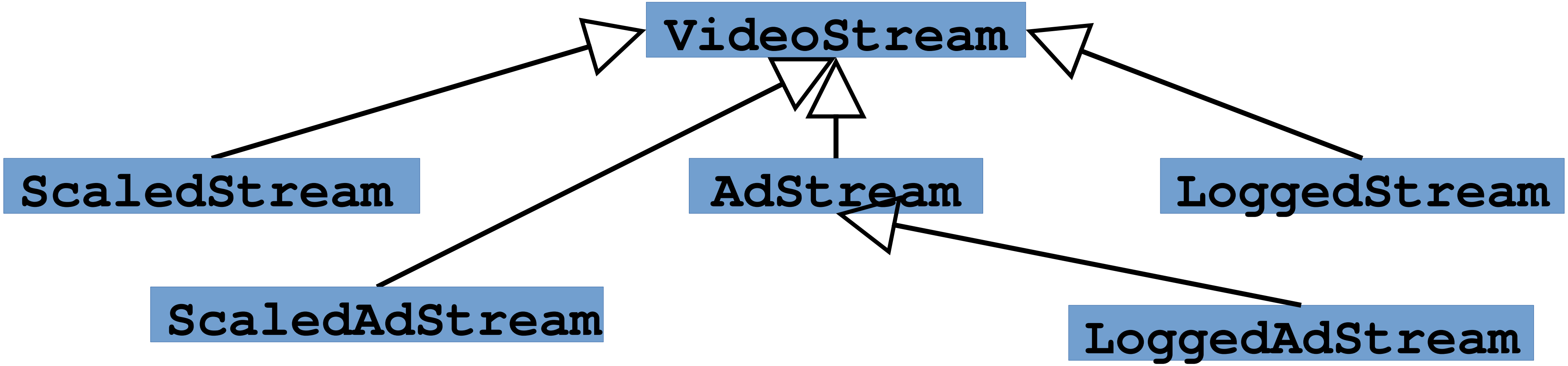

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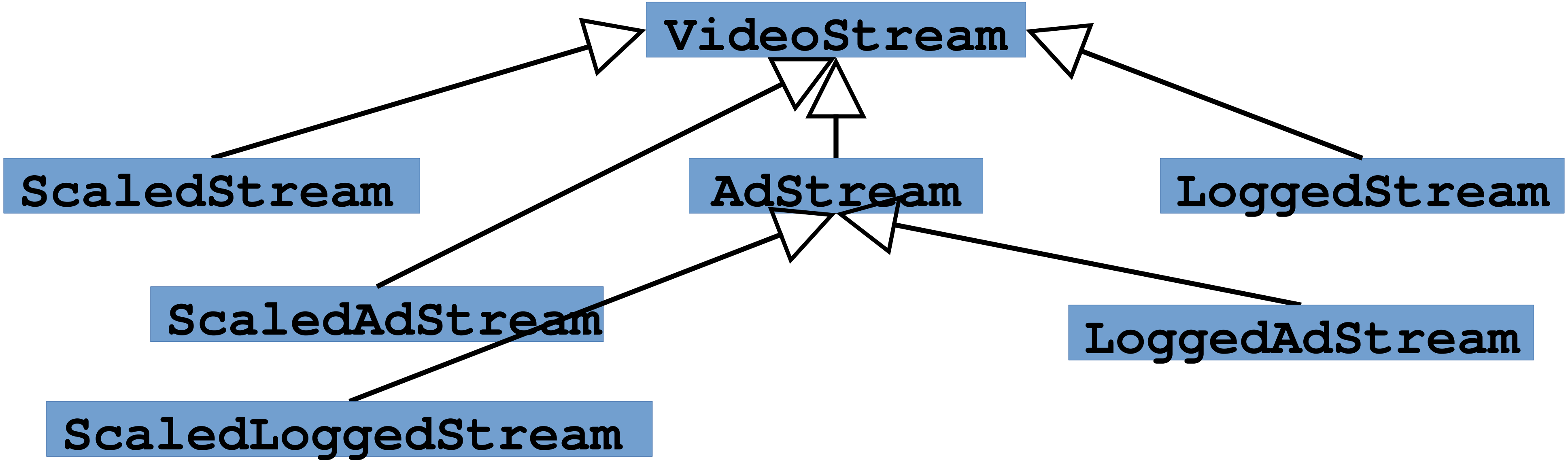

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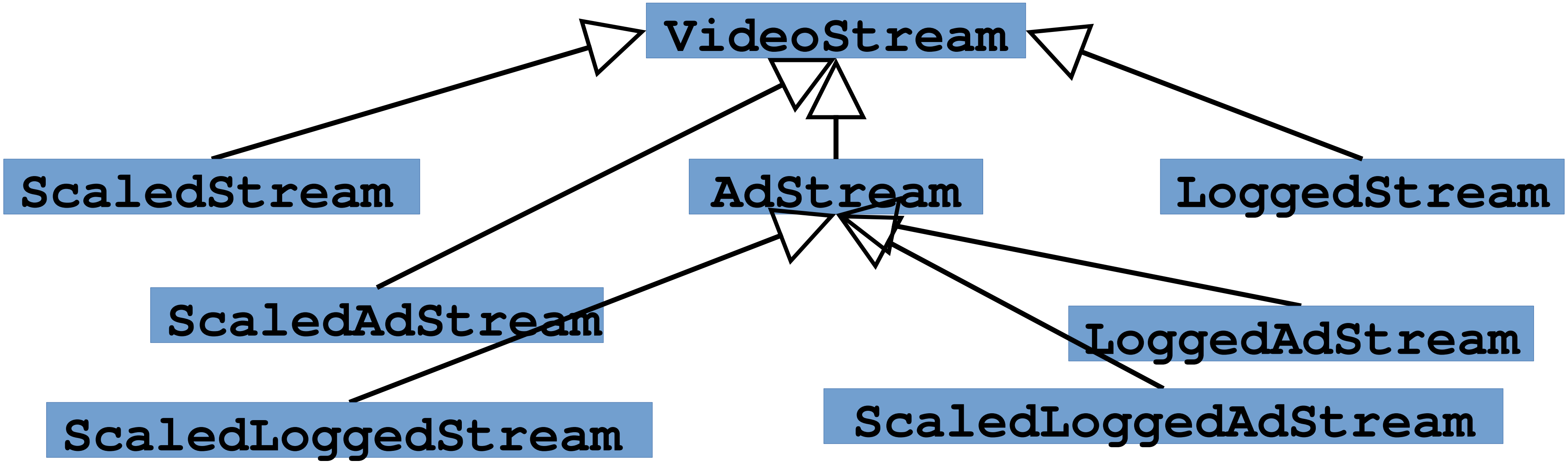

