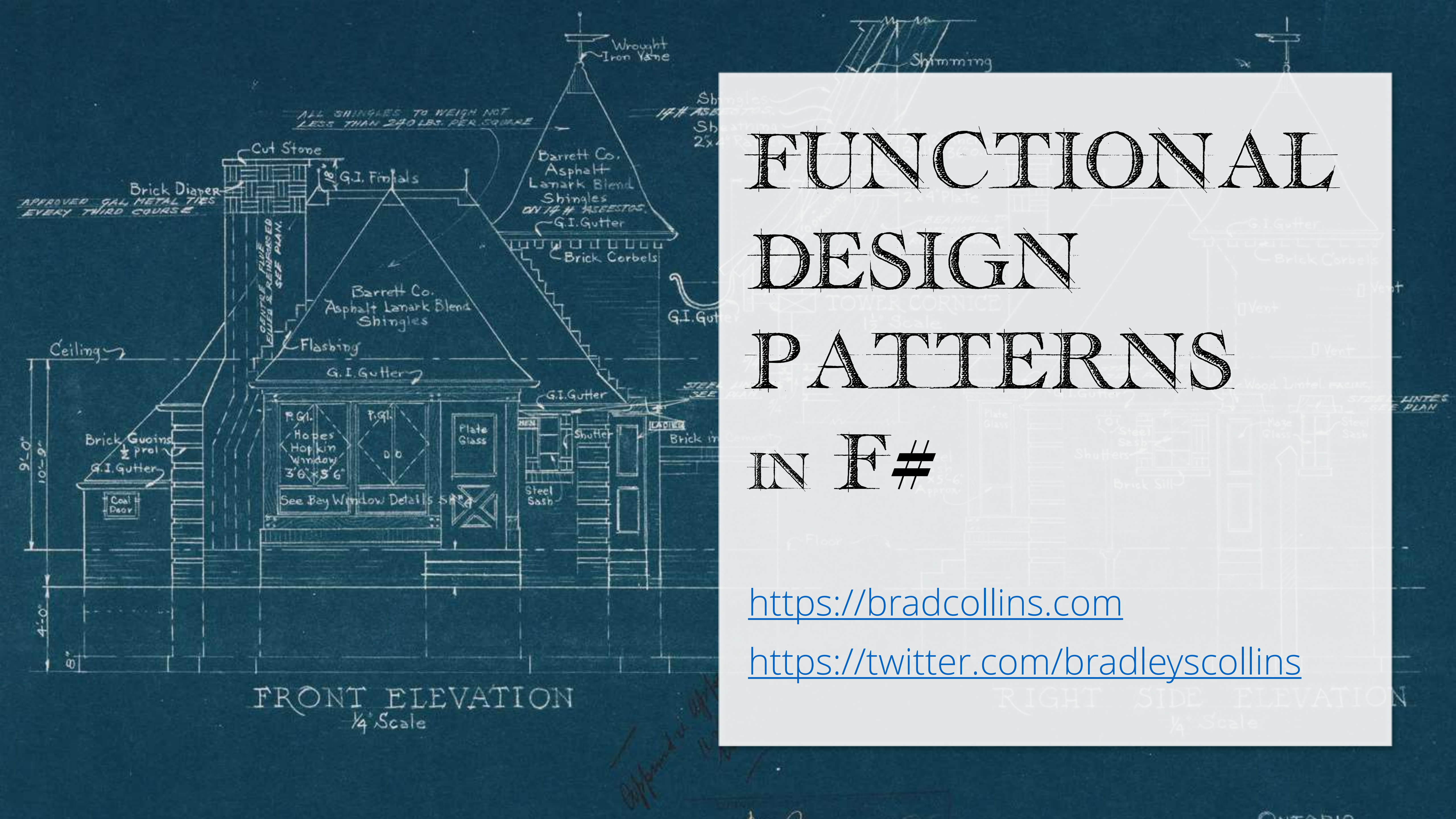

FUNCTIONAL DESIGN PATTERNS IN F#

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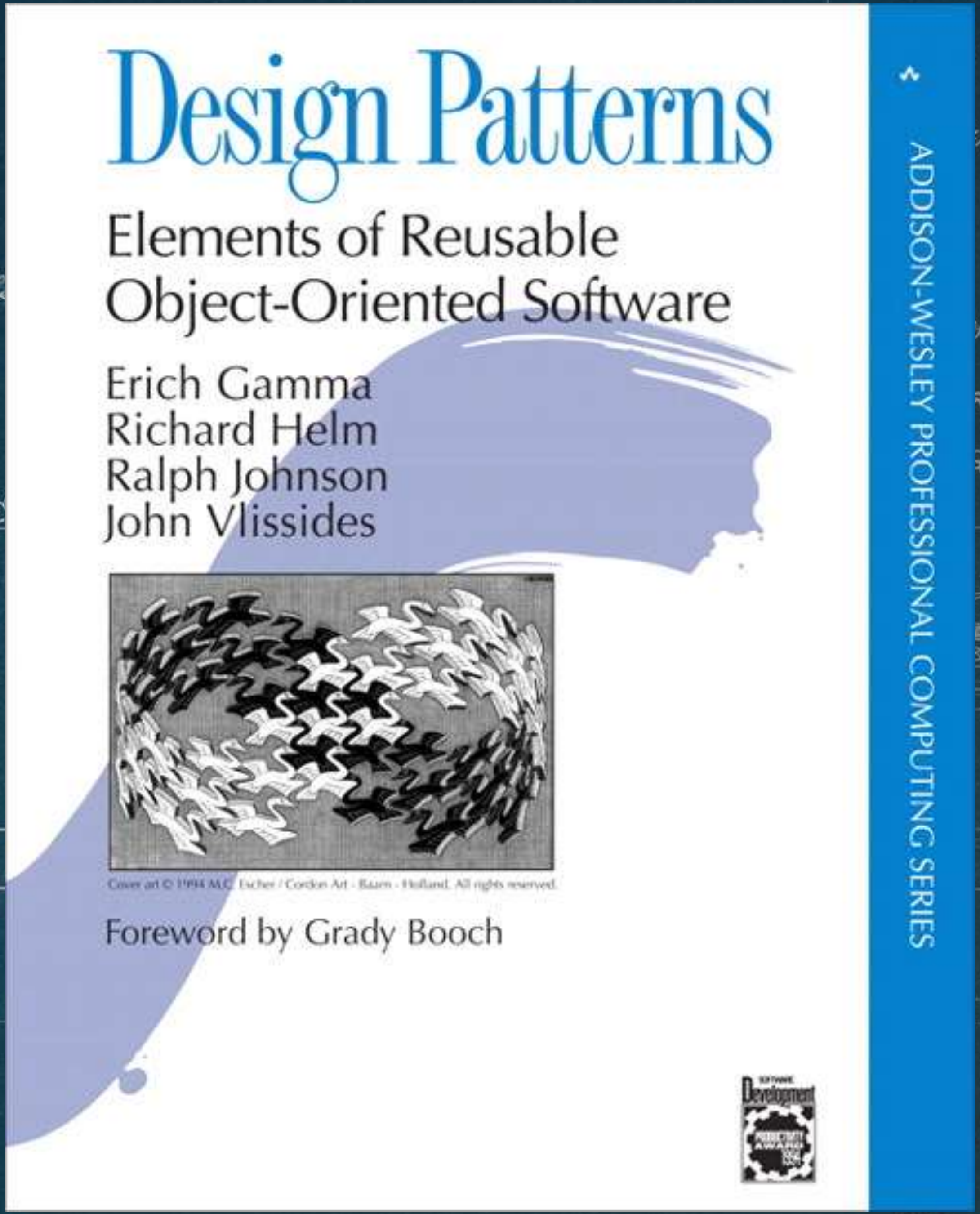

Design Patterns

Elements of Reusable
Object-Oriented Software

Erich Gamma
Richard Helm
Ralph Johnson
John Vlissides

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Foreword by Grady Booch

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Real-World Functional Programming

With examples in F# and C#

SAMPLE CHAPTER

Tomas Petricek with Jon Skeet

Foreword by Mads Torgersen

MANNING

THE BOOK OF F#

BREAKING FREE WITH

FUNCTIONAL PROG

DAVE FANCHER

COVERS F# 3.1

F# DEEP

Editors Tomas Petricek • Phillip Trelford

Contributors Chris Ballard • Keith Battocchi • Colin Bull • Chao-Jen Chen • Yan Cui •
Evelina Gabasova • Dmitry Morozov • Tomas Petricek • Don Syme • Phil

Expert F# 4.0

Fourth Edition

Don Syme
Adam Granicz
Antonio Cisternino

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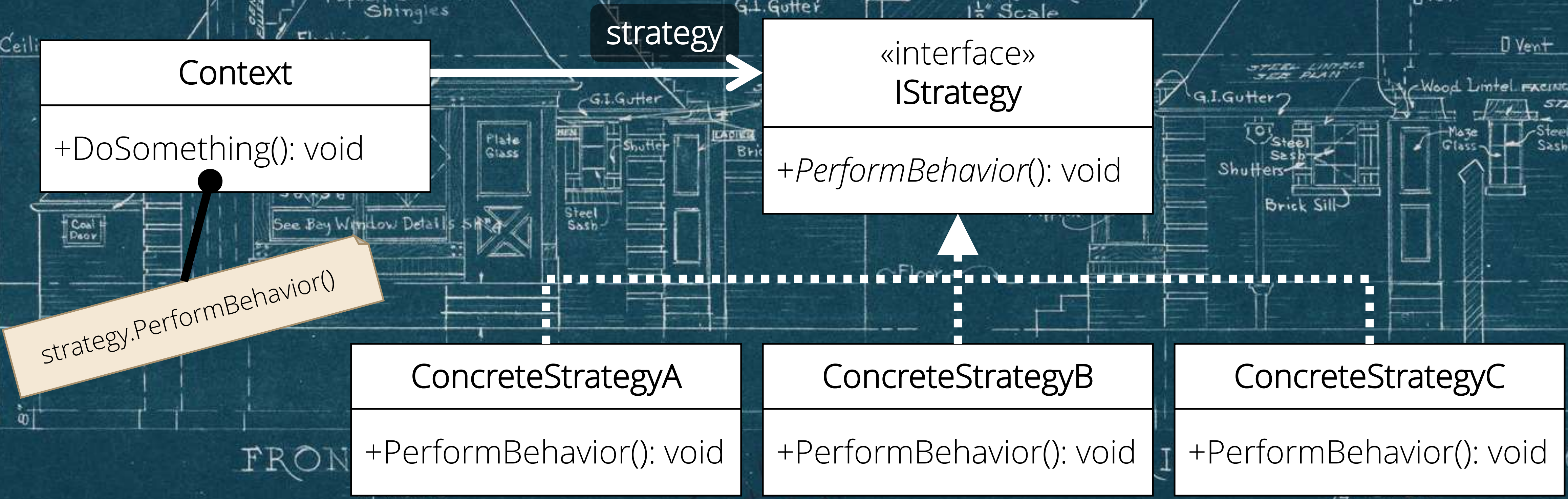
OBJECT-ORIENTED

- Builder
- Null Object
- Template Method
- Strategy
- Adapter
- State
- Dependency Injection
- Visitor

FUNCTIONAL

- Currying
- Pattern Matching
- Partial Application
- Function Builder
- Monads
- Map-Reduce
- Algebraic Data Types

STRATEGY



Context

+DoSomething(): void

strategy

«interface»
IStrategy

+*PerformBehavior*(): void

strategy.PerformBehavior()

ConcreteStrategyA

+PerformBehavior(): void

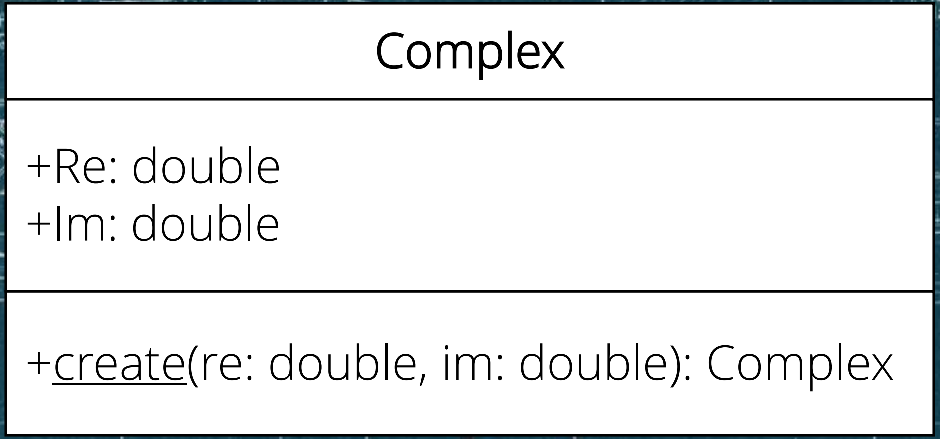
ConcreteStrategyB

+PerformBehavior(): void

ConcreteStrategyC

+PerformBehavior(): void

STRATEGY

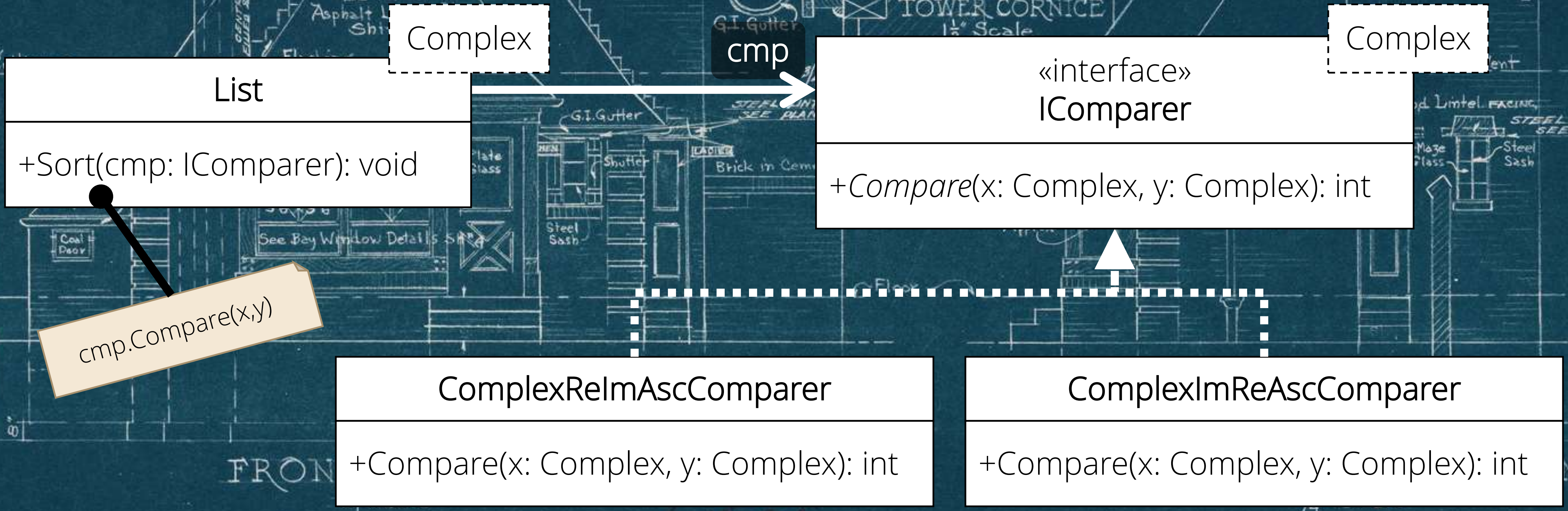


Complex

+Re: double
+Im: double

+create(re: double, im: double): Complex

STRATEGY



Complex

List

+Sort(cmp: IComparer): void

cmp.Compare(x,y)

cmp

Complex

«interface»
IComparer

+*Compare*(x: Complex, y: Complex): int

ComplexReImAscComparer

+Compare(x: Complex, y: Complex): int

ComplexImReAscComparer

+Compare(x: Complex, y: Complex): int

C#

STRATEGY

```csharp
public class Complex
{
    public readonly double Re;
    public readonly double Im;
    public Complex(double re, double im)
    {
        Re = re;
        Im = im;
    }
}
```

