Design Principles and Design Patterns

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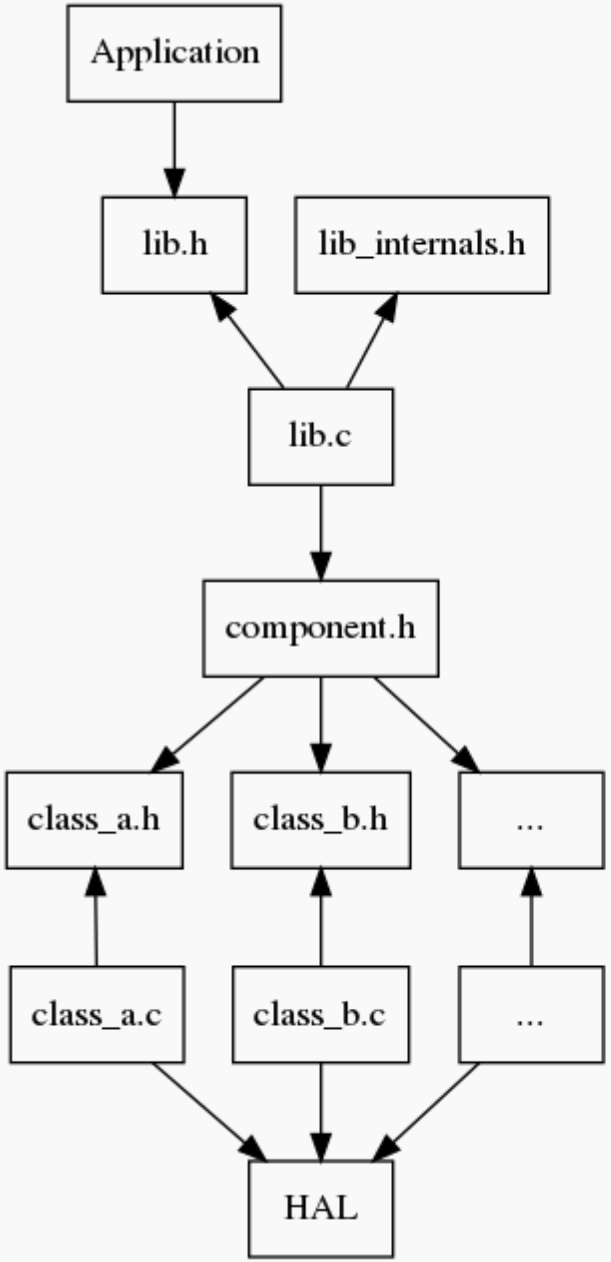
Outline

Introduction

Architecture and Dependencies



User's application code

Library code

Low level code,
written by implementor

Symptoms of Rotting Design

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1. Rigidity

Symptoms of Rotting Design

1. Rigidity
2. Fragility

Symptoms of Rotting Design

1. Rigidity
2. Fragility
3. Immobility

Symptoms of Rotting Design

1. Rigidity
2. Fragility
3. Immobility
4. Viscosity

Rigidity

Rigidity

- Deficient in or devoid of flexibility

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- Software for which extra effort is expended in order to make changes.

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- Deficient in or devoid of flexibility
- Software for which extra effort is expended in order to make changes.
- The system is hard to change because every change forces many other changes to other parts of the system.

Rigidity

How it happens

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- Overly procedural code

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- Lack of abstractions

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- Spreading a single responsibility throughout several parts

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How it happens

- Overly procedural code
- Lack of abstractions
- Solving a generic problem with implementation specific details
- Spreading a single responsibility throughout several parts
- When components need a lot of knowledge about each other in order to function

Rigidity

```
1  #include <stdint.h>
2
3  #define ADC_BITS (12)
4  #define ADC_DATA_SHIFT (2)
5  #define ADC_SIGN_CONVERSION (1)
6  #define RAW_ADC_BITS (15) // Sum of the above bits
7
8  #define LFSR_LENGTH (4)
9  #define LFSR_REPEATS (2)
10 #define CORRELATED_BITS (20) // ADC bits + lfsr length + log2(repeats)
11
12 typedef int16_t rpo_raw_adc_t;
13 typedef int24_t rpo_correlated_int_t;
14
15 #if sizeof(rpo_raw_adc_t) < (RAW_ADC_BITS / 2 + 1)
16 #    error "rpo_raw_adc_t is too small to store ADC results"
17 #endif
18
19 #if sizeof(rpo_correlated_int_t) < (RAW_ADC_BITS / 2 + 1)
20 #    error "rpo_correlated_int_t is too small to store correlated adc results"
21 #endif
```