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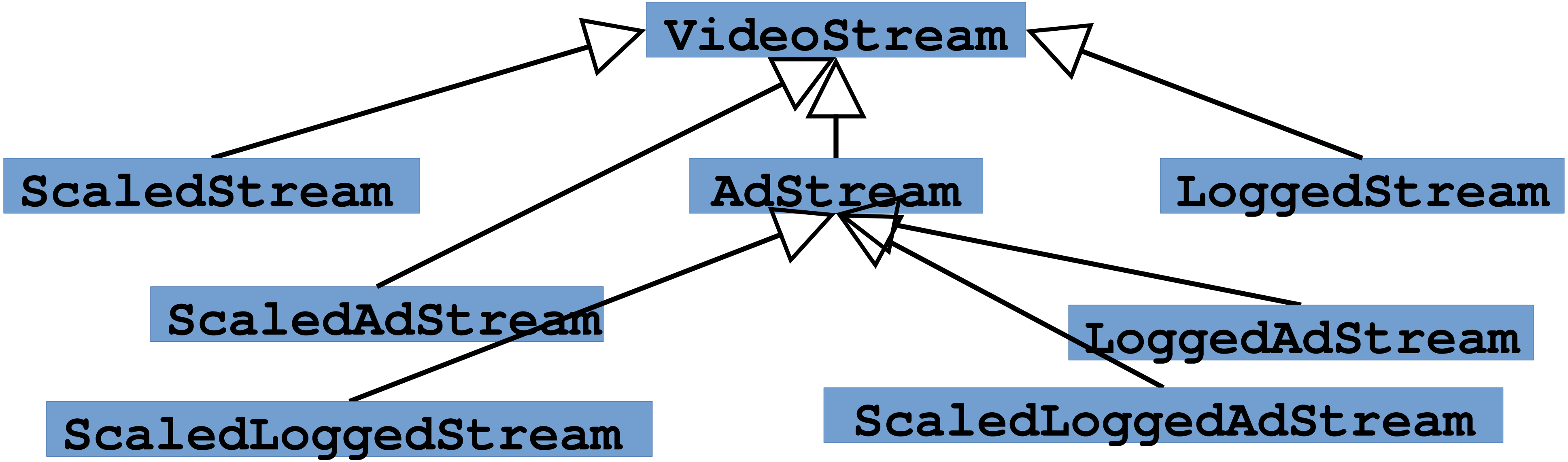

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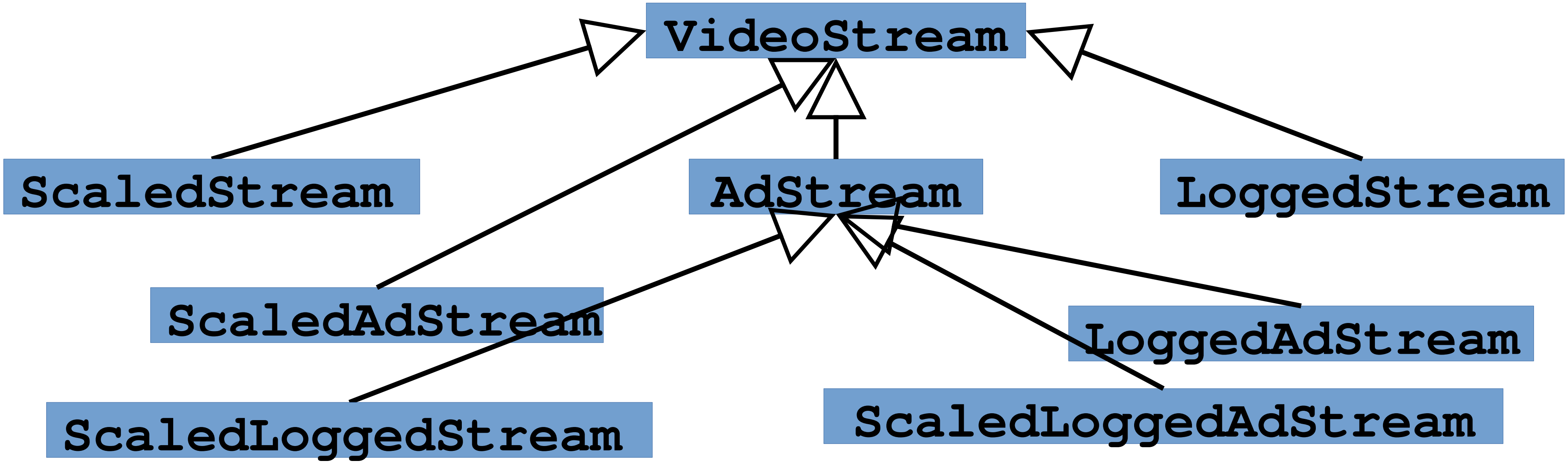

- For *k* additions: 2^k classes
  - And you may not know which even make sense right away…

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  - Decouple the addition of behavior from the **`VideoStream`** class

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- Goal:
  - Decouple the addition of behavior from the **`VideoStream`** class
  - But inheritance of implementation is strongly coupling!

  - So what can we do instead?

Let’s work through it on the board…

e.g. Structural Pattern: Decorator

- Goal: Flexibly add state/behavior to an object

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[redacted] interface

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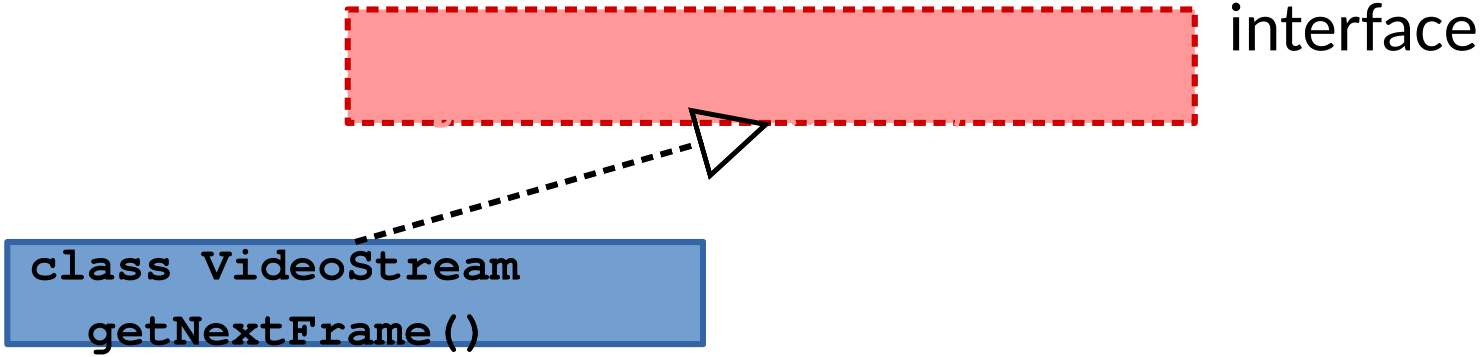