C#

STRATEGY

```
public class ComplexReImAscComparer : IComparer<Complex>
{
    public int Compare(Complex x, Complex y)
    {
        var re = Math.Sign(x.Re - y.Re);
        return re != 0 ? re : Math.Sign(x.Im - y.Im);
    }
}
```

C#

STRATEGY

```
public class ComplexImReAscComparer : IComparer<Complex>
{
    public int Compare(Complex x, Complex y)
    {
        var im = Math.Sign(x.Im - y.Im);
        return im != 0 ? im : Math.Sign(x.Re - y.Re);
    }
}
```

C#

STRATEGY

```
var xs = new List<Complex>()
{
    new Complex( 4,  9),
    new Complex(-3,  1),
    new Complex( 1, -6),
    new Complex(-3, -2),
    new Complex( 7,  1),
};
```

C#

STRATEGY

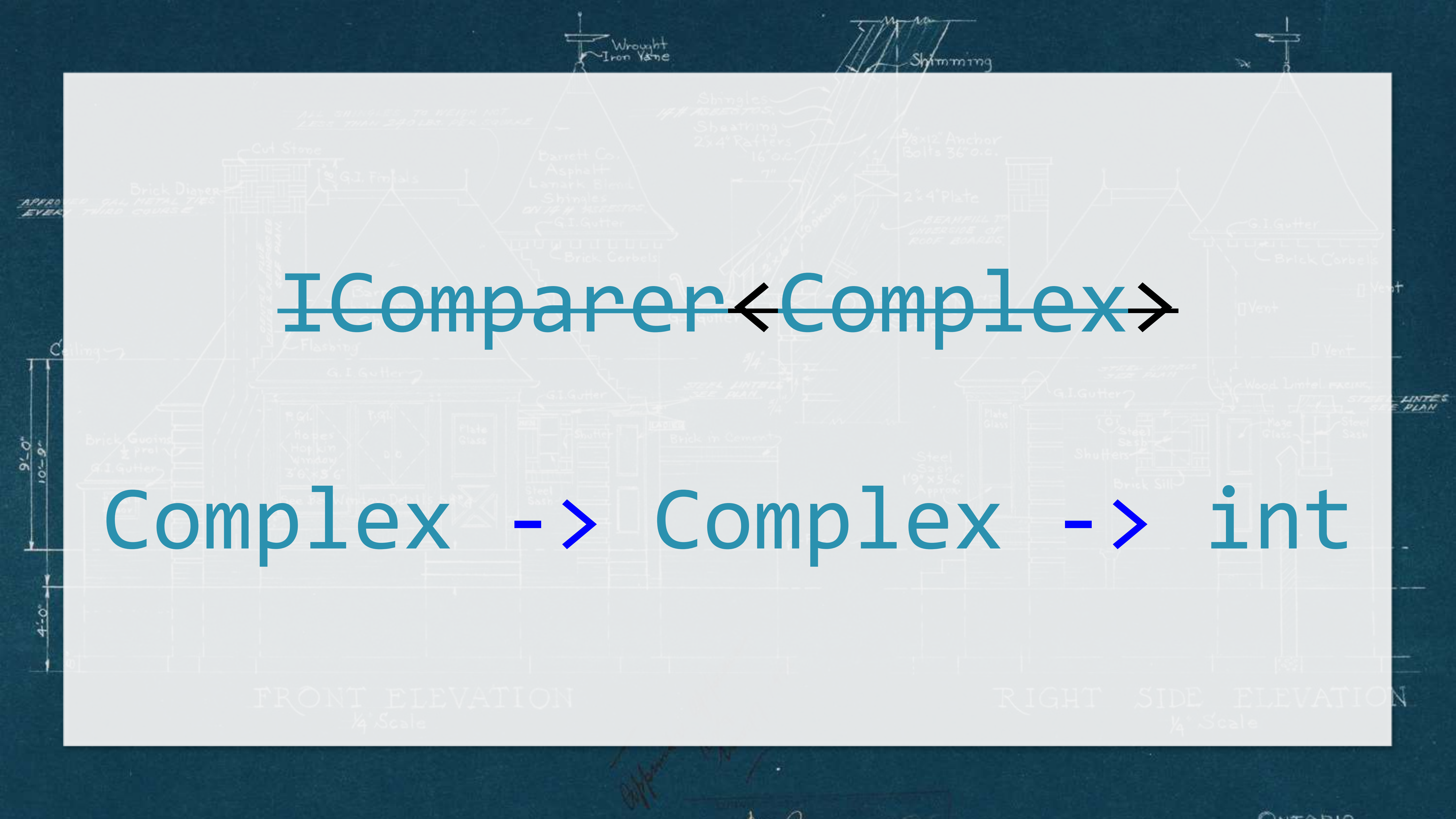
```
Console.WriteLine("Ascending by Re, Im");
xs.Sort(new ComplexReImAscComparer());
foreach (var x in xs) Console.WriteLine(x);

Console.WriteLine();
Console.WriteLine("Ascending by Im, Re");
xs.Sort(new ComplexImReAscComparer());
foreach (var x in xs) Console.WriteLine(x);
```

```
Ascending by Re, Im
-3.0 - i2.0
-3.0 + i1.0
 1.0 - i6.0
 4.0 + i9.0
 7.0 + i1.0
Ascending by Im, Re
 1.0 - i6.0
-3.0 - i2.0
-3.0 + i1.0
 7.0 + i1.0
 4.0 + i9.0
```

C#

STRATEGY

```csharp
public class ComplexReImAscComparer : IComparer<Complex>
{
    public int Compare(Complex x, Complex y)
    {
        var re = Math.Sign(x.Re - y.Re);
        return re != 0 ? re : Math.Sign(x.Im - y.Im);
    }
}
```



~~IComparer<Complex>~~

Complex -> Complex -> int

F#

STRATEGY

```
type Complex = { Re : float; Im : float }

let xs = [ { Re =  4.0; Im =  9.0 }
           { Re = -3.0; Im =  1.0 }
           { Re =  1.0; Im = -6.0 }
           { Re = -3.0; Im = -2.0 }
           { Re =  7.0; Im =  1.0 } ]
```

F#

STRATEGY

```
let compareReImAsc x y =
    let re = sign (x.Re - y.Re)
    if re <> 0 then re else sign (x.Im - y.Im)

let compareImReAsc x y =
    let im = sign (x.Im - y.Im)
    if im <> 0 then im else sign (x.Re - y.Re)
```

F#

STRATEGY

```
printfn "Ascending by Re, Im"
xs
|> List.sortWith compareReImAsc
|> List.iter (printfn "%O")
printfn ""
printfn "Ascending by Im, Re"
xs
|> List.sortWith compareImReAsc
|> List.iter (printfn "%O")
```

```
Ascending by Re, Im
-3.0 - i2.0
-3.0 + i1.0
 1.0 - i6.0
 4.0 + i9.0
 7.0 + i1.0
Ascending by Im, Re
 1.0 - i6.0
-3.0 - i2.0
-3.0 + i1.0
 7.0 + i1.0
 4.0 + i9.0
```

STRATEGY

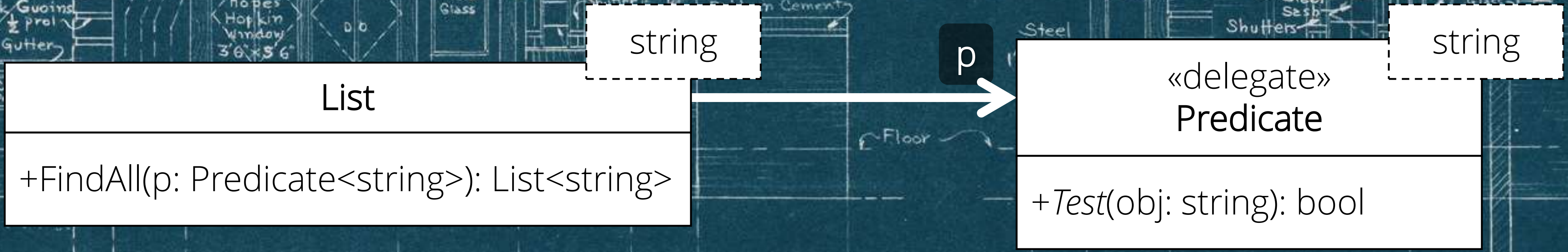
C#

```
public class ComplexReImAscComparer : IComparer<Complex>
{
    public int Compare(Complex x, Complex y)
    {
        var re = Math.Sign(x.Re - y.Re);
        return re != 0 ? re : Math.Sign(x.Im - y.Im);
    }
}

public class ComplexImReAscComparer : IComparer<Complex>
{
    public int Compare(Complex x, Complex y)
    {
        var im = Math.Sign(x.Im - y.Im);
        return im != 0 ? im : Math.Sign(x.Re - y.Re);
    }
}
```

F#

```
let compareReImAsc x y =
    let re = sign (x.Re - y.Re)
    if re <> 0 then re else sign (x.Im - y.Im)

let compareImReAsc x y =
    let im = sign (x.Im - y.Im)
    if im <> 0 then im else sign (x.Re - y.Re)
```

STRATEGY



string

List

+FindAll(p: Predicate<string>): List<string>

p

string

«delegate»
Predicate

+*Test*(obj: string): bool

STRATEGY

C#

```
public class StartsWith
{
    public string Prefix { get; private set; }
    public StartsWith(string prefix)
    {
        Prefix = prefix;
    }
    public bool Test(string sample)
    {
        return sample.StartsWith(Prefix);
    }
}
```

C#

STRATEGY

```
var words = new List<string>()
{
    "Lorem",      "ipsum",
    "dolor",      "sit",
    "amet",       "consectetur",
    "adipiscing", "elit",
};
```

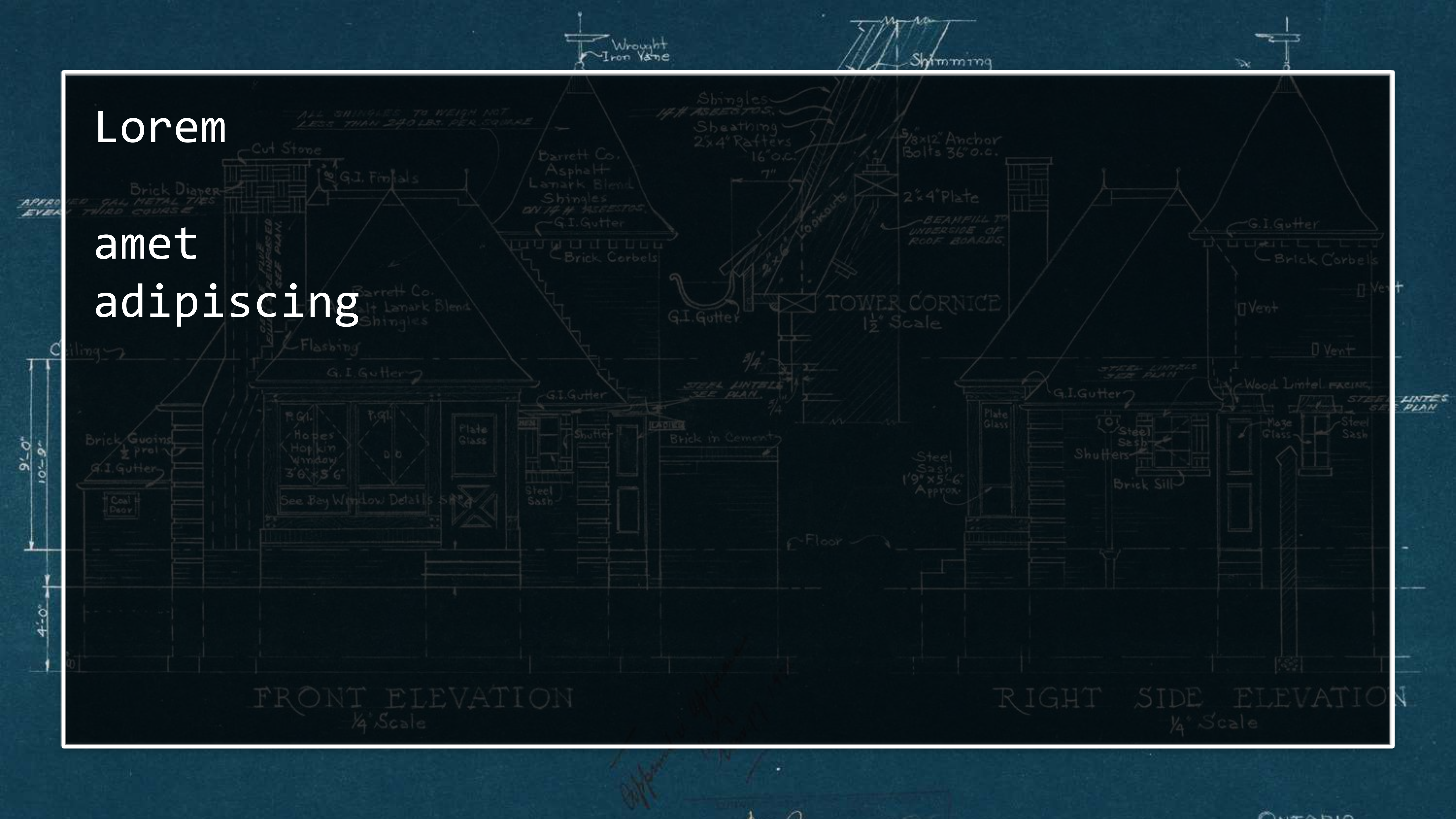
C#

STRATEGY

```csharp
var startsWithL = new StartsWith("L");
var lWords = words.FindAll(startsWithL.Test);
foreach (var word in lWords) Console.WriteLine(word);

var startsWithA = new StartsWith("a");
var aWords = words.FindAll(startsWithA.Test);
foreach (var word in aWords) Console.WriteLine(word);
```