Rigidity

```
1  #include <stdint.h>
2
3  #define ADC_BITS (14) // Changing this
4  #define ADC_DATA_SHIFT (2)
5  #define ADC_SIGN_CONVERSION (1)
6  #define RAW_ADC_BITS (17) // Changes this
7
8  #define LFSR_LENGTH (4)
9  #define LFSR_REPEATS (2)
10 #define CORRELATED_BITS (22) // Changes this
11
12 typedef int24_t rpo_raw_adc_t; // Changes this
13 typedef int24_t rpo_correlated_int_t;
14
15 #if sizeof(rpo_raw_adc_t) < (RAW_ADC_BITS / 2 + 1)
16 #    error "rpo_raw_adc_t is too small to store ADC results"
17 #endif
18
19 #if sizeof(rpo_correlated_int_t) < (RAW_ADC_BITS / 2 + 1)
20 #    error "rpo_correlated_int_t is too small to store correlated adc results"
21 #endif
```

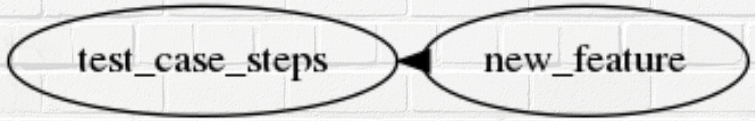
Rigidity

Refactor to reduce rigidity

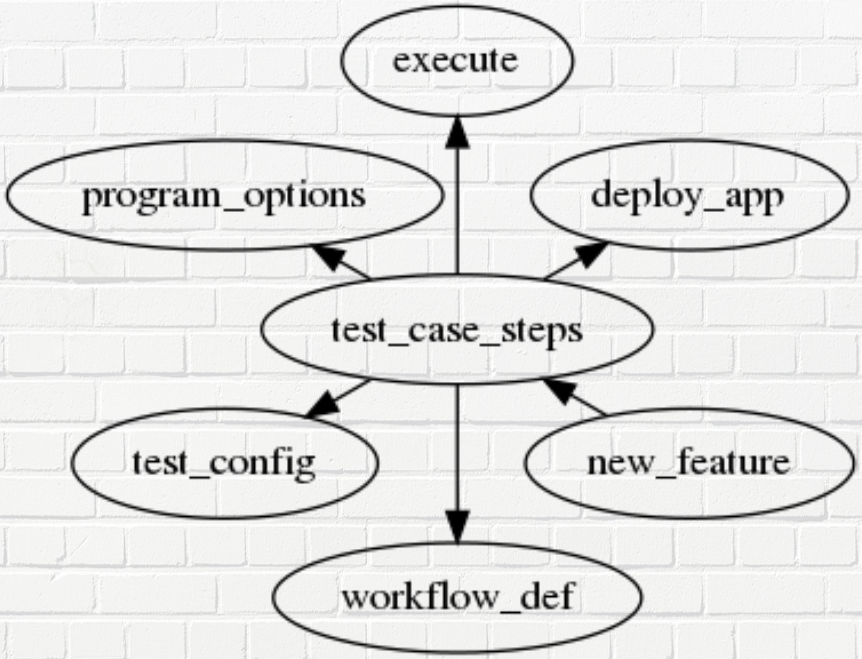
```
1  #include <stdint.h>
2
3  #define ADC_BITS (14)
4  #define ADC_DATA_SHIFT (2)
5  #define ADC_SIGN_CONVERSION (1)
6  #define RAW_ADC_BITS (ADC_BITS + ADC_DATA_SHIFT + ADC_SIGN_CONVERSION)
7  typedef_min_int(rpo_raw_adc_t, RAW_ADC_BITS);
8
9  #define LFSR_LENGTH (4)
10 #define LFSR_REPEATS (2)
11 #define CORRELATED_BITS (RAW_ADC_BITS + LFSR_LENGTH + log_2(LFSR_REPEATS))
12 typedef_min_int(rpo_correlated_int_t, CORRELATED_BITS);
```