interface

```
class VideoStream
  getNextFrame()
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The core/simplest behavior will always be necessary

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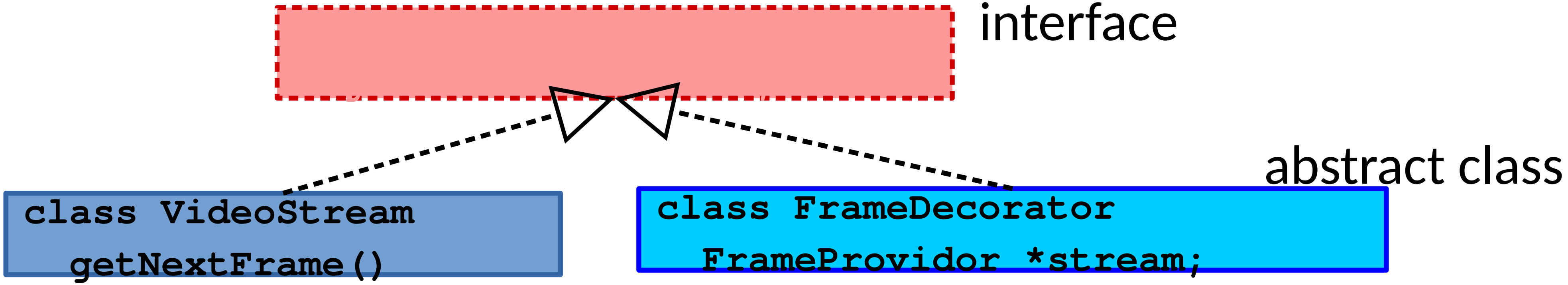

interface

abstract class

```
class VideoStream
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```
class FrameDecorator
  FrameProvidor *stream;
```

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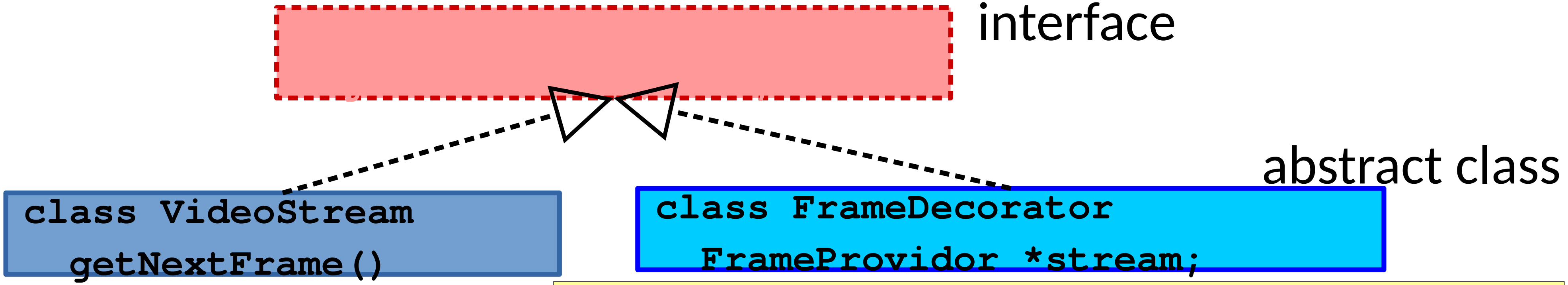

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This only exists to provide the **`*stream`** to concrete decorations!

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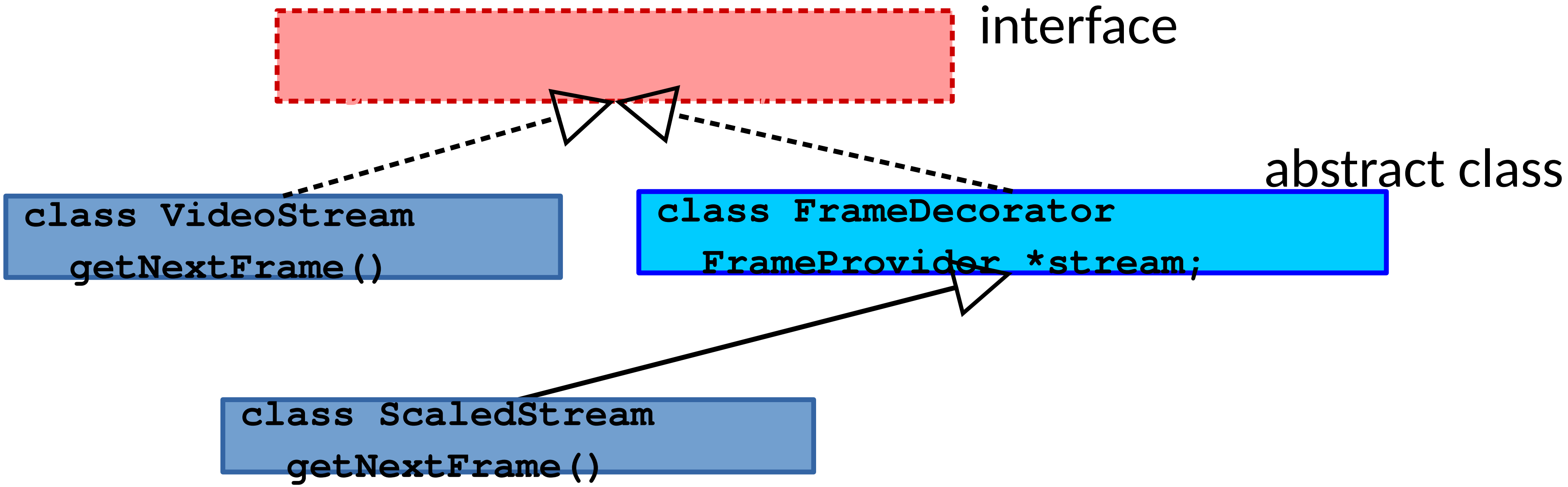

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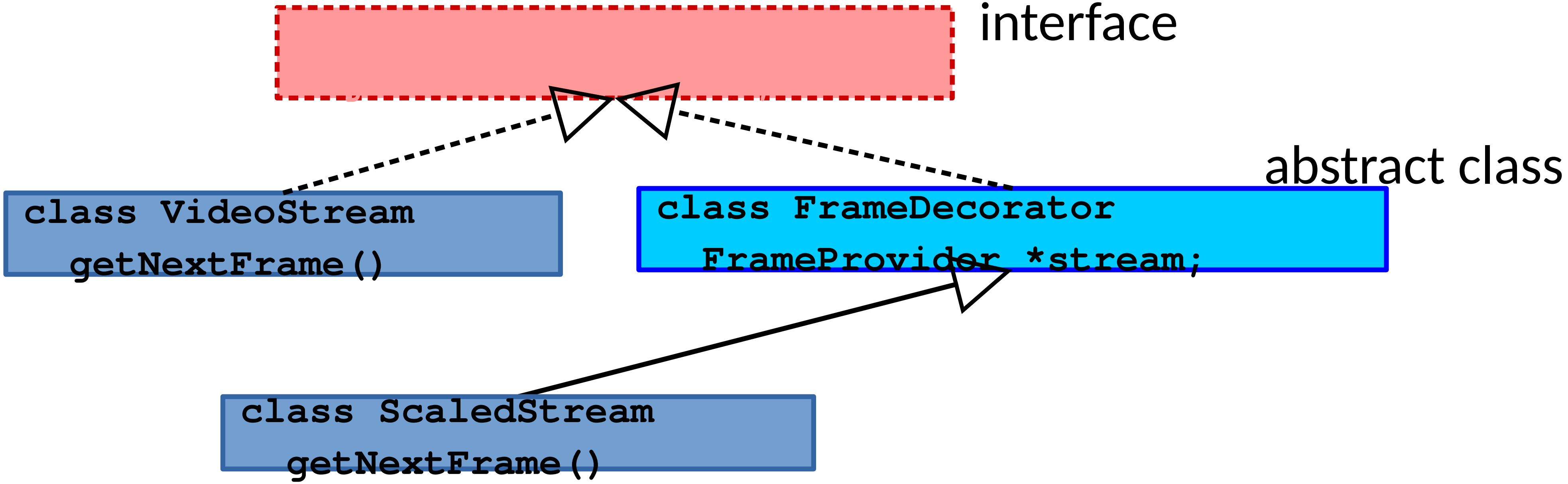

interface

abstract class