Lorem

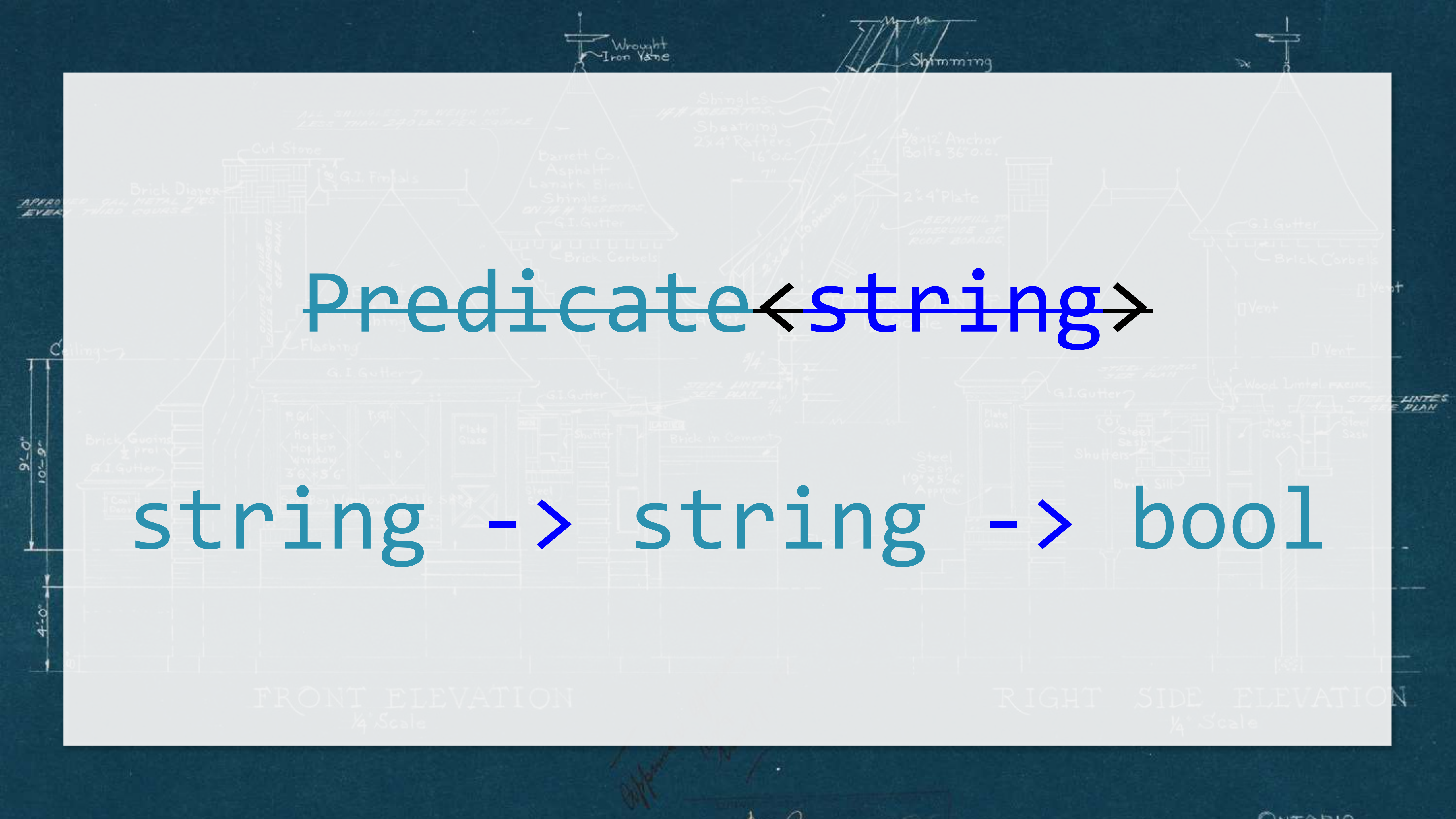
amet adipiscing



C#

STRATEGY

```csharp
public class StartsWith
{
    public string Prefix { get; private set; }
    public StartsWith(string prefix)
    {
        Prefix = prefix;
    }
    public bool Test(string sample)
    {
        return sample.StartsWith(Prefix);
    }
}
```



~~Predicate<string>~~

string -> string -> bool

F#

STRATEGY

```
let startsWith prefix (str : string) =
    str.StartsWith prefix

let words = [ "Lorem";      "ipsum"
              "dolor";      "sit"
              "amet";       "consectetur"
              "adipiscing"; "elit" ]
```

F#

STRATEGY

```
let startsWithL = startsWith "L"
words
|> List.filter startsWithL
|> List.iter (printfn "%s")

let startsWithA = startsWith "a"
words
|> List.filter startsWithA
|> List.iter (printfn "%s")
```

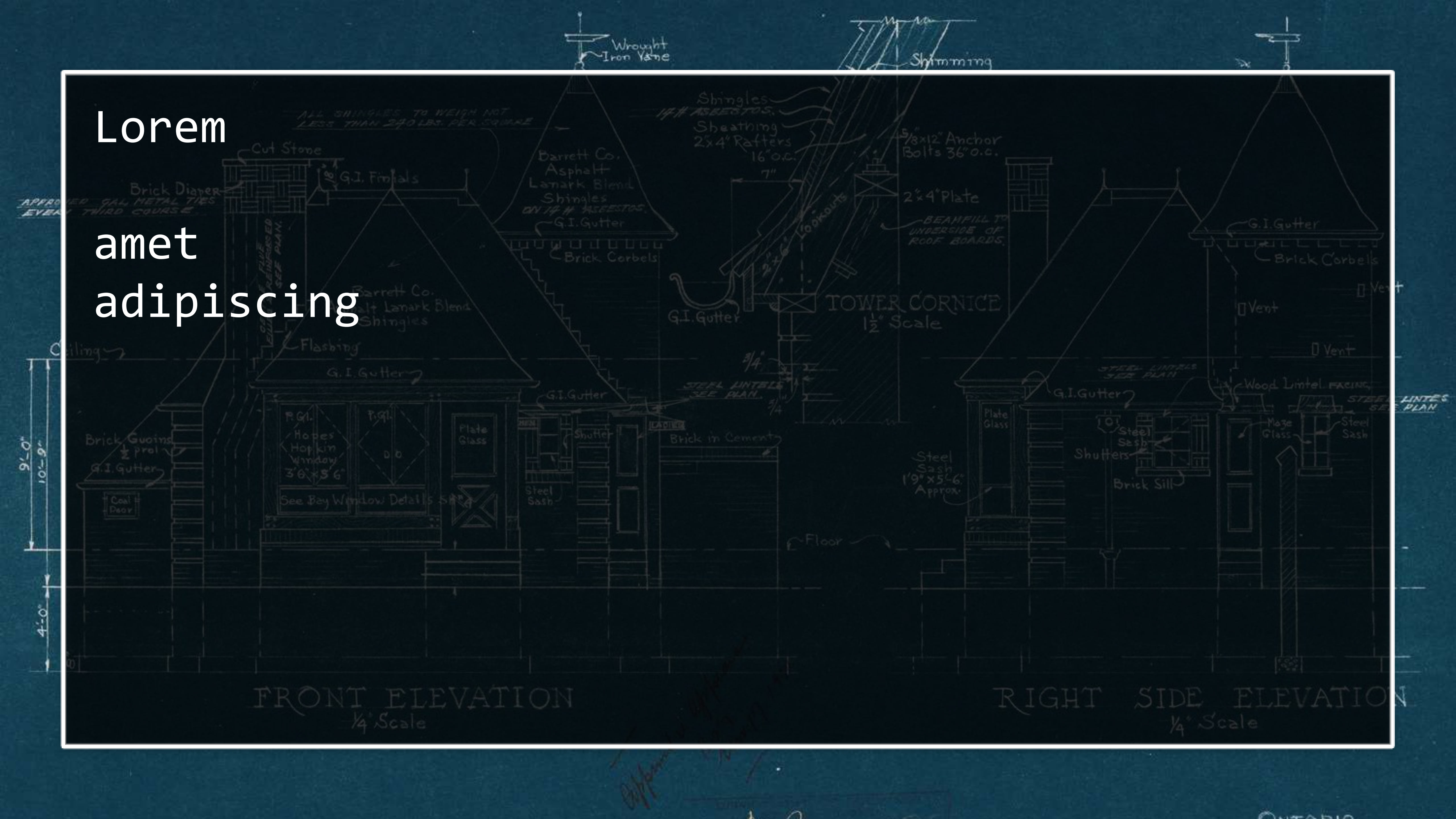
F#

STRATEGY

```
words
|> List.filter (startsWith "L")
|> List.iter (printfn "%s")

words
|> List.filter (startsWith "a")
|> List.iter (printfn "%s")
```

Lorem

amet adipiscing



STRATEGY

C#

```
public class StartsWith
{
    public string Prefix { get; private set; }
    public StartsWith(string prefix)
    {
        Prefix = prefix;
    }
    public bool Test(string sample)
    {
        return sample.StartsWith(Prefix);
    }
}
```

F#

```
let startsWith prefix (str : string) =
    str.StartsWith prefix
```

C#

AN OBSERVATION

```
public class ComplexReImAscComparer : IComparer<Complex>
{
    public int Compare(Complex x, Complex y)
    {
        var re = Math.Sign(x.Re - y.Re);
        return re != 0 ? re : Math.Sign(x.Im - y.Im);
    }
}
```

Just a function

C#

AN OBSERVATION

```
public class StartsWith
{
    public string Prefix { get; private set; }
    public StartsWith(string prefix)
    {
        Prefix = prefix;
    }
    public bool Test(string sample)
    {
        return sample.StartsWith(Prefix);
    }
}
```

A little state

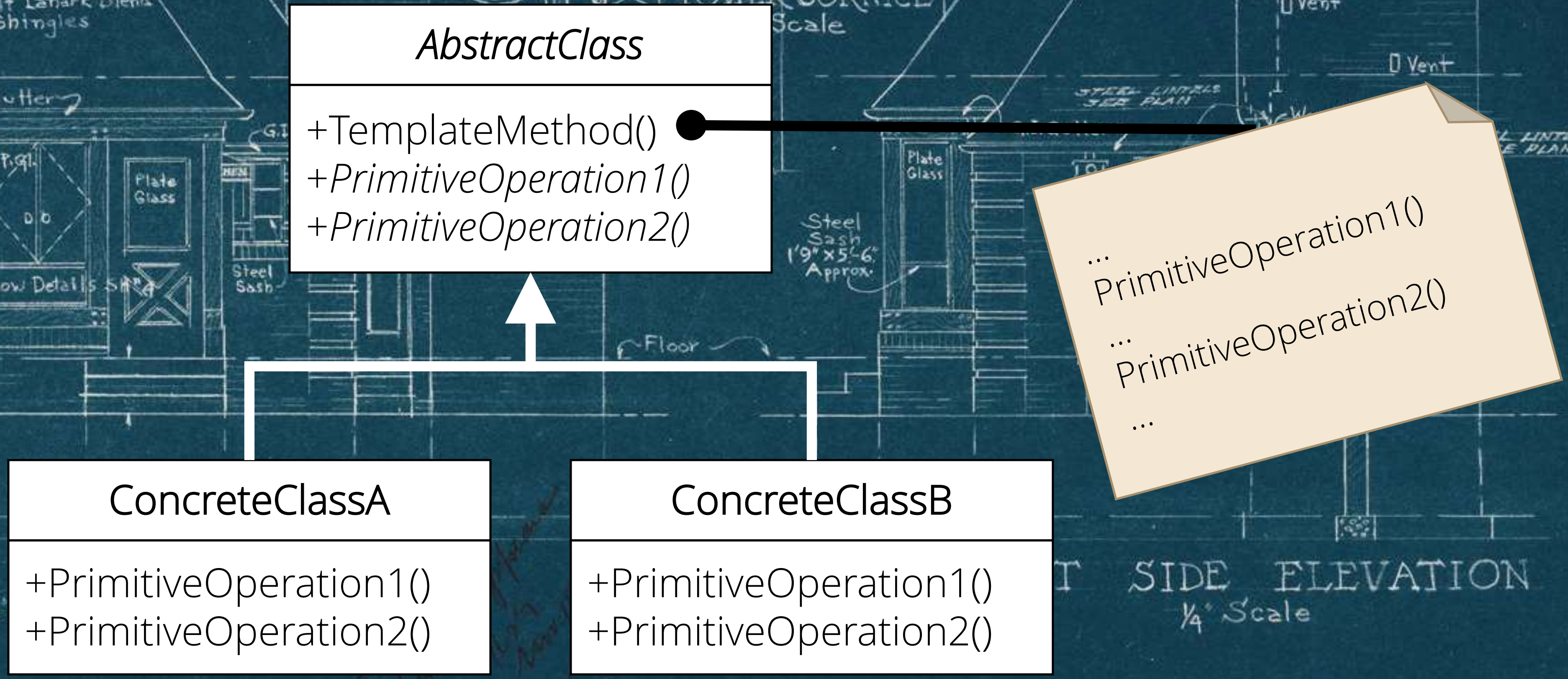
Just a function

> If you have a class with two methods, and one of them is the constructor, you have **a function**.