Rigidity

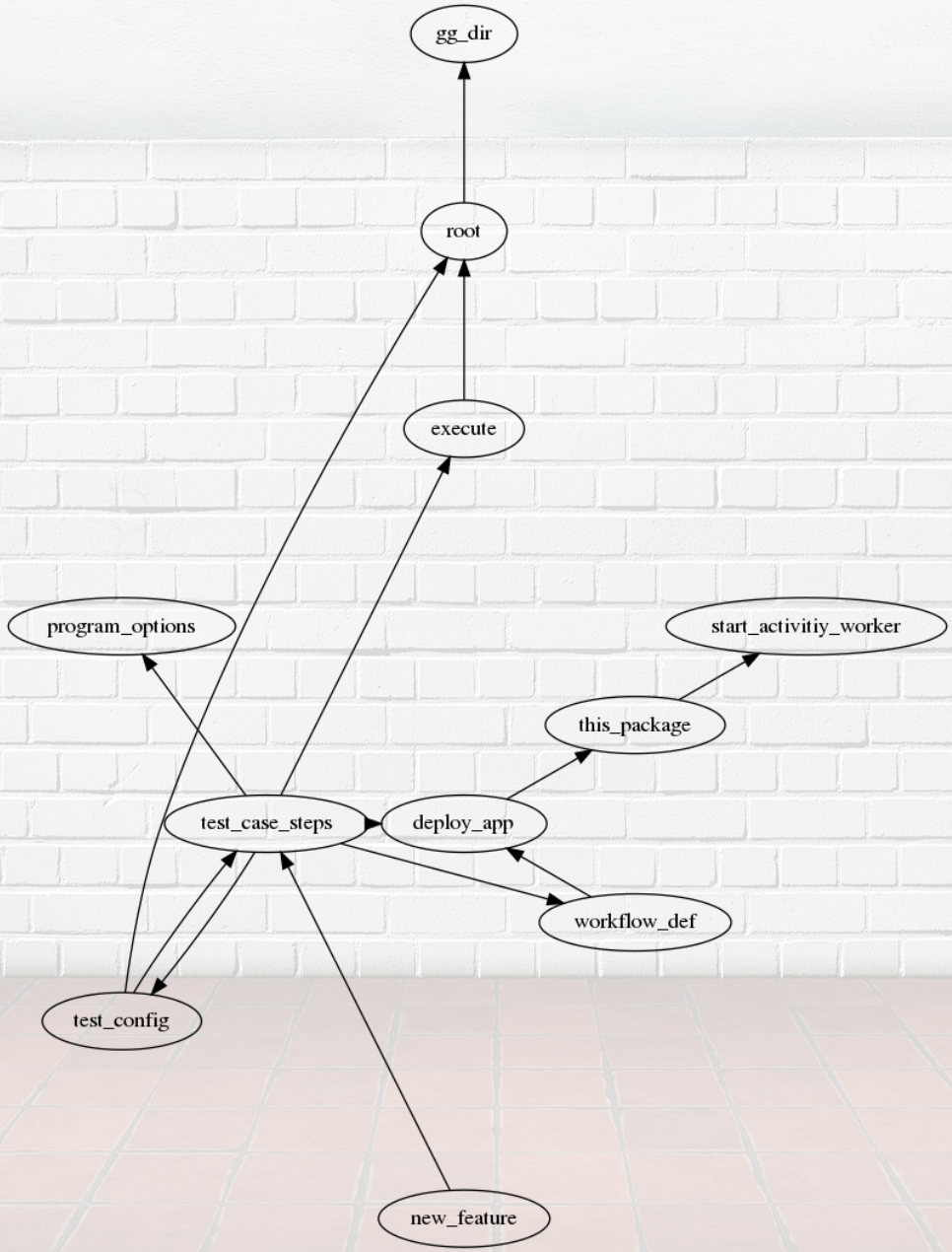
Rigidity



Rigidity


execute
program_options
deploy_app
test_case_steps
test_config
new_feature
workflow_def