```
class VideoStream
  getNextFrame()
```

```
class FrameDecorator
  FrameProvider *stream;
```

```
class ScaledStream
  getNextFrame()
```

What does its **`getNextFrame()`** look like?

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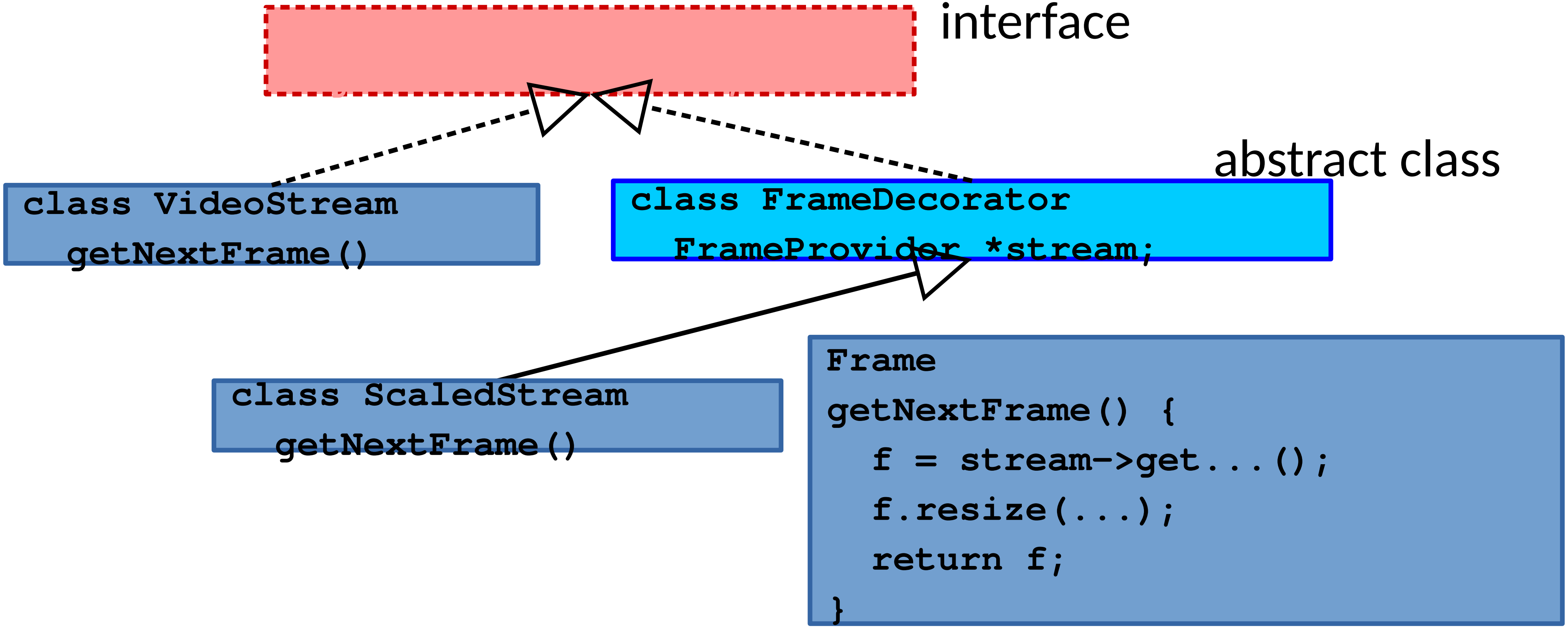

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class ScaledStream
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```
Frame
getNextFrame() {
  f = stream->get...();
  f.resize(...);
  return f;
}
```