— @JackDied via @ReidNEvans

emphasis mine

TEMPLATE METHOD



AbstractClass

+TemplateMethod()
+*PrimitiveOperation1()*
+*PrimitiveOperation2()*

ConcreteClassA

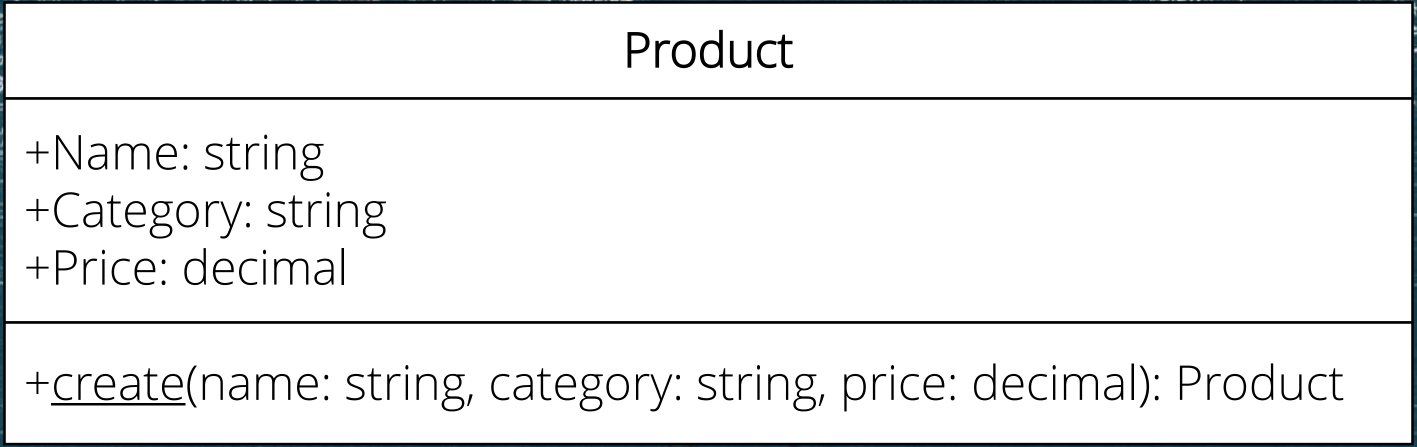
+PrimitiveOperation1()
+PrimitiveOperation2()

ConcreteClassB

+PrimitiveOperation1()
+PrimitiveOperation2()

…
PrimitiveOperation1()
…
PrimitiveOperation2()
…

TEMPLATE METHOD

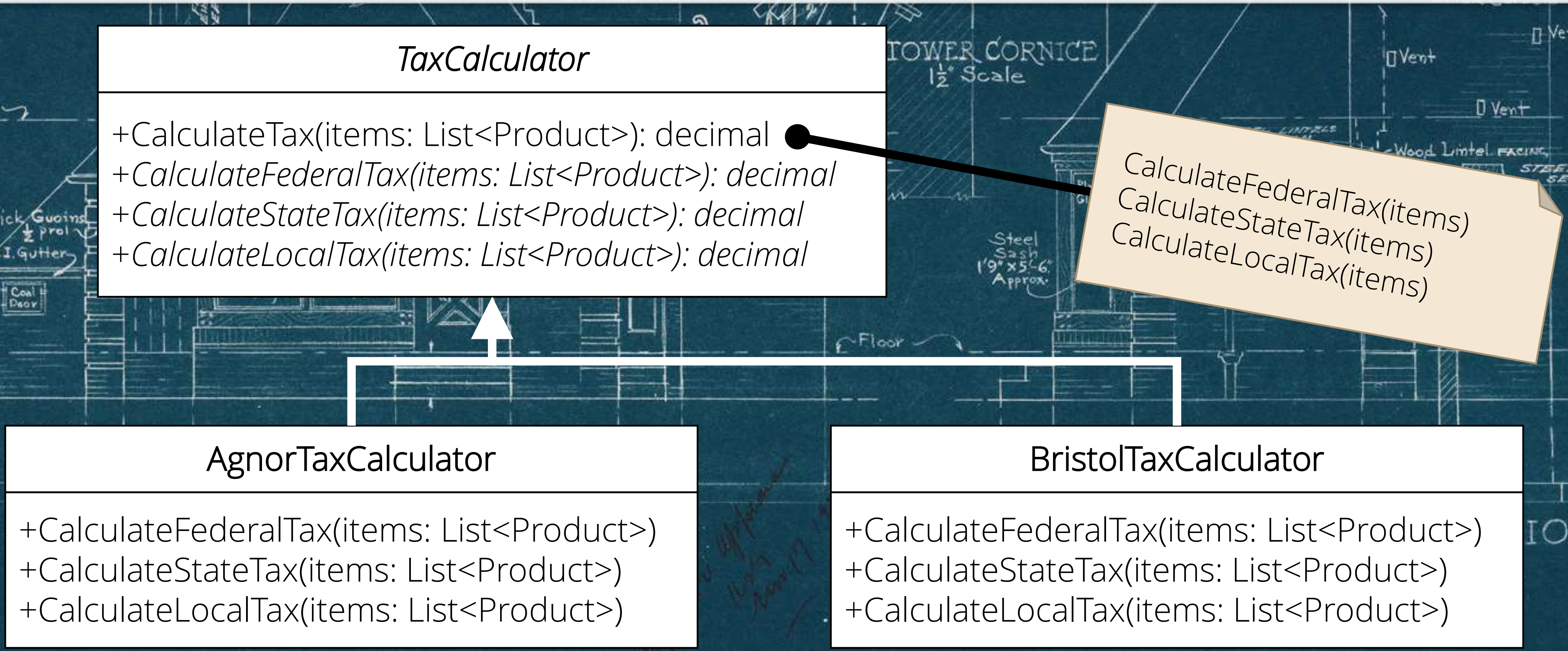


Product

+Name: string
+Category: string
+Price: decimal

+create(name: string, category: string, price: decimal): Product

TEMPLATE METHOD



TaxCalculator

+CalculateTax(items: List<Product>): decimal
+CalculateFederalTax(items: List<Product>): decimal
+CalculateStateTax(items: List<Product>): decimal
+CalculateLocalTax(items: List<Product>): decimal

CalculateFederalTax(items)
CalculateStateTax(items)
CalculateLocalTax(items)

AgnorTaxCalculator

+CalculateFederalTax(items: List<Product>)
+CalculateStateTax(items: List<Product>)
+CalculateLocalTax(items: List<Product>)

BristolTaxCalculator

+CalculateFederalTax(items: List<Product>)
+CalculateStateTax(items: List<Product>)
+CalculateLocalTax(items: List<Product>)

C#

TEMPLATE METHOD

```csharp
public struct Product
{
    public readonly string Name;
    public readonly string Category;
    public readonly decimal Price;
    public Product(string name, string category, decimal price)
    {
        Name = name;
        Category = category;
        Price = price;
    }
}
```

C#

TEMPLATE METHOD

```
public abstract class TaxCalculator
{
    public decimal CalculateTax(List<Product> items)
    {
        return CalculateFederalTax(items)
            + CalculateStateTax(items)
            + CalculateLocalTax(items);
    }
    public abstract decimal CalculateFederalTax(List<Product> items);
    public abstract decimal CalculateStateTax(List<Product> items);
    public abstract decimal CalculateLocalTax(List<Product> items);
}
```

C#

TEMPLATE METHOD

```csharp
public class AgnorTaxCalculator : TaxCalculator
{
    public override decimal CalculateFederalTax(List<Product> items)
    {
        return 0;
    }
    public override decimal CalculateStateTax(List<Product> items)
    {
        const decimal rate = 0.06m;
        var subtotal = 0.0m;
        foreach (var item in items) subtotal += item.Price;
        return subtotal * rate;
    }
}
```

C#

TEMPLATE METHOD

```
public class AgnorTaxCalculator : TaxCalculator
{
    // ...

    public override decimal CalculateLocalTax(List<Product> items)
    {
        const decimal rate = 0.03m;
        var subtotal = 0.0m;
        foreach (var item in items) subtotal += item.Price;
        return subtotal * rate;
    }
}
```

TEMPLATE METHOD

C#

```
public class BristolTaxCalculator : TaxCalculator
{
    public override decimal CalculateFederalTax(List<Product> items)
    {
        const decimal rate = 0.20m;
        var subtotal = 0.0m;
        foreach (var item in items) subtotal += item.Price;
        return subtotal * rate;
    }
    public override decimal CalculateStateTax(List<Product> items)
    {
        return 0;
    }
}
```

C#

TEMPLATE METHOD

```
public class BristolTaxCalculator : TaxCalculator
{
    // ...

    public override decimal CalculateLocalTax(List<Product> items)
    {
        const decimal rate = 0.015m;
        var subtotal = 0.0m;
        foreach (var item in items)
        {
            if (item.Category == "Food" || item.Category == "Medical") continue;
            subtotal += item.Price;
        }
        return subtotal * rate;
    }
}
```

C#

TEMPLATE METHOD

```
var items = new List<Product>()
{
    new Product("Fan",               "Appliance",   19.99m),
    new Product("Nexium",            "Medical",     69.99m),
    new Product("Chicken Thighs",    "Food",         7.99m),
    new Product("Corn Flakes",       "Food",         4.99m),
    new Product("Bed Sheets",        "Linen",      129.99m),
    new Product("Adjustable Wrench", "Hardware",     6.99m),
};
```

C#

TEMPLATE METHOD

```
var subtotal = 0.0m;
foreach (var item in items) subtotal += item.Price;

var agnorTax = new AgnorTaxCalculator().CalculateTax(items);
var bristolTax = new BristolTaxCalculator()
    .CalculateTax(items);

Console.WriteLine("Tax on ${0} of goods in Agnor: ${1:0.00}",
    subtotal, agnorTax);
Console.WriteLine("Tax on ${0} of goods in Bristol: ${1:0.00}",
    subtotal, bristolTax);
```

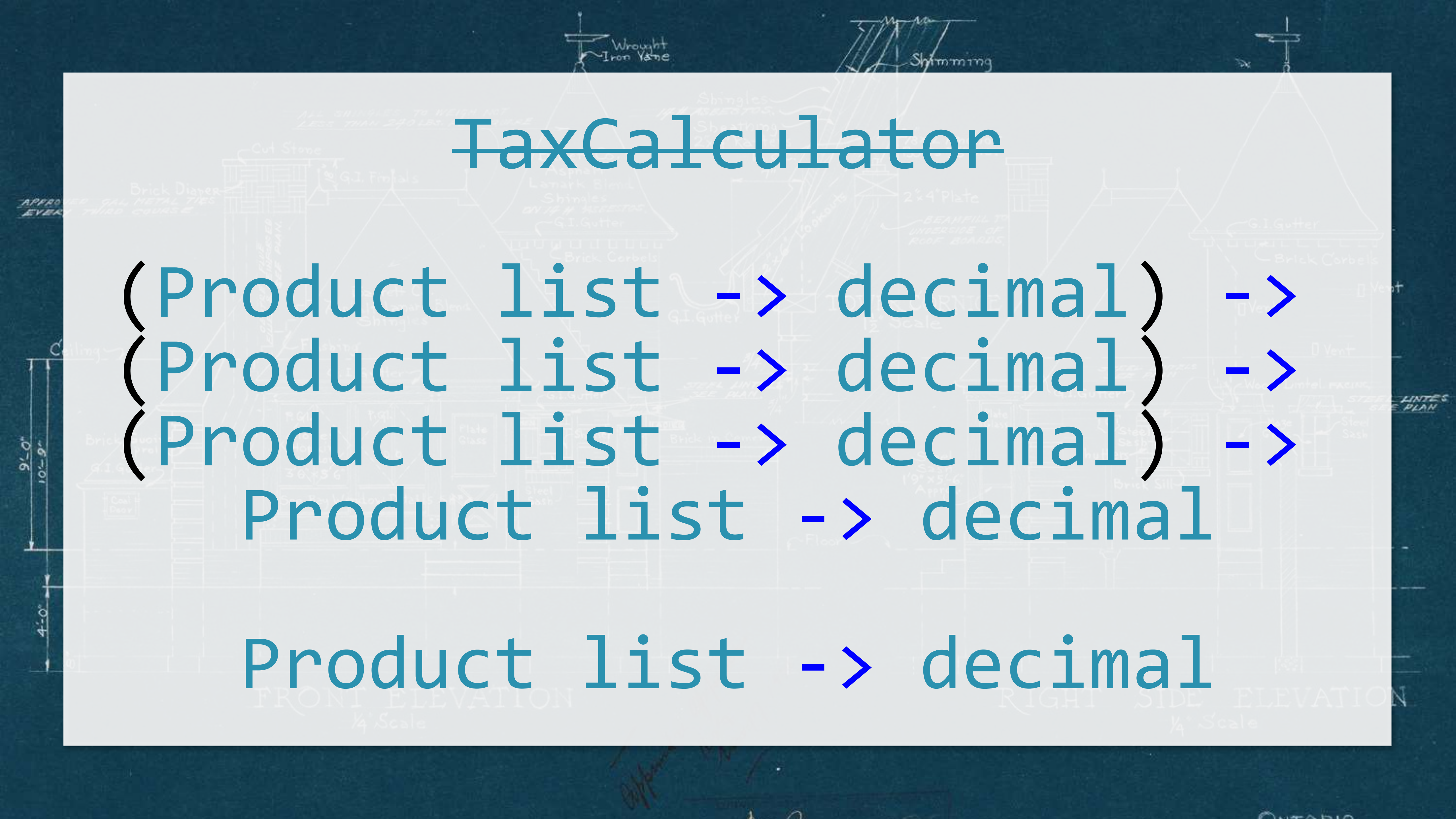
Tax on $239.94 of goods in Agnor: $21.59

Tax on $239.94 of goods in Bristol: $50.34

C#

TEMPLATE METHOD

```
public abstract class TaxCalculator
{
    public decimal CalculateTax(List<Product> items)
    {
        return CalculateFederalTax(items)
            + CalculateStateTax(items)
            + CalculateLocalTax(items);
    }
    public abstract decimal CalculateFederalTax(List<Product> items);
    public abstract decimal CalculateStateTax(List<Product> items);
    public abstract decimal CalculateLocalTax(List<Product> items);
}
public class AgnorTaxCalculator : TaxCalculator
{
    public override decimal CalculateFederalTax(List<Product> items)
    {
        return 0;
    }
    public override decimal CalculateStateTax(List<Product> items)
    {
        const decimal rate = 0.06m;
        var subtotal = 0.0m;
        foreach (var item in items) subtotal += item.Price;
        return subtotal * rate;
    }
    public override decimal CalculateLocalTax(List<Product> items)
    {
        const decimal rate = 0.03m;
        var subtotal = 0.0m;
        foreach (var item in items) subtotal += item.Price;
        return subtotal * rate;
    }
}
```