Rigidity


gg_dir
root
execute
program_options
start_activitiy_worker
this_package
test_case_steps
deploy_app
workflow_def
test_config
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Rigidity

How to avoid it

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- Break the code into smaller, self-contained concepts

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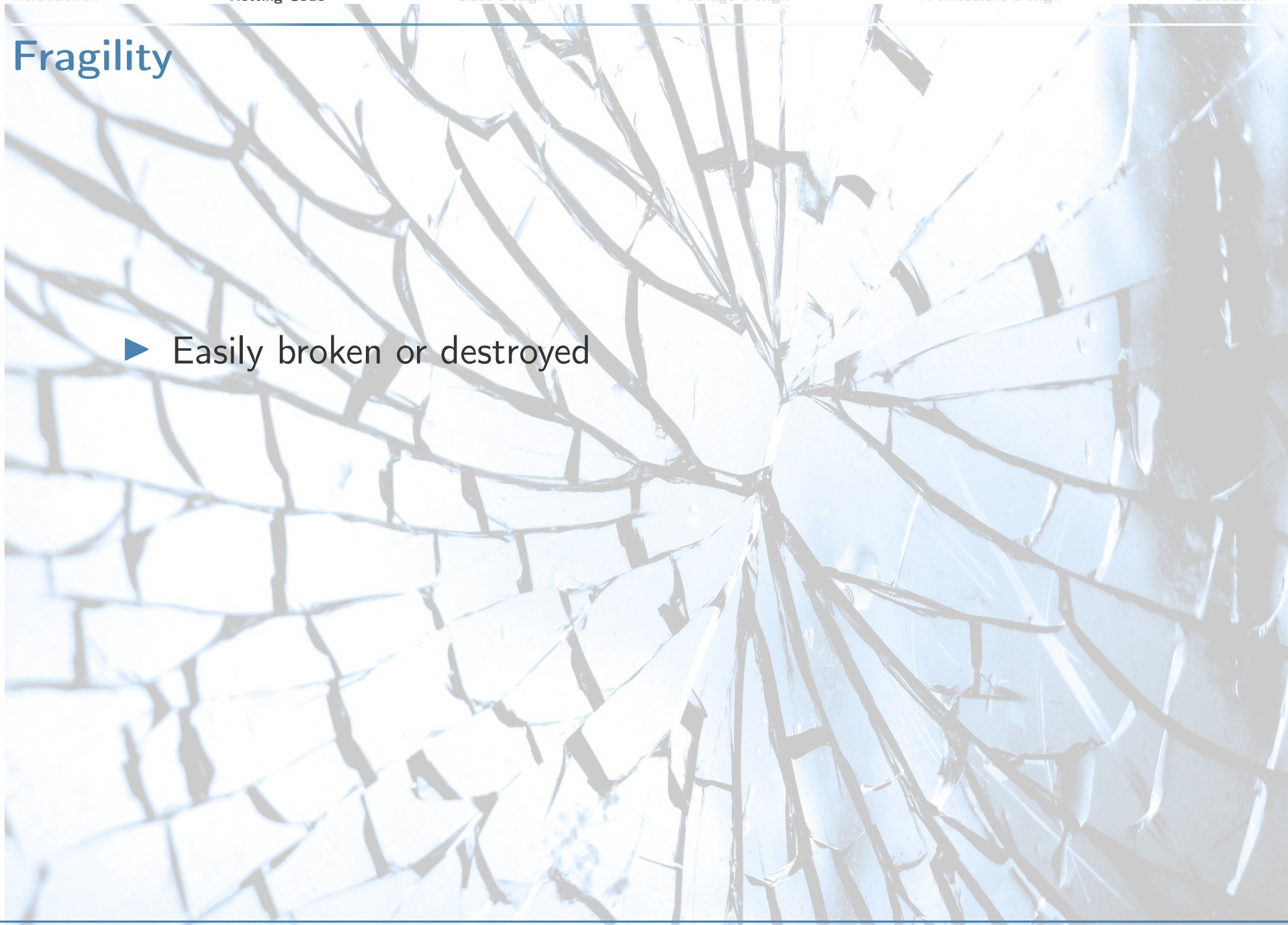
Rigidity

How to avoid it

- Break the code into smaller, self-contained concepts
- Solve the details and provide a problem oriented abstraction
- Solving a generic problem with implementation specific details
- Write DRY code (Don't repeat yourself)
- Define the code in logical pieces. Set boundaries and responsibilities.