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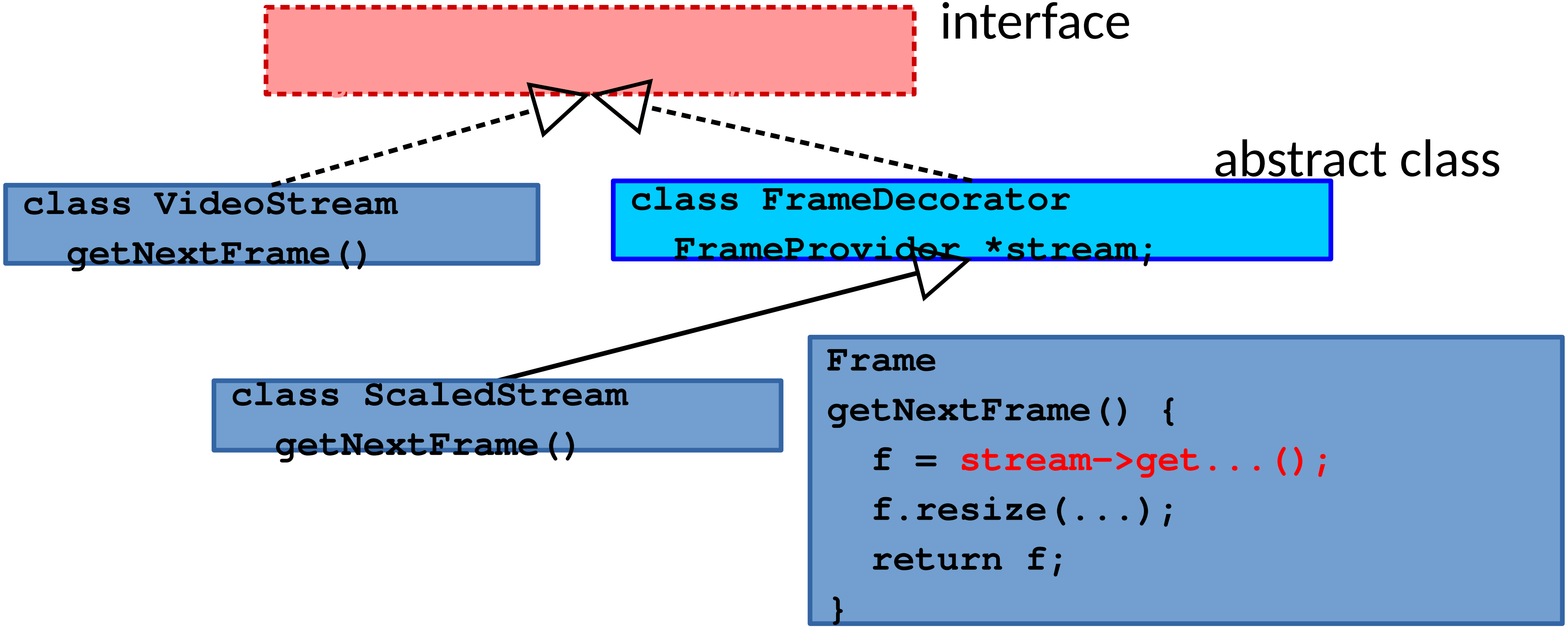

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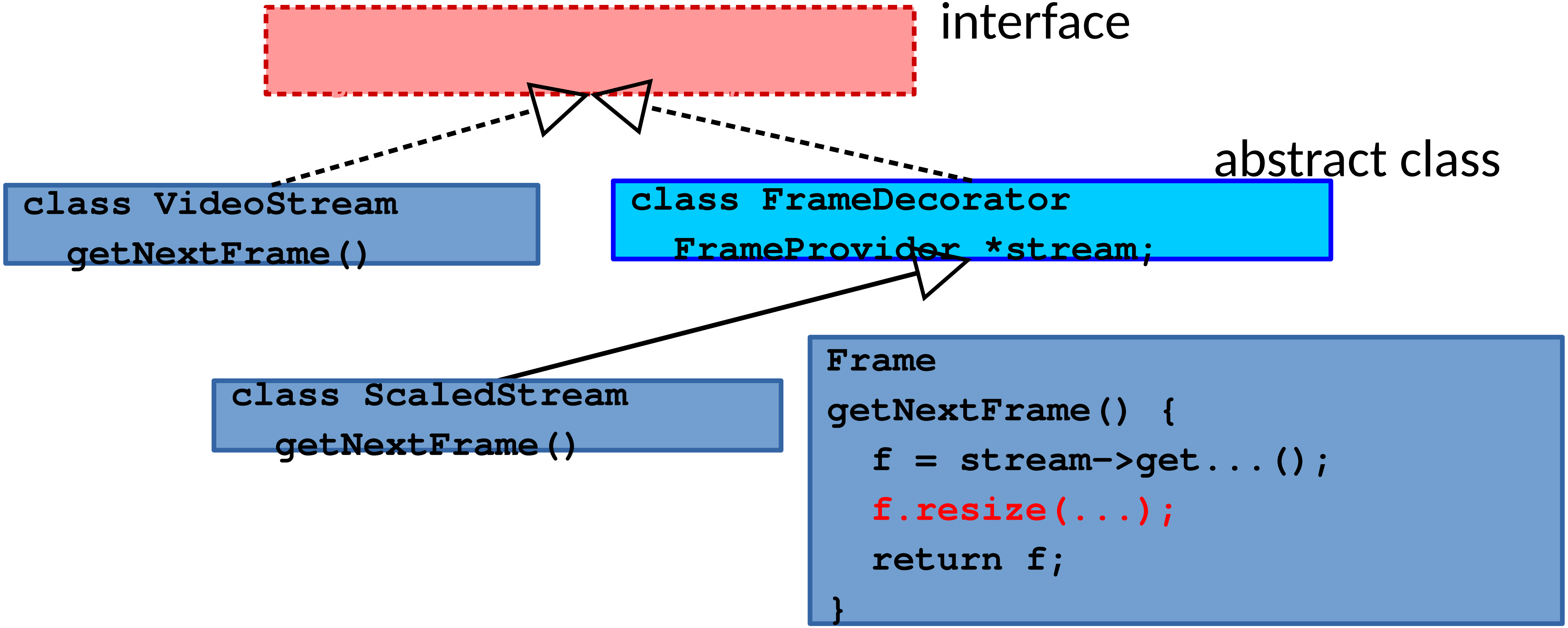

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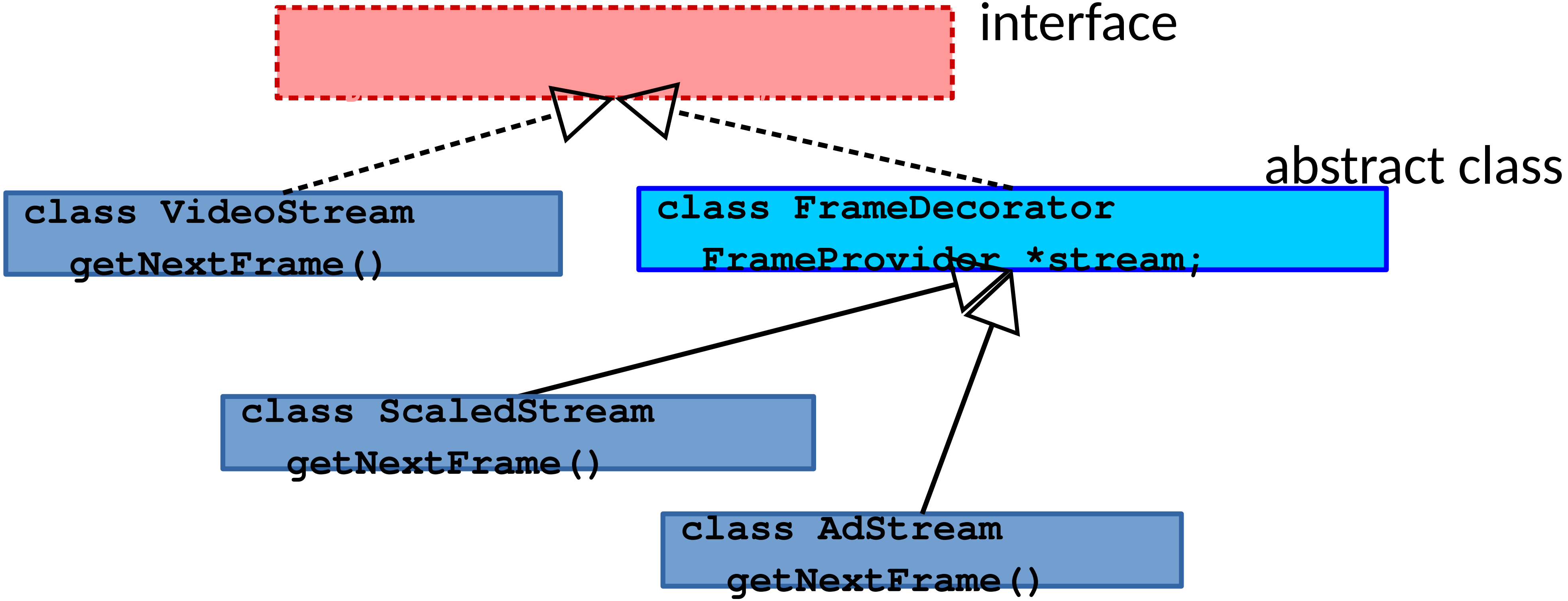