~~TaxCalculator~~

```
(Product list -> decimal) ->
(Product list -> decimal) ->
(Product list -> decimal) ->
  Product list -> decimal

  Product list -> decimal
```

F#

TEMPLATE METHOD

```fsharp
type Product =
  { Name : string
    Category : string
    Price : decimal }

let calculateTax calcFedTax calcStateTax calcLocalTax items =
    calcFedTax items +
    calcStateTax items +
    calcLocalTax items
```

F#

TEMPLATE METHOD

```
let getPrice item = item.Price
let taxAt rate subtotal = rate * subtotal
let buildTaxCalculator exemptCategories rate =
    let isTaxable item = exemptCategories
                         |> List.contains item.Category
                         |> not

    Seq.filter isTaxable
    >> Seq.map getPrice
    >> Seq.sum
    >> taxAt rate
```

F#

TEMPLATE METHOD

```fsharp
let calculateTaxInAgnor =
    let calcFedTax _ = 0.0m
    let calcStateTax = buildTaxCalculator [] 0.06m
    let calcLocalTax = buildTaxCalculator [] 0.03m

    calculateTax calcFedTax calcStateTax calcLocalTax
```

F#

TEMPLATE METHOD

```fsharp
let calculateTaxInBristol =
    let calcFedTax = buildTaxCalculator [] 0.20m
    let calcStateTax _ = 0.0m
    let calcLocalTax =
        buildTaxCalculator ["Food"; "Medical"] 0.015m

    calculateTax calcFedTax calcStateTax calcLocalTax
```

TEMPLATE METHOD

F#

```
let items = [
  { Name="Fan";               Category="Appliance"; Price= 19.99m }
  { Name="Nexium";            Category="Medical";   Price= 69.99m }
  { Name="Chicken Thighs";    Category="Food";      Price=  7.99m }
  { Name="Corn Flakes";       Category="Food";      Price=  4.99m }
  { Name="Bed Sheets";        Category="Linen";     Price=129.99m }
  { Name="Adjustable Wrench"; Category="Hardware";  Price=  6.99m }
]
```

F#

TEMPLATE METHOD

```
let subtotal = items
               |> Seq.map getPrice
               |> Seq.sum

let agnorTax = calculateTaxInAgnor items
let bristolTax = calculateTaxInBristol items

printfn "Tax on $%.2f of goods in Agnor: $%.2f"
    subtotal agnorTax
printfn "Tax on $%.2f of goods in Bristol: $%.2f"
    subtotal bristolTax
```

Tax on $239.94 of goods in Agnor: $21.59

Tax on $239.94 of goods in Bristol: $50.34

TEMPLATE METHOD

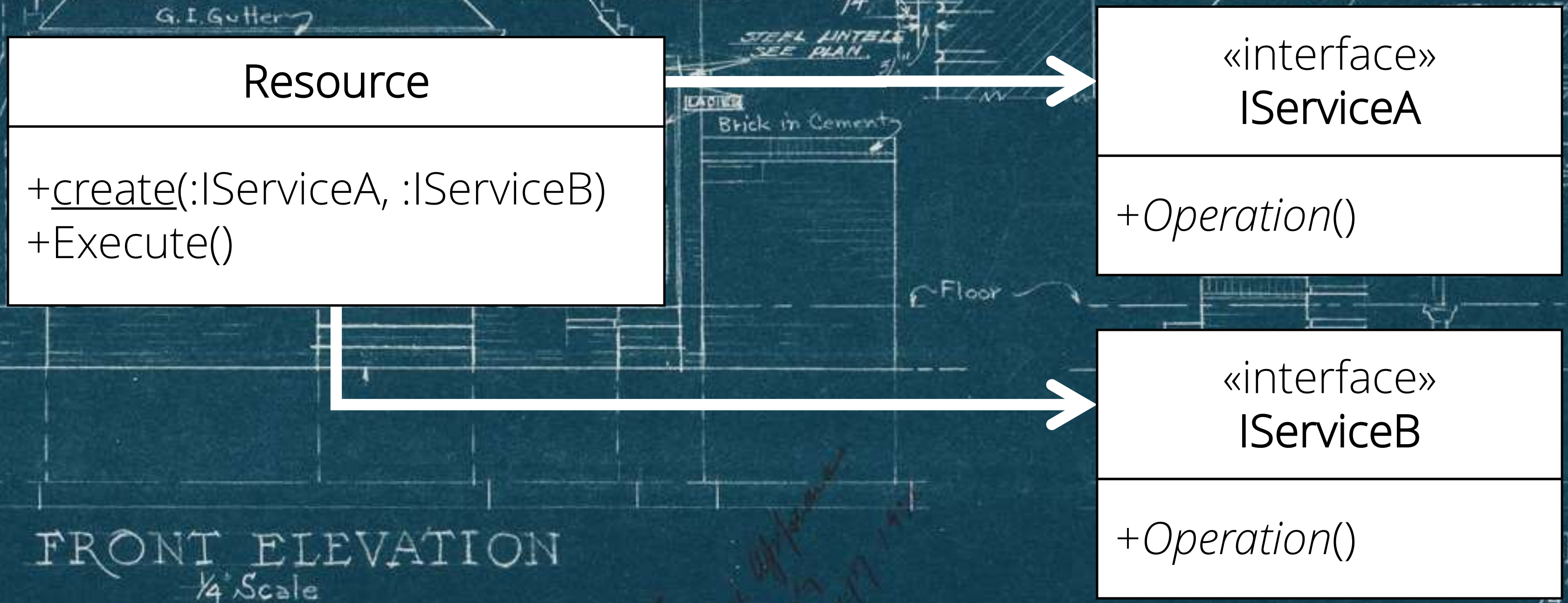
C#

```csharp
public abstract class TaxCalculator
{
    public decimal CalculateTax(List<Product> items)
    {
        return CalculateFederalTax(items)
            + CalculateStateTax(items)
            + CalculateLocalTax(items);
    }
    public abstract decimal CalculateFederalTax(List<Product> items);
    public abstract decimal CalculateStateTax(List<Product> items);
    public abstract decimal CalculateLocalTax(List<Product> items);
}
public class AgnorTaxCalculator : TaxCalculator
{
    public override decimal CalculateFederalTax(List<Product> items)
    {
        return 0;
    }
    public override decimal CalculateStateTax(List<Product> items)
    {
        const decimal rate = 0.06m;
        var subtotal = 0.0m;
        foreach (var item in items) subtotal += item.Price;
        return subtotal * rate;
    }
    public override decimal CalculateLocalTax(List<Product> items)
    {
        const decimal rate = 0.03m;
        var subtotal = 0.0m;
        foreach (var item in items) subtotal += item.Price;
        return subtotal * rate;
    }
}
public class BristolTaxCalculator : TaxCalculator
{
    public override decimal CalculateFederalTax(List<Product> items)
    {
        const decimal rate = 0.20m;
        var subtotal = 0.0m;
        foreach (var item in items) subtotal += item.Price;
        return subtotal * rate;
    }
    public override decimal CalculateStateTax(List<Product> items)
    {
        return 0;
    }
    public override decimal CalculateLocalTax(List<Product> items)
    {
        const decimal rate = 0.015m;
        var subtotal = 0.0m;
        foreach (var item in items)
        {
            if (item.Category == "Food" || item.Category == "Medical") continue;
            subtotal += item.Price;
        }
        return subtotal * rate;
    }
}
```

F#

```fsharp
let calculateTax calcFedTax calcStateTax calcLocalTax items =
    calcFedTax items +
    calcStateTax items +
    calcLocalTax items
let getPrice item = item.Price
let taxAt rate subtotal = rate * subtotal
let buildTaxCalculator exemptCategories rate =
    let isTaxable item = exemptCategories
                         |> List.contains item.Category
                         |> not

    Seq.filter isTaxable
    >> Seq.map getPrice
    >> Seq.sum
    >> taxAt rate
let calculateTaxInAgnor =
     let calcFedTax _ = 0.0m
     let calcStateTax = buildTaxCalculator [] 0.06m
     let calcLocalTax = buildTaxCalculator [] 0.03m

     calculateTax calcFedTax calcStateTax calcLocalTax
 let calculateTaxInBristol =
    let calcFedTax = buildTaxCalculator [] 0.20m
    let calcStateTax _ = 0.0m
    let calcLocalTax =
        buildTaxCalculator ["Food"; "Medical"] 0.015m

    calculateTax calcFedTax calcStateTax calcLocalTax
```

DEPENDENCY INJECTION



Resource

+create(:IServiceA, :IServiceB)
+Execute()

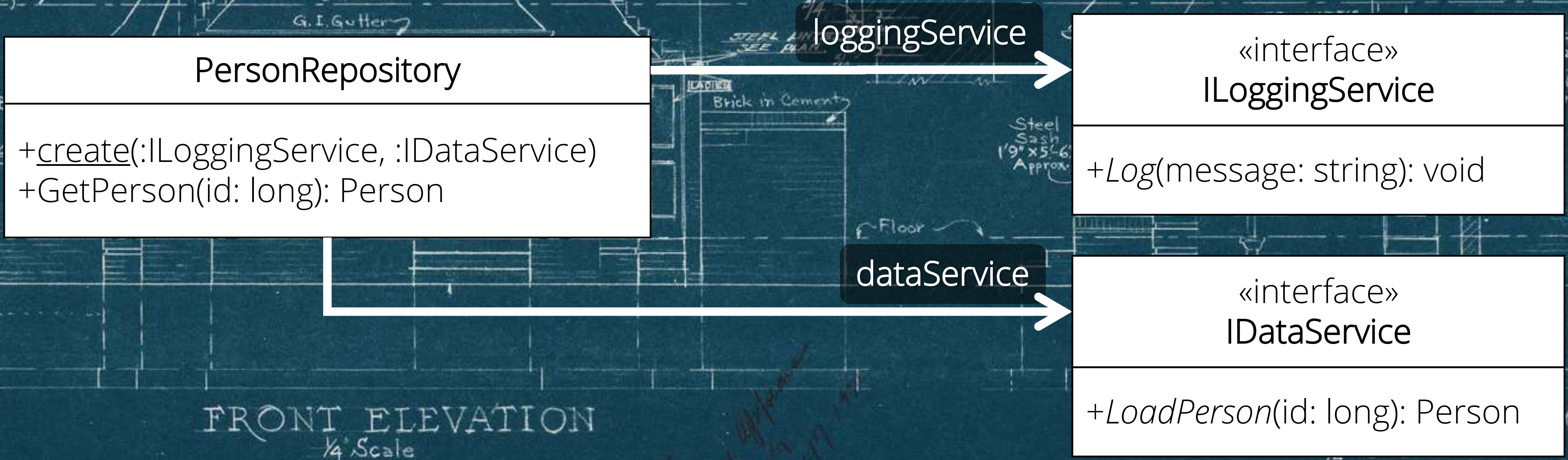
«interface»
IServiceA

+*Operation*()

«interface»
IServiceB

+*Operation*()

DEPENDENCY INJECTION



PersonRepository

+create(:ILoggingService, :IDataService)
+GetPerson(id: long): Person

loggingService

dataService

«interface»
ILoggingService

+*Log*(message: string): void

«interface»
IDataService

+*LoadPerson*(id: long): Person

C#

DEPENDENCY INJECTION

```csharp
public class PersonRepository
{
    private readonly ILoggingService loggingSvc;
    private readonly IDataService dataSvc;
    public PersonRepository(ILoggingService loggingSvc,
                            IDataService dataSvc)
    {
        this.loggingSvc = loggingSvc;
        this.dataSvc = dataSvc;
    }
}
```

C#

DEPENDENCY INJECTION

```
public class PersonRepository
{
    // ...

    public Person GetPerson(long id)
    {
        var person = dataSvc.LoadPerson(id);
        loggingSvc.Log($"Loaded Person: {person?.ToString() ?? "(null)"}");
        return person;
    }
}
```

C#

DEPENDENCY INJECTION

```
public interface ILoggingService
{
    void Log(string message);
}

public class ConsoleLogger : ILoggingService
{
    public void Log(string message)
    {
        Console.WriteLine(message);
    }
}
```