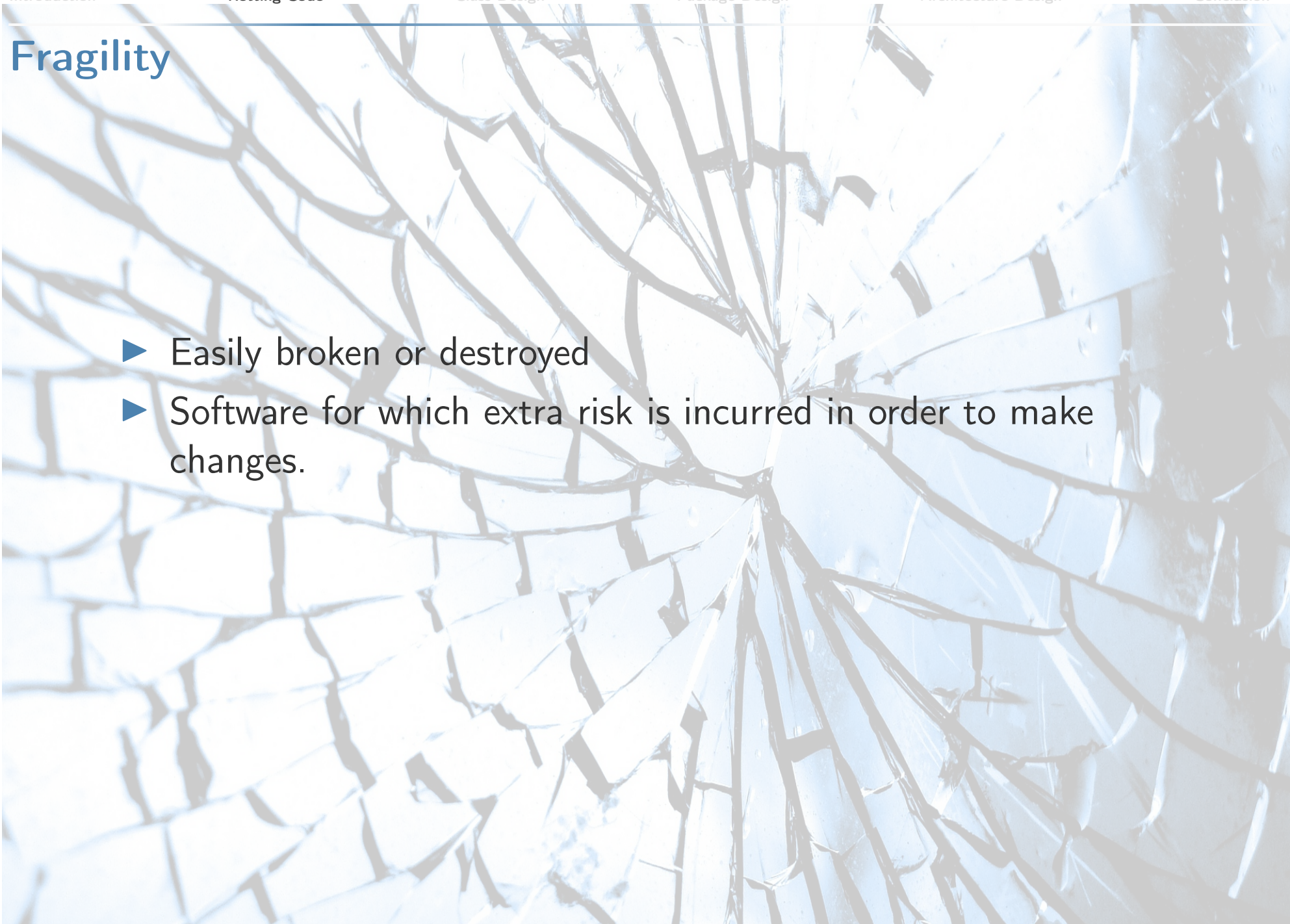
Fragility

Fragility



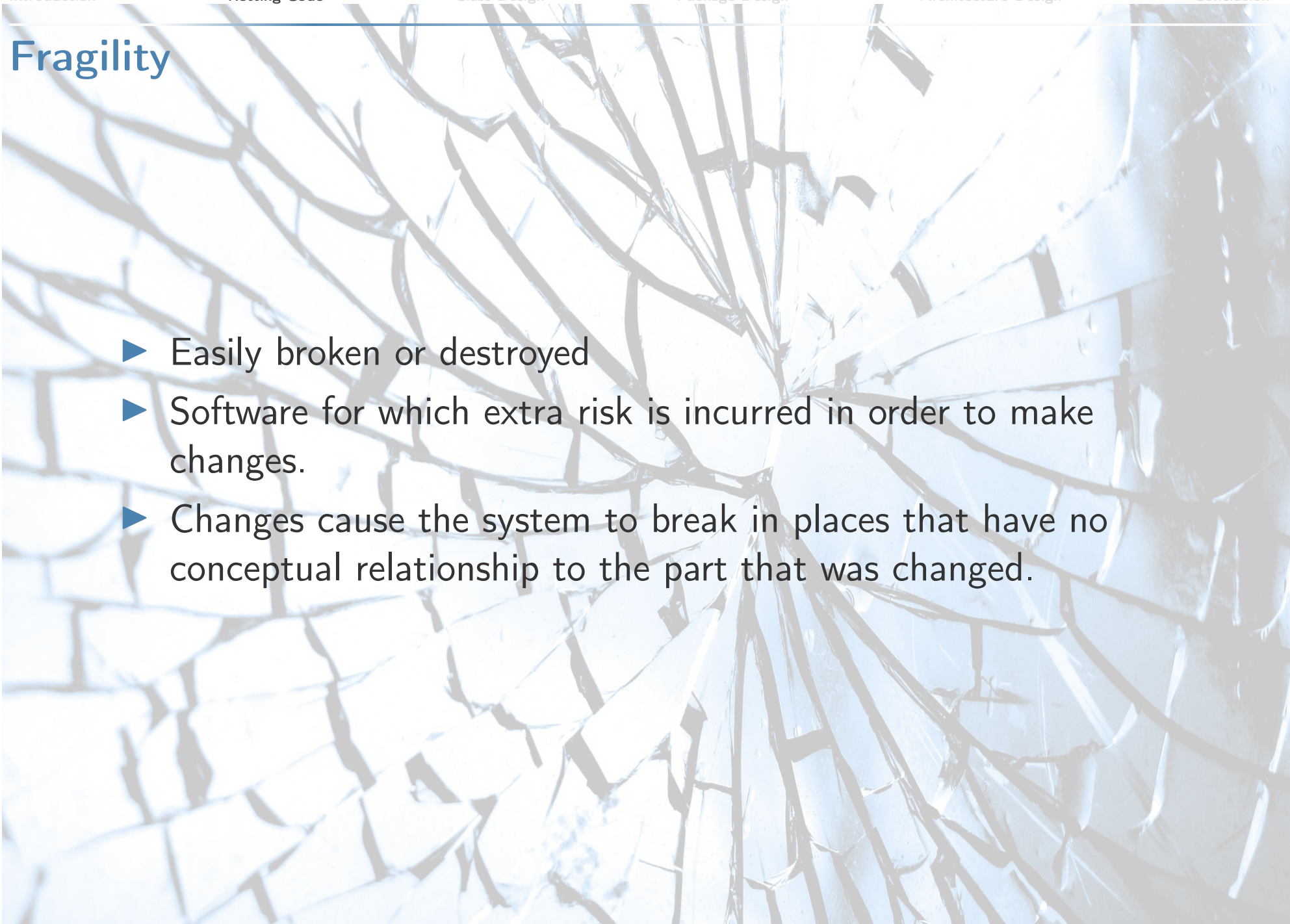
- Easily broken or destroyed

Fragility



- Easily broken or destroyed
- Software for which extra risk is incurred in order to make changes.