interface

abstract class

`class VideoStream`
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`class ScaledStream`
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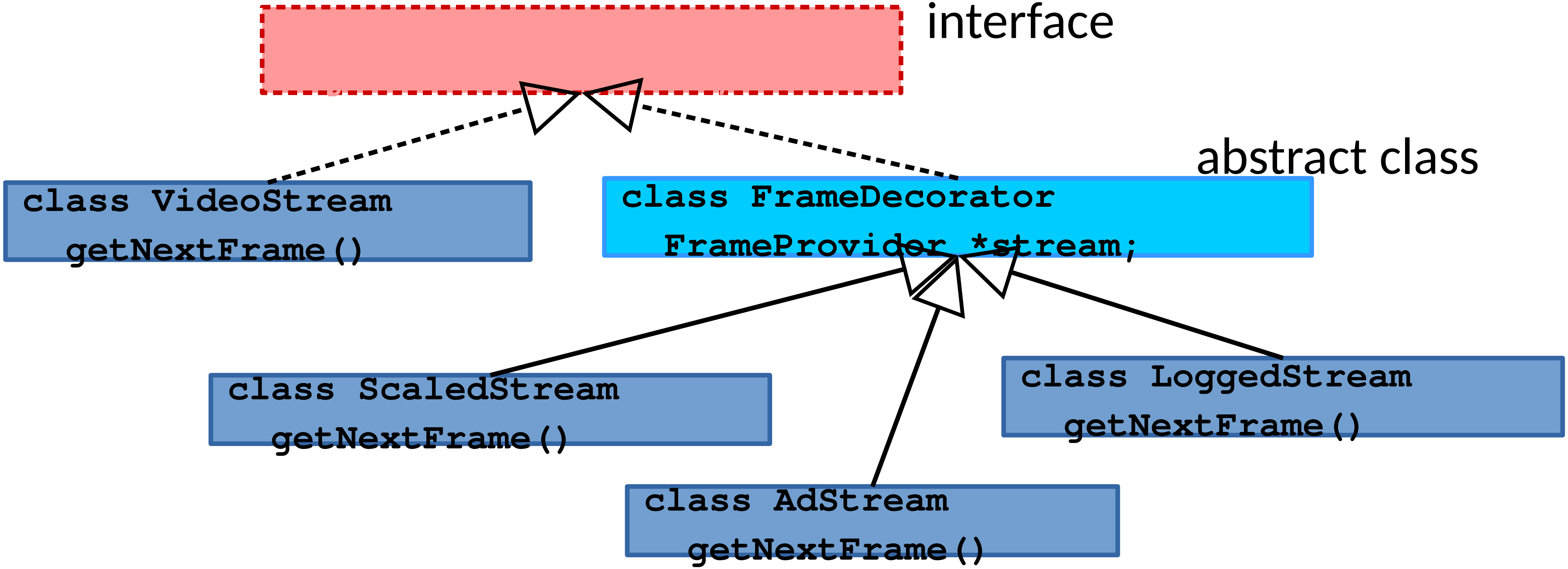

interface

abstract class

`class VideoStream`
`getNextFrame()`

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`FrameProvider *stream;`

`class ScaledStream`
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`class LoggedStream`
`getNextFrame()`

`class AdStream`
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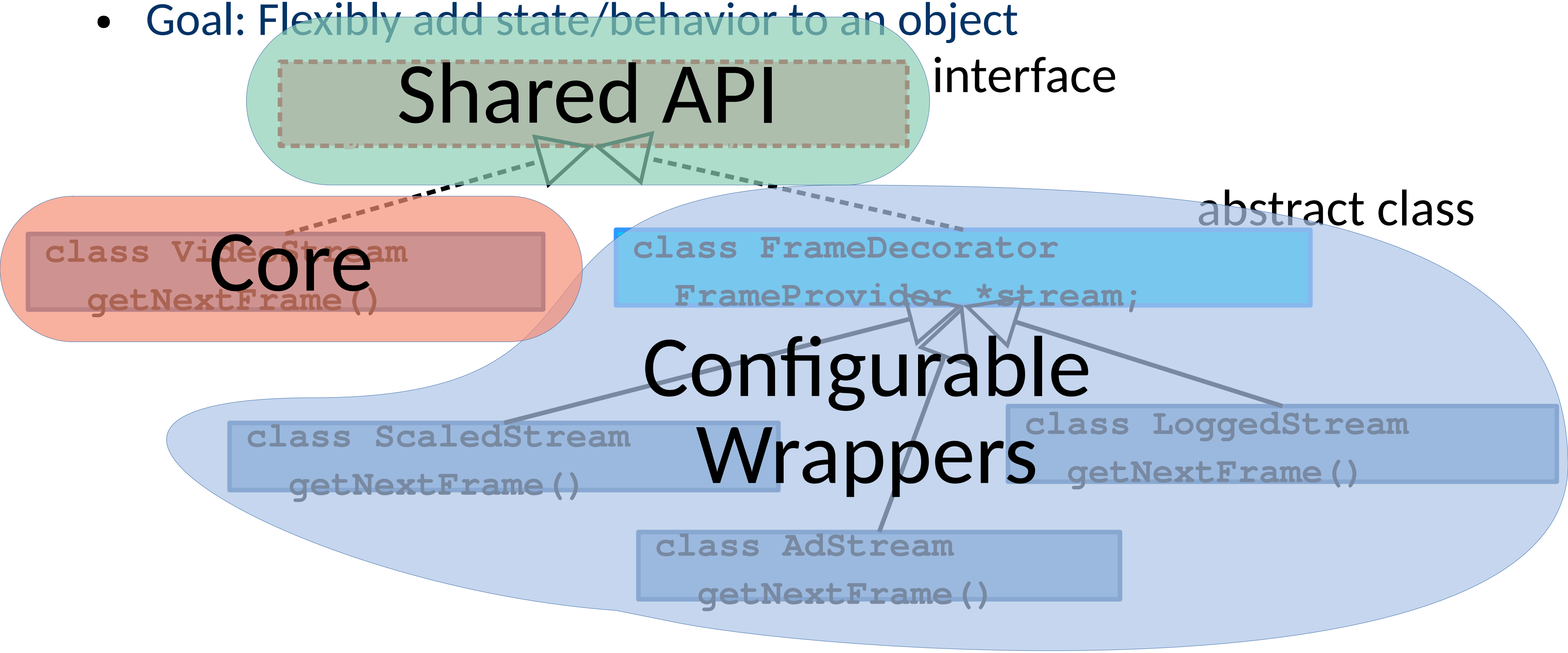