C#

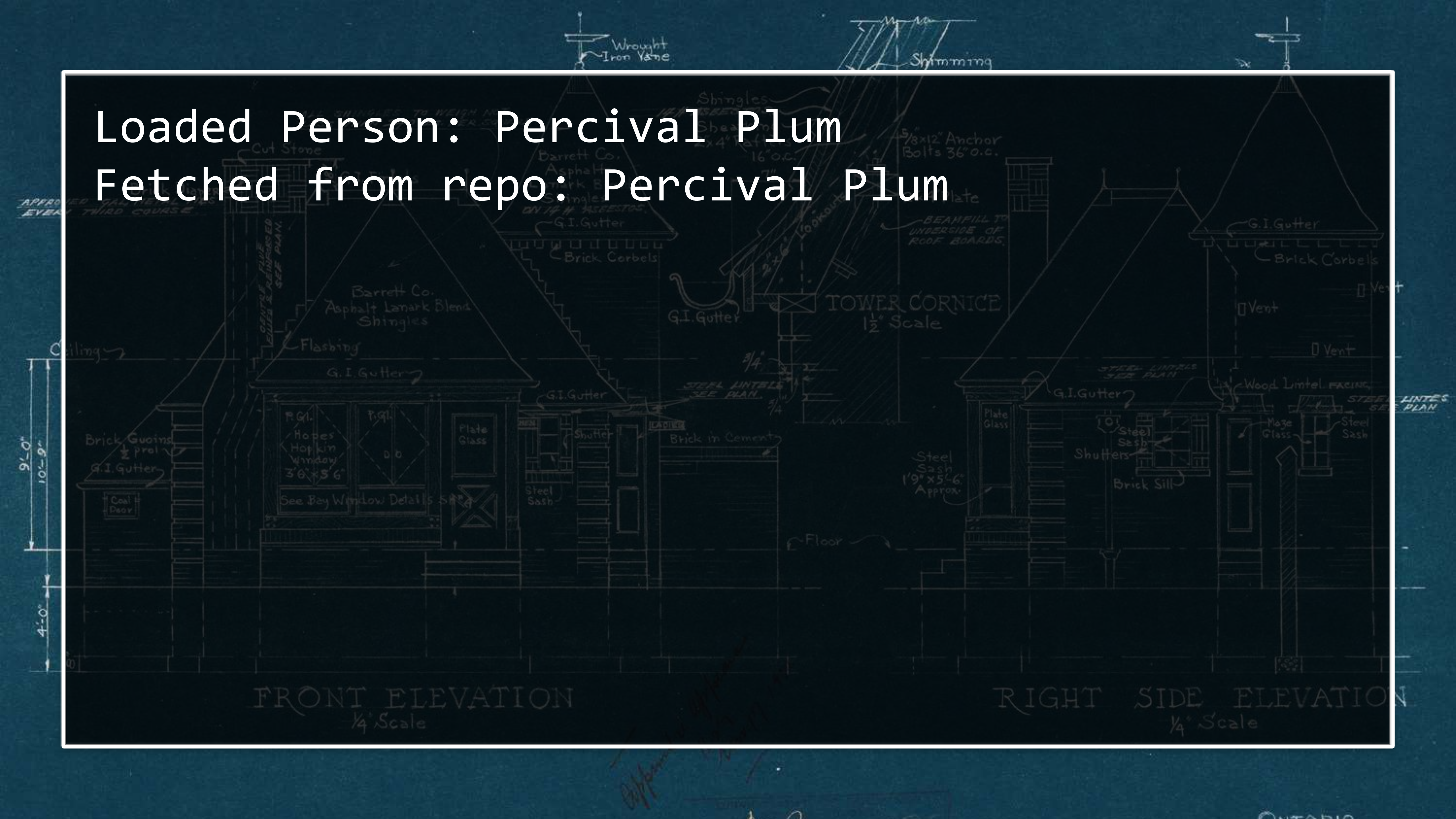
DEPENDENCY INJECTION

```
public interface IDataService
{
    Person LoadPerson(long id);
}

public class SimpleDataService : IDataService
{
    private readonly List<Person> persons = new List<Person>() { /* ... */ };
    public Person LoadPerson(long id)
    {
        return id < persons.Count ? persons[(int)id] : null;
    }
}
```

C#

DEPENDENCY INJECTION

```
var loggerSvc = new ConsoleLogger();
var dataSvc = new SimpleDataService();
var repo = new PersonRepository(loggerSvc, dataSvc);

var person = repo.GetPerson(5);

Console.WriteLine($"Fetched from repo: {person}");
```



```
Loaded Person: Percival Plum
Fetched from repo: Percival Plum
```

C#

DEPENDENCY INJECTION

```
public class PersonRepository
{
    private readonly ILoggingService loggingSvc;
    private readonly IDataService dataSvc;
    public PersonRepository(ILoggingService loggingSvc, IDataService dataSvc)
    {
        this.loggingSvc = loggingSvc;
        this.dataSvc = dataSvc;
    }
    public Person GetPerson(long id)
    {
        var person = dataSvc.LoadPerson(id);
        loggingSvc.Log($"Loaded Person: {person?.ToString() ?? "(null)"}");
        return person;
    }
}
public class ConsoleLogger : ILoggingService
{
    public void Log(string message)
    {
        Console.WriteLine(message);
    }
}
public class SimpleDataService : IDataService
{
    private readonly List<Person> persons = new List<Person>() { /* ... */ };
    public Person LoadPerson(long id)
    {
        return id < persons.Count ? persons[(int)id] : null;
    }
}
```

~~PersonRepository~~

```
(string -> unit) ->
(long -> Person option) ->
long -> Person option

long -> Person option
```

DEPENDENCY INJECTION

F#

```
let repository log loadPerson id =
    let person = loadPerson id
    log (sprintf "Loaded Person: %O" person)
    person

let logger = printfn "%s"
let dataSvc id =
    [  (* ... *) ]
    |> List.tryItem id
```

F#

DEPENDENCY INJECTION

```
let getPerson = repository logger dataSvc
let person = getPerson 5
printfn "Fetched from repo: %O" person
```

```
Loaded Person: Some(Percival Plum)
Fetched from repo: Some(Percival Plum)
```

DEPENDENCY INJECTION

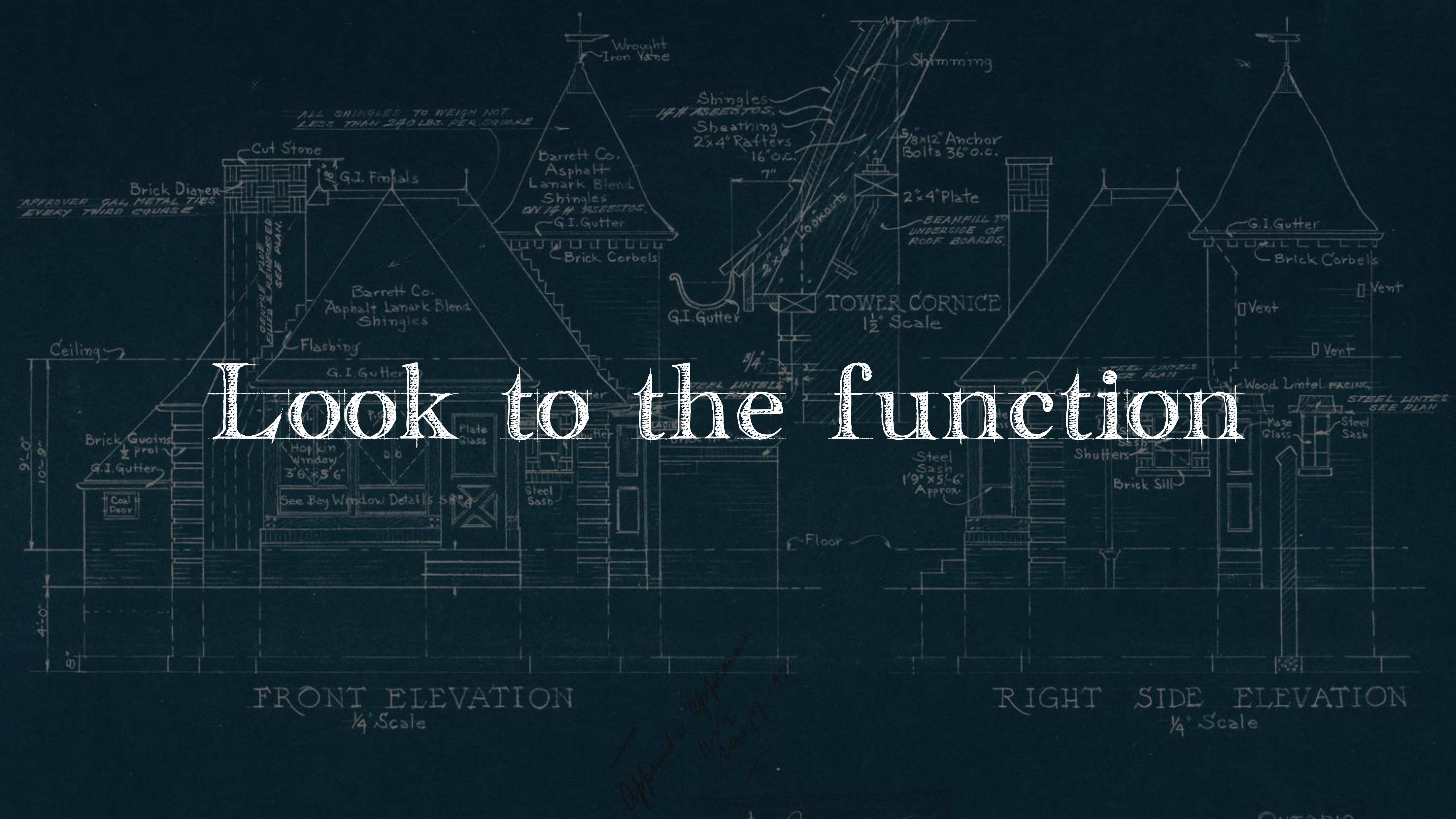
C#

```
public interface ILoggingService
{
    void Log(string message);
}
public interface IDataService
{
    Person LoadPerson(long id);
}
public class PersonRepository
{
    private readonly ILoggingService loggingSvc;
    private readonly IDataService dataSvc;
    public PersonRepository(ILoggingService loggingSvc, IDataService dataSvc)
    {
        this.loggingSvc = loggingSvc;
        this.dataSvc = dataSvc;
    }
    public Person GetPerson(long id)
    {
        var person = dataSvc.LoadPerson(id);
        loggingSvc.Log($"Loaded Person: {person?.ToString() ?? "(null)"}");
        return person;
    }
}
public class ConsoleLogger : ILoggingService
{
    public void Log(string message)
    {
        Console.WriteLine(message);
    }
}
public class SimpleDataService : IDataService
{
    private readonly List<Person> persons = new List<Person>() { /* ... */ };
    public Person LoadPerson(long id)
    {
        return id < persons.Count ? persons[(int)id] : null;
    }
}
```

F#

```
let repository log loadPerson id =
    let person = loadPerson id
    log (sprintf "Loaded Person: %O" person)
    person

let logger = printfn "%s“
let dataSvc id =
    [ (* ... *) ]
    |> List.tryItem id
```