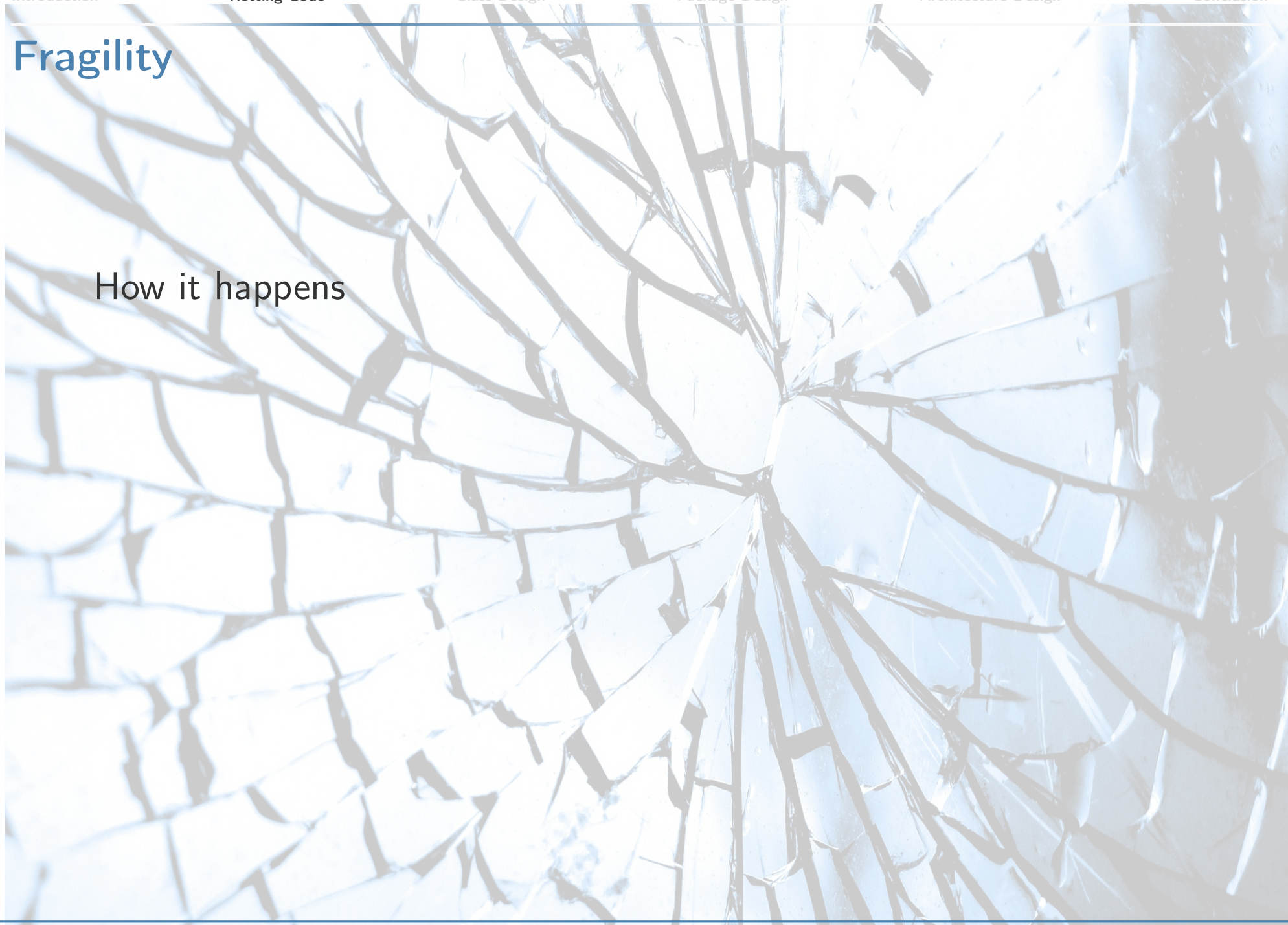
Fragility



- Easily broken or destroyed
- Software for which extra risk is incurred in order to make changes.
- Changes cause the system to break in places that have no conceptual relationship to the part that was changed.

Fragility