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  - Enables dynamically adding/removing behavior!

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- Goal: Flexibly add state/behavior to an object
- Also called `Wrapper` (for now obvious reasons)
- Benefits
  - Avoid class explosion
  - Works when inheritance on core is prohibited
  - Enables dynamically adding/removing behavior!
- Can the added & original behaviors change independently?

e.g. Structural Pattern: Decorator

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- Downsides?
  - Address no longer gives object identity
    - How might you resolve this?
  - The indirection is itself a form of complexity
    - Debugging why one link in a chain fails is more complex

Problem: Separate Caller & Callee

- What if we want to fully decouple actions to be taken from their call sites?

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auto result = foo(x, y, z);
...
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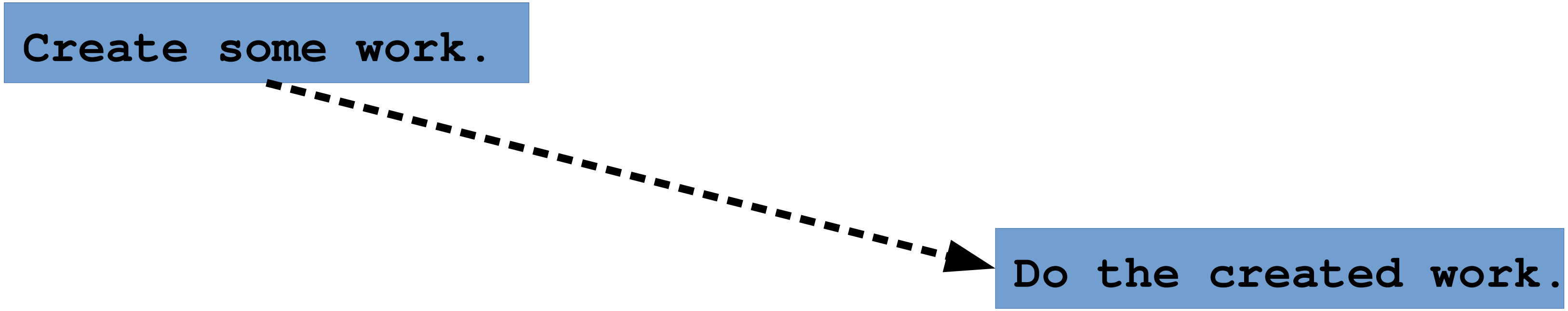

`Create some work.`

`Do the created work.`

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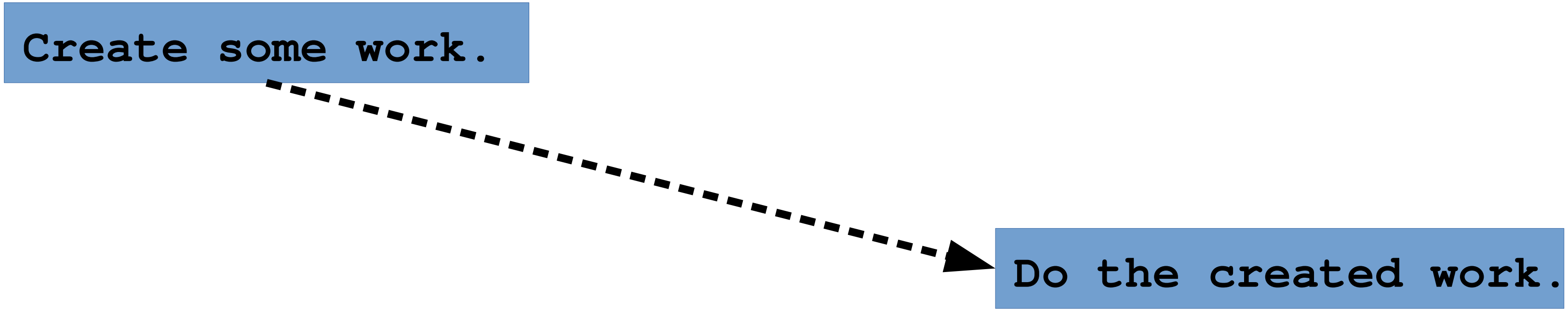

`Create some work.`

`Do the created work.`

  - What interface captures this?

Problem: Separate Caller & Callee

- What if we want to fully decouple actions to be taken from their call sites?
  - Sometimes you must execute an action without any knowledge of what that action is.

```
[redacted]
auto result = [redacted]([redacted]);
[redacted]
```

Problem: Separate Caller & Callee

- What if we want to fully decouple actions to be taken from their call sites?
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```
auto result = worker.doWork();
```

Problem: Separate Caller & Callee

- What if we want to fully decouple actions to be taken from their call sites?
  - Sometimes you must execute an action without any knowledge of what that action is.

```
auto result = worker.doWork();
```

```
class Work {
  // Information about work
  // ...
  Result doWork() {...}
};
```

Problem: Separate Caller & Callee

- What if we want to fully decouple actions to be taken from their call sites?
  - Sometimes you must execute an action without any knowledge of what that action is.

```
auto result = worker.doWork();
```

```
class Work {
  // Information about work
  // ...
  Result doWork() {...}
};
```

```
class OtherKindOfWork {
  Result doWork() {...}
};
```

Problem: Separate Caller & Callee

- What if we want to fully decouple actions to be taken from their call sites?
  - Sometimes you must execute an action without any knowledge of what that action is.