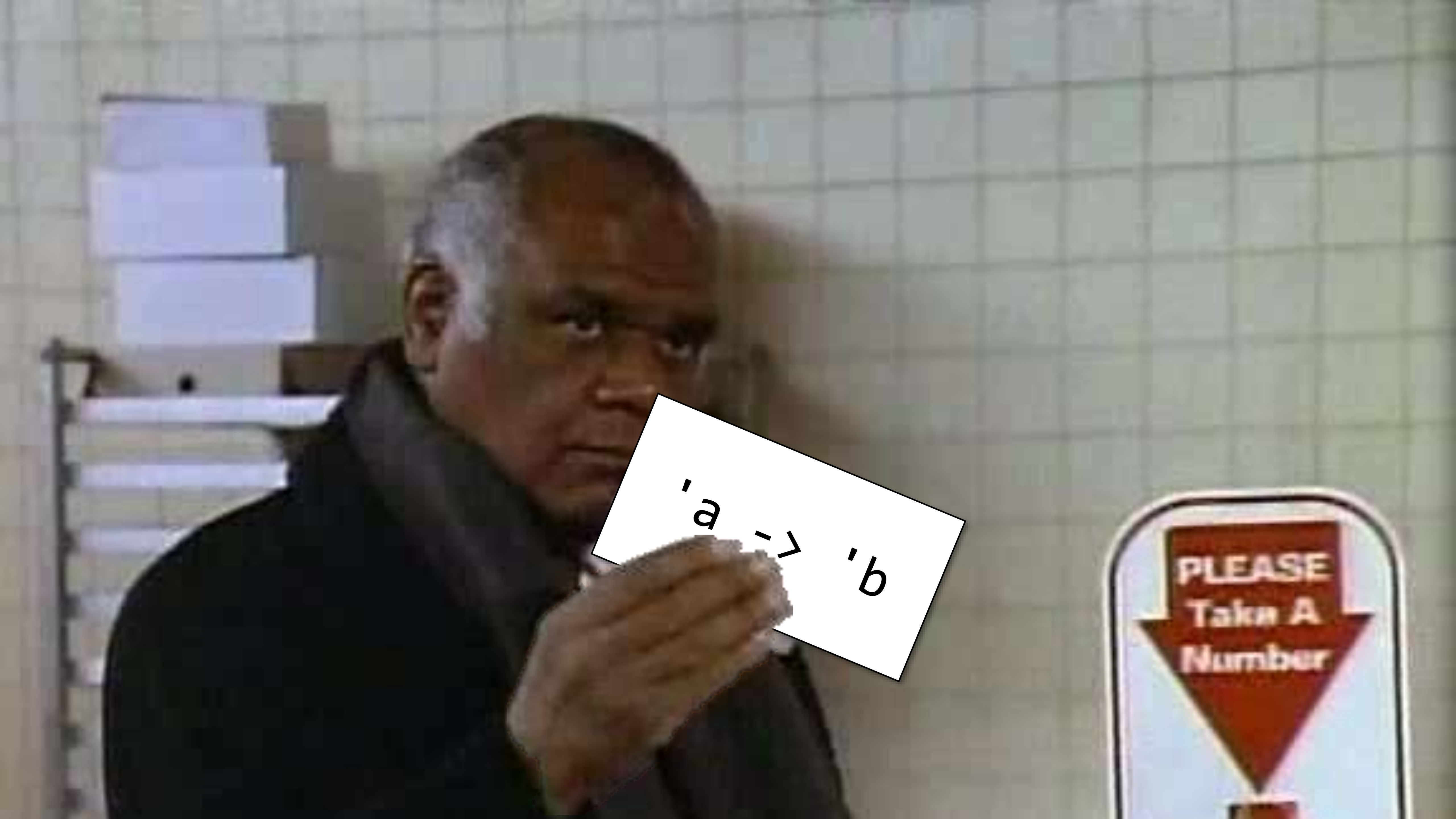
Look to the function

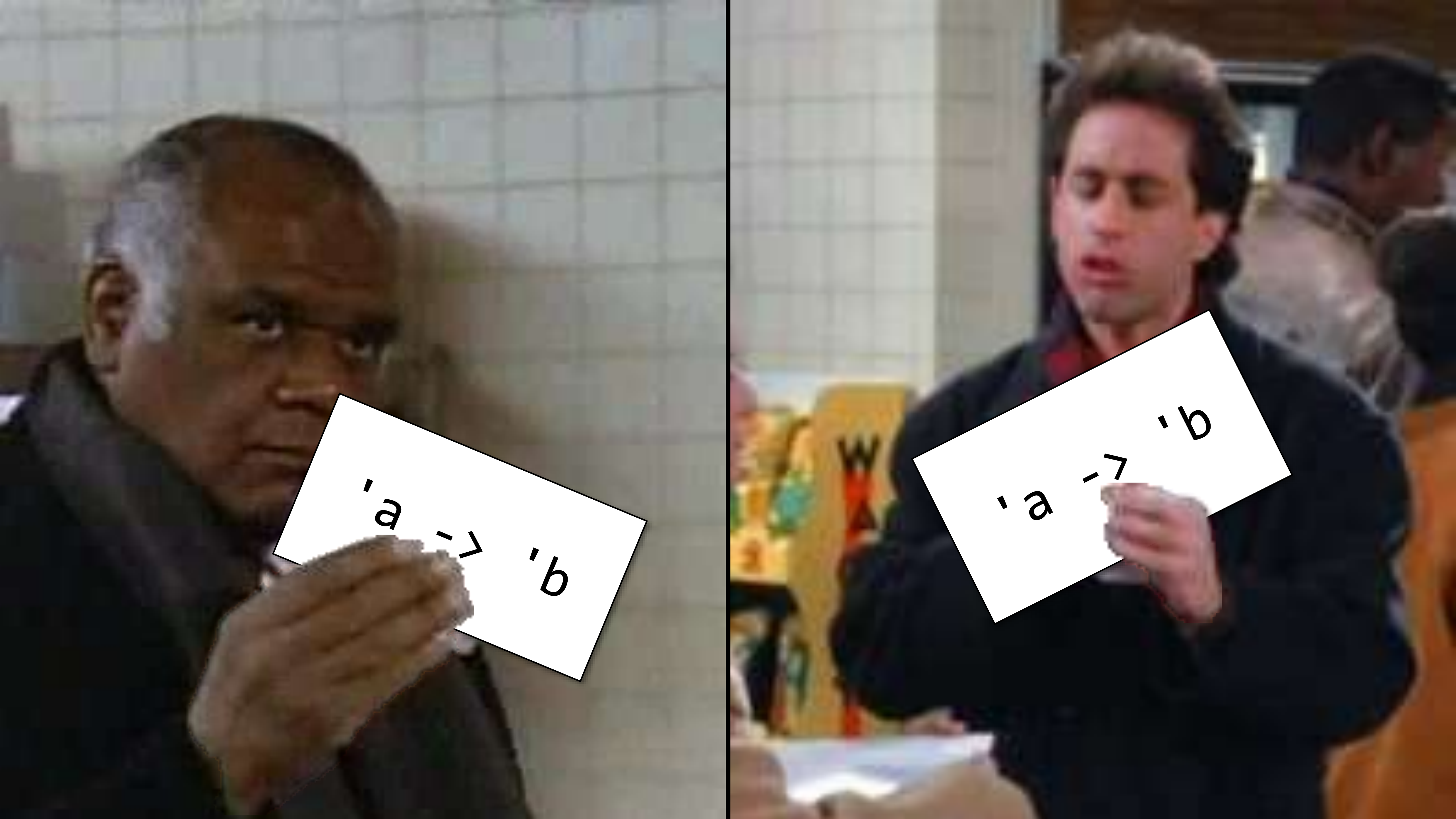


LOOK TO THE FUNCTION

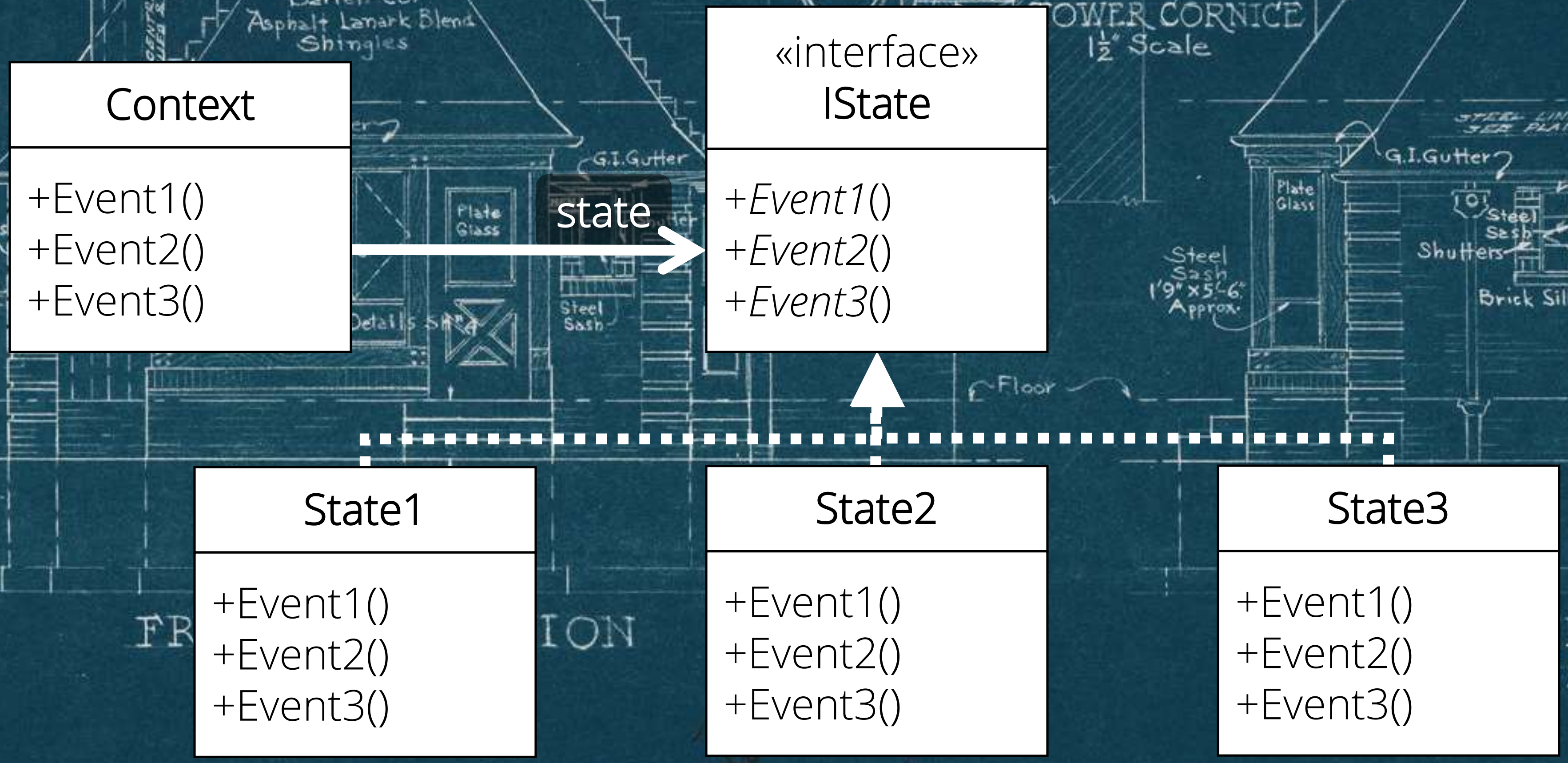
- Pass around as a first-class value
- Load with state/functionality via partial application
- No class baggage: Just a function signature
- Easier testing: Match a function signature, not a class/interface

'a -> 'b


'a -> 'b
PLEASE Take A Number

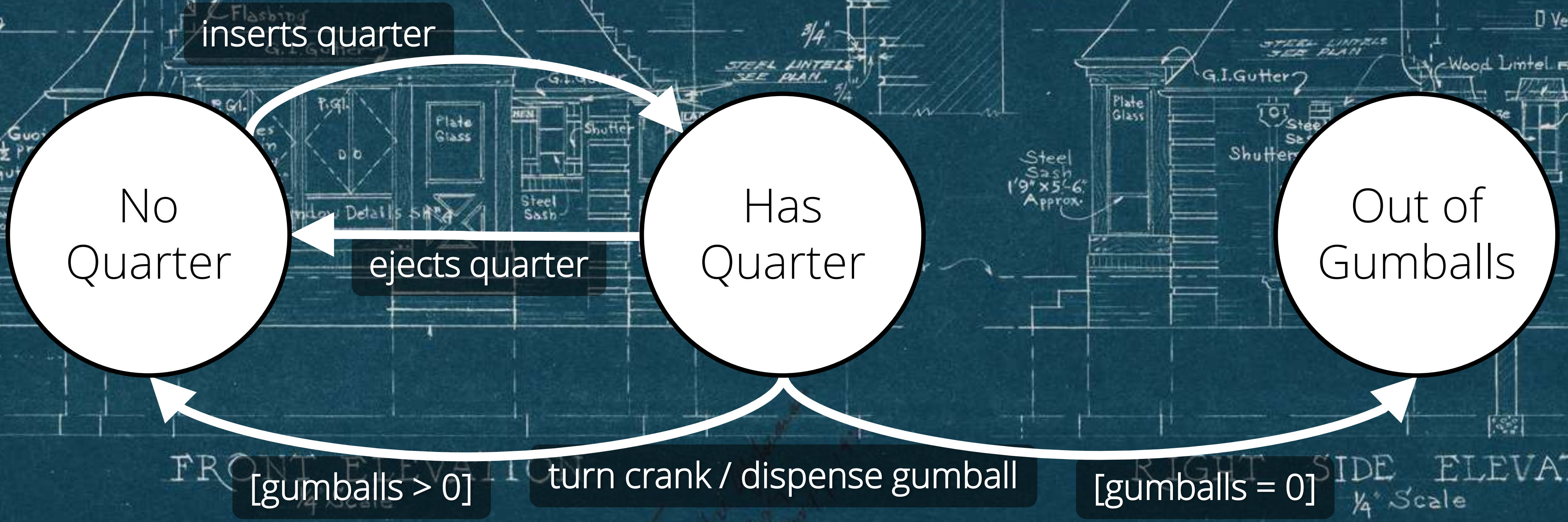

'a -> 'b
'a -> 'b

STATE

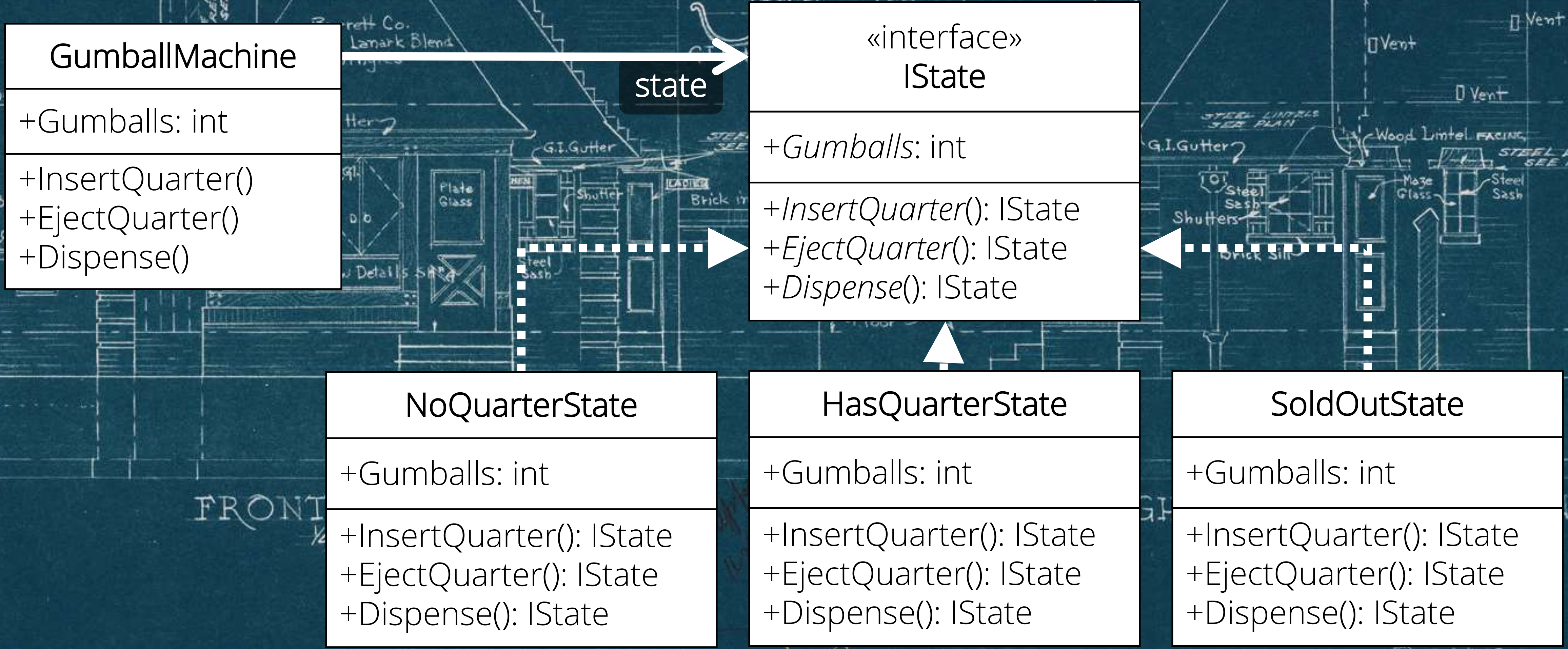


Context
+Event1()
+Event2()
+Event3()
state
«interface»
IState
+*Event1*()
+*Event2*()
+*Event3*()
State1
+Event1()
+Event2()
+Event3()
State2
+Event1()
+Event2()
+Event3()
State3
+Event1()
+Event2()
+Event3()

STATE


No Quarter
Has Quarter
Out of Gumballs
inserts quarter
ejects quarter
turn crank / dispense gumball
[gumballs > 0]
[gumballs = 0]

STATE



GumballMachine

+Gumballs: int

+InsertQuarter()
+EjectQuarter()
+Dispense()

state

«interface»
IState

+*Gumballs*: int

+*InsertQuarter*(): IState
+*EjectQuarter*(): IState
+*Dispense*(): IState

NoQuarterState

+Gumballs: int

+InsertQuarter(): IState
+EjectQuarter(): IState
+Dispense(): IState

HasQuarterState

+Gumballs: int

+InsertQuarter(): IState
+EjectQuarter(): IState
+Dispense(): IState

SoldOutState

+Gumballs: int

+InsertQuarter(): IState
+EjectQuarter(): IState
+Dispense(): IState

C#

STATE

```
public interface IState
{
    int Gumballs { get; }
    IState InsertQuarter();
    IState EjectQuarter();
    IState Dispense();
}
```

C#

STATE

```
public class GumballMachine
{
    private IState state;
    public GumballMachine(int gumballs)
    {
        this.state = new NoQuarterState(gumballs);
    }

    public int Gumballs { get { return state.Gumballs; } }
}
```

C#

STATE

```csharp
public class GumballMachine
{
    // ...
    public void InsertQuarter() { state = state.InsertQuarter(); }
    public void EjectQuarter()  { state = state.EjectQuarter(); }
    public void Dispense()      { state = state.Dispense(); }
    public override string ToString()
    {
        return $"Gumball Machine with {Gumballs} gumballs";
    }
}
```

C#

STATE

```
public class NoQuarterState : IState
{
    public NoQuarterState(int gumballs) { Gumballs = gumballs; }
    public int Gumballs { get; private set; }
    public IState InsertQuarter()
    {
        return new HasQuarterState(Gumballs);
    }
    public IState EjectQuarter() { return this; }
    public IState Dispense() { return this; }
}
```

C#

STATE

```
public class HasQuarterState : IState
{
    public HasQuarterState(int gumballs) { Gumballs = gumballs; }
    public int Gumballs { get; private set; }
    public IState InsertQuarter() { return this; }
    public IState EjectQuarter()
    {
        return new NoQuarterState(Gumballs);
    }
}
```

C#

STATE

```
public class HasQuarterState : IState
{
    // ...

    public IState Dispense()
    {
        return Gumballs == 1
            ? new SoldOutState() as IState
            : new NoQuarterState(Gumballs - 1);
    }
}
```

C#

STATE

```
public class SoldOutState : IState
{
    public int Gumballs { get { return 0; } }
    public IState InsertQuarter() { return this; }
    public IState EjectQuarter() { return this; }
    public IState Dispense() { return this; }
}
```

C#

STATE

```
var machine = new GumballMachine(3);
machine.InsertQuarter();
Console.WriteLine($"After Insert Quarter: {machine}");
machine.Dispense();
Console.WriteLine($"After Dispense: {machine}");
machine.InsertQuarter();
Console.WriteLine($"After Insert Quarter: {machine}");
machine.EjectQuarter();
Console.WriteLine($"After Eject Quarter: {machine}");
// ...
```

```
After Insert Quarter: Gumball Machine with 3 gumballs
After Dispense: Gumball Machine with 2 gumballs
After Insert Quarter: Gumball Machine with 2 gumballs
After Eject Quarter: Gumball Machine with 2 gumballs
After Dispense: Gumball Machine with 2 gumballs
After Insert Quarter: Gumball Machine with 2 gumballs
After Dispense: Gumball Machine with 1 gumballs
After Insert Quarter: Gumball Machine with 1 gumballs
After Dispense: Gumball Machine with 0 gumballs
After Insert Quarter: Gumball Machine with 0 gumballs
After Dispense: Gumball Machine with 0 gumballs
```

F#

STATE

```
type State =
| NoQuarter of int
| HasQuarter of int
| SoldOut

type Event =
| InsertQuarter
| EjectQuarter
| Dispense
```

F#

STATE

```
let execute event state =
    match event, state with
    | InsertQuarter, NoQuarter n -> HasQuarter n
    | EjectQuarter, HasQuarter n -> NoQuarter n
    | Dispense, HasQuarter gumballs ->
        match gumballs with
        | 1 -> SoldOut
        | _ -> NoQuarter (gumballs - 1)
    | _ -> state
```

F#

STATE

```
let events = [ InsertQuarter
               Dispense
               InsertQuarter
               EjectQuarter
               Dispense
               InsertQuarter
               Dispense
               InsertQuarter
               Dispense
               InsertQuarter
               Dispense ]
```

F#

STATE

```fsharp
let init = EjectQuarter, NoQuarter 3
events
|> Seq.scan (fun current event ->
                let _, state = current
                event, execute event state)
            init
|> Seq.skip 1
|> Seq.iter (fun (evt, state) ->
                printfn "%A -> %A" evt state)
```

```
InsertQuarter -> HasQuarter 3
Dispense -> NoQuarter 2
InsertQuarter -> HasQuarter 2
EjectQuarter -> NoQuarter 2
Dispense -> NoQuarter 2
InsertQuarter -> HasQuarter 2
Dispense -> NoQuarter 1
InsertQuarter -> HasQuarter 1
Dispense -> SoldOut
InsertQuarter -> SoldOut
Dispense -> SoldOut
```

STATE

C#

```
public interface Istate
{
    int Gumballs { get; }
    IState InsertQuarter();
    IState EjectQuarter();
    IState Dispense();
}
public class NoQuarterState : Istate
{
    public NoQuarterState(int gumballs) { Gumballs = gumballs; }
    public int Gumballs { get; private set; }
    public IState InsertQuarter() { return new HasQuarterState(Gumballs); }
    public IState EjectQuarter() { return this; }
    public IState Dispense() { return this; }
}
public class HasQuarterState : Istate
{
    public HasQuarterState(int gumballs) { Gumballs = gumballs; }
    public int Gumballs { get; private set; }
    public IState InsertQuarter() { return this; }
    public IState EjectQuarter() { return new NoQuarterState(Gumballs); }
    public IState Dispense()
    {
        return Gumballs == 1 ? new SoldOutState() as IState : new NoQuarterState(Gumballs - 1);
    }
}
public class SoldOutState : Istate
{
    public int Gumballs { get { return 0; } }
    public IState InsertQuarter() { return this; }
    public IState EjectQuarter() { return this; }
    public IState Dispense() { return this; }
}
public class GumballMachine
{
    private IState state;
    public GumballMachine(int gumballs) { this.state = new NoQuarterState(gumballs); }
    public int Gumballs { get { return state.Gumballs; } }
    public void InsertQuarter() { state = state.InsertQuarter(); }
    public void EjectQuarter() { state = state.EjectQuarter(); }
    public void Dispense() { state = state.Dispense(); }
    public override string ToString() { return $"Gumball Machine with {Gumballs} gumballs"; }
}
```

F#

```
type State =
| NoQuarter of int
| HasQuarter of int
| SoldOut

type Event =
| InsertQuarter
| EjectQuarter
| Dispense

let execute event state =
    match event, state with
    | InsertQuarter, NoQuarter n -> HasQuarter n
    | EjectQuarter, HasQuarter n -> NoQuarter n
    | Dispense, HasQuarter gumballs ->
        match gumballs with
        | 1 -> SoldOut
        | _ -> NoQuarter (gumballs - 1)
    | _ -> state
```

STATE

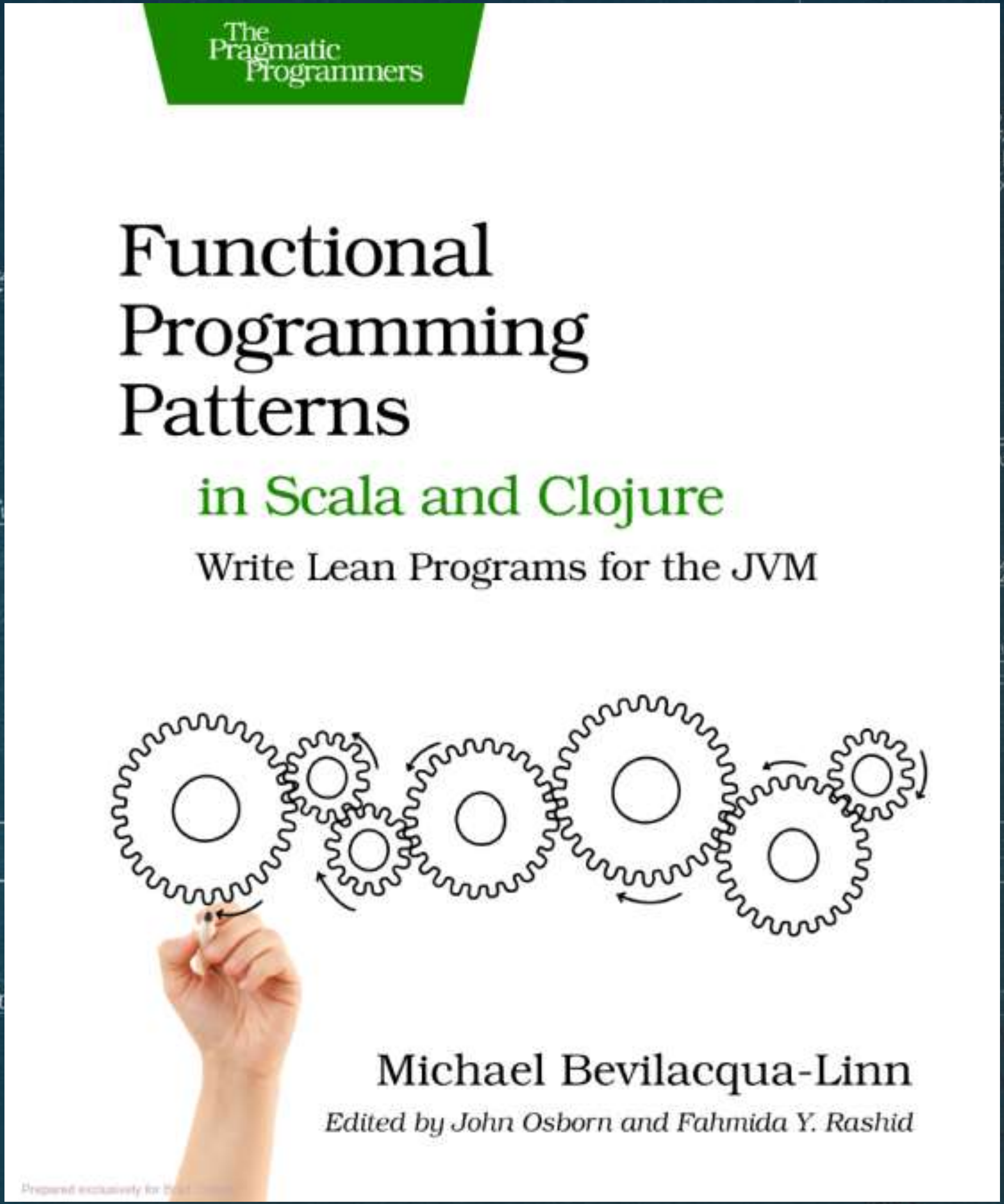
- Discriminated unions:
  - Poor man’s inheritance/polymorphism
  - Represent events as values instead of method calls
- Pattern matching:
  - Handle catch-all/default cases all in one place
  - Compiler fails to compile if all cases are not covered

SUMMARY

- Look to the function
- Use partial application to load functions with state
- Use discriminated unions for polymorphic values and represent events as values
- Use pattern matching to employ the compiler as guarantee that all cases are covered

OTHER EXAMPLES

- Visitor
- Composite
- Adapter
- Null Object



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Functional Programming Patterns

in Scala and Clojure

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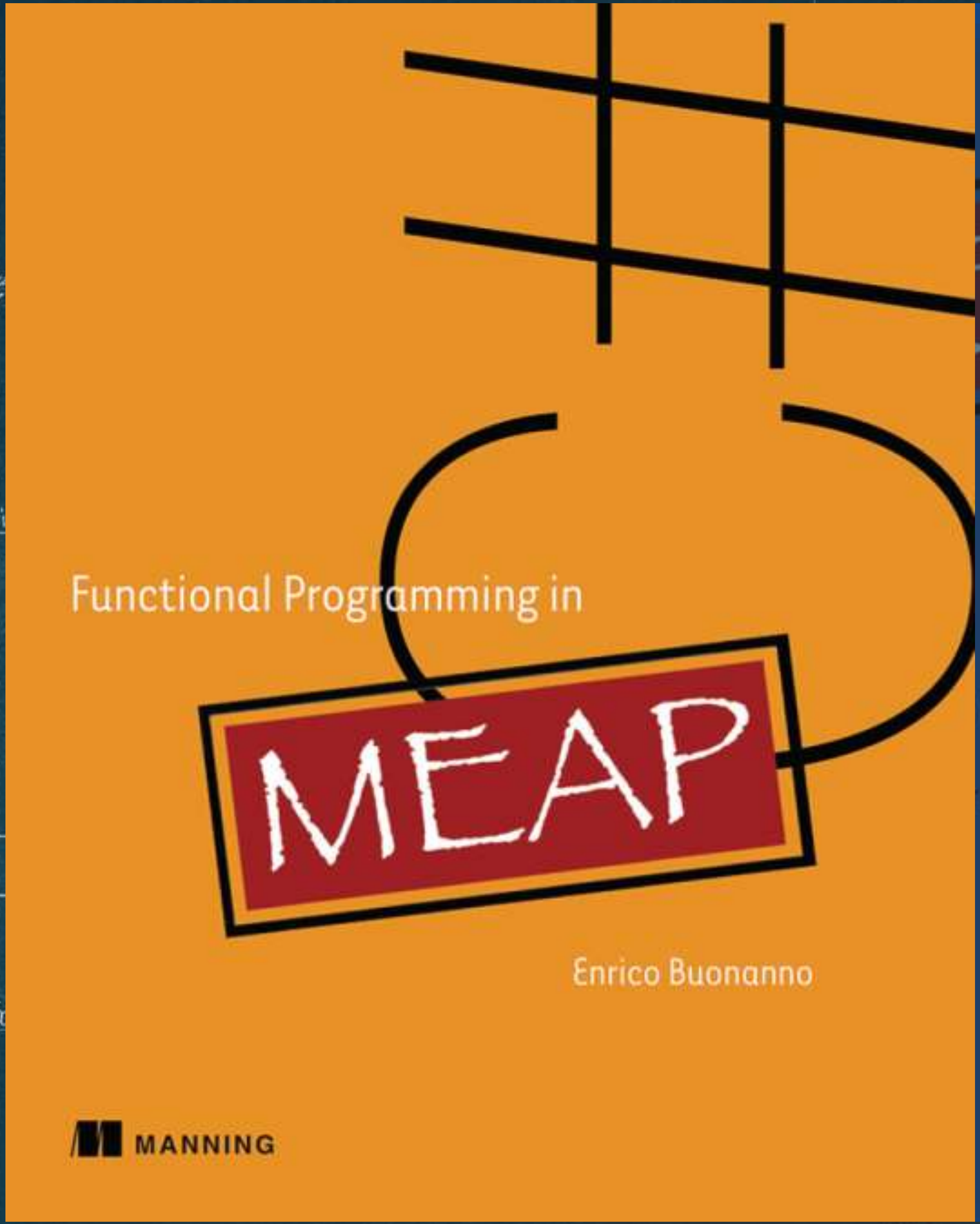
Michael Bevilacqua-Linn

Edited by John Osborn and Fahmida Y. Rashid

- Additional examples
- Gentle introduction to Scala & Clojure

Can’t do F# at work?



C#

Functional Programming in

MEAP

Enrico Buonanno

MANNING

EAP

Java

in

ograms using functional techniques

Pierre-Yves Saumont

Atencio

JavaScript

nming in

t programs using functional techniques

```
int(*func)(int, int)

int (Class::*method)(int, int)
```

```
int(*func)(int, int)

int (Class::*method)(int, int)

Func<int, int, int> func

function func(x,y) { /*...*/ }
```

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