```
auto result = worker.doWork();
```

```
class Work {
  virtual Result doWork() = 0;
};
```

```
class WorkKind1 : public Work {
  Result doWork() override{...}
};
```

```
class WorkKind2 : public Work {
  Result doWork() override{...}
};
```

e.g. Behavioral Pattern: Command

```
class Command {
public:
  virtual void execute() = 0;
};
```

e.g. Behavioral Pattern: Command

- This is the ***command pattern***

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Why not just use a lambda?

The Command Pattern

- Benefits
  - **Decouples a request / behavior from the invoker**

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  - Invoker decides when to invoke without caring what

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auto result = foo(x, y, z);
 ...
```

The Command Pattern

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  - Decouples a request / behavior from the invoker
  - Invoker decides when to invoke without caring what
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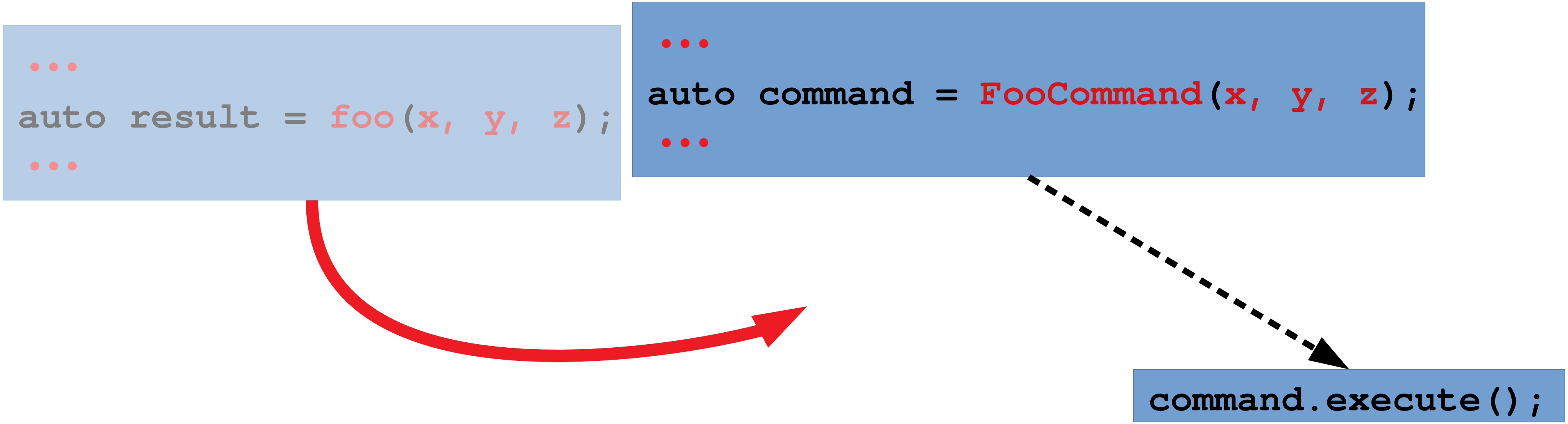

```
...
auto result = foo(x, y, z);
...
```

```
...
auto command = FooCommand(x, y, z);
...
```

```
command.execute();
```

The Command Pattern

- Benefits
  - Decouples a request / behavior from the invoker
  - Invoker decides when to invoke without caring what
  - Parametrizable via constructor
  - Sequences of commands can be easily batched

The Command Pattern

- Issues
  - How much state should it hold? (Passed to constructor vs passed to execute)

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- Issues
  - How much state should it hold?
  - Does it perform undo/redo?
  - Can you batch commands?
  - How does temporal decoupling affect operation logic?

The Big Picture

- There is nothing *special* about design patterns!

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  - What is the API you want?

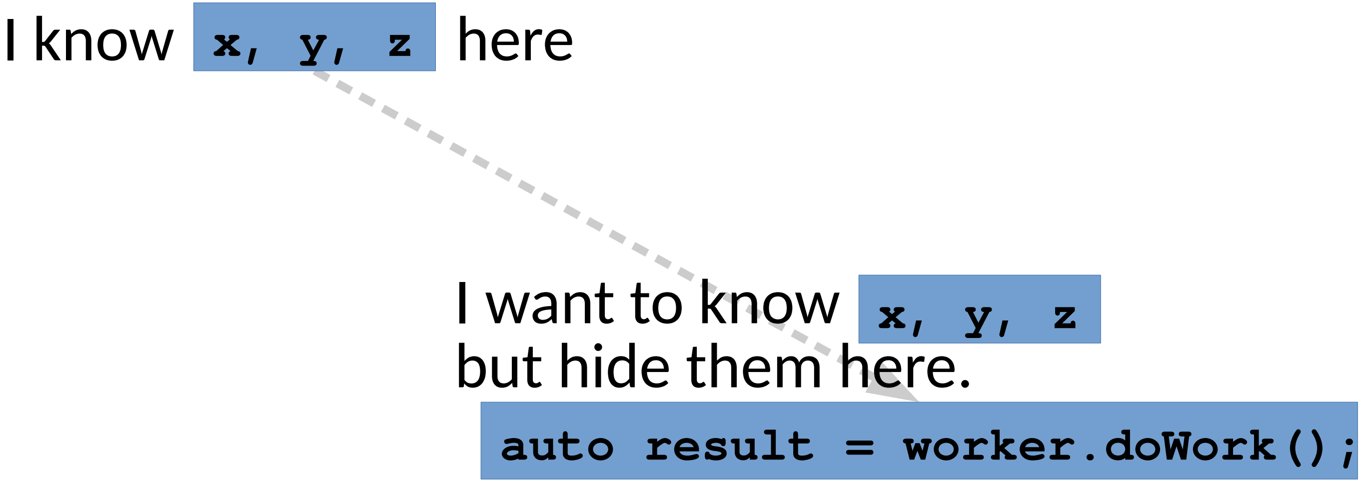
```
...
auto result = foo(x, y, z);
...
```

VS

```
auto result = worker.doWork();
```

The Big Picture

- There is nothing *special* about design patterns!
  - What is the API you want?
  - What do you know, what do you need to know, & when?



I know `x, y, z` here

I want to know `x, y, z`
but hide them here.

```
auto result = worker.doWork();
```

The Big Picture

- There is nothing *special* about design patterns!
  - What is the API you want?
  - What do you know, what do you need to know, & when?
  - How can you hide design decisions to get the API you want?

I know `x, y, z` here

```
class Command {
public:
  virtual void doWork() = 0;
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I want to know `x, y, z`
but hide them here.

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auto result = worker.doWork();
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Design Patterns

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- They provide a common language for design decisions
- They illustrate common trade offs & how to solve them
- I heartily recommend learning State, Strategy, & Visitor as well
  - We will explore these a little in class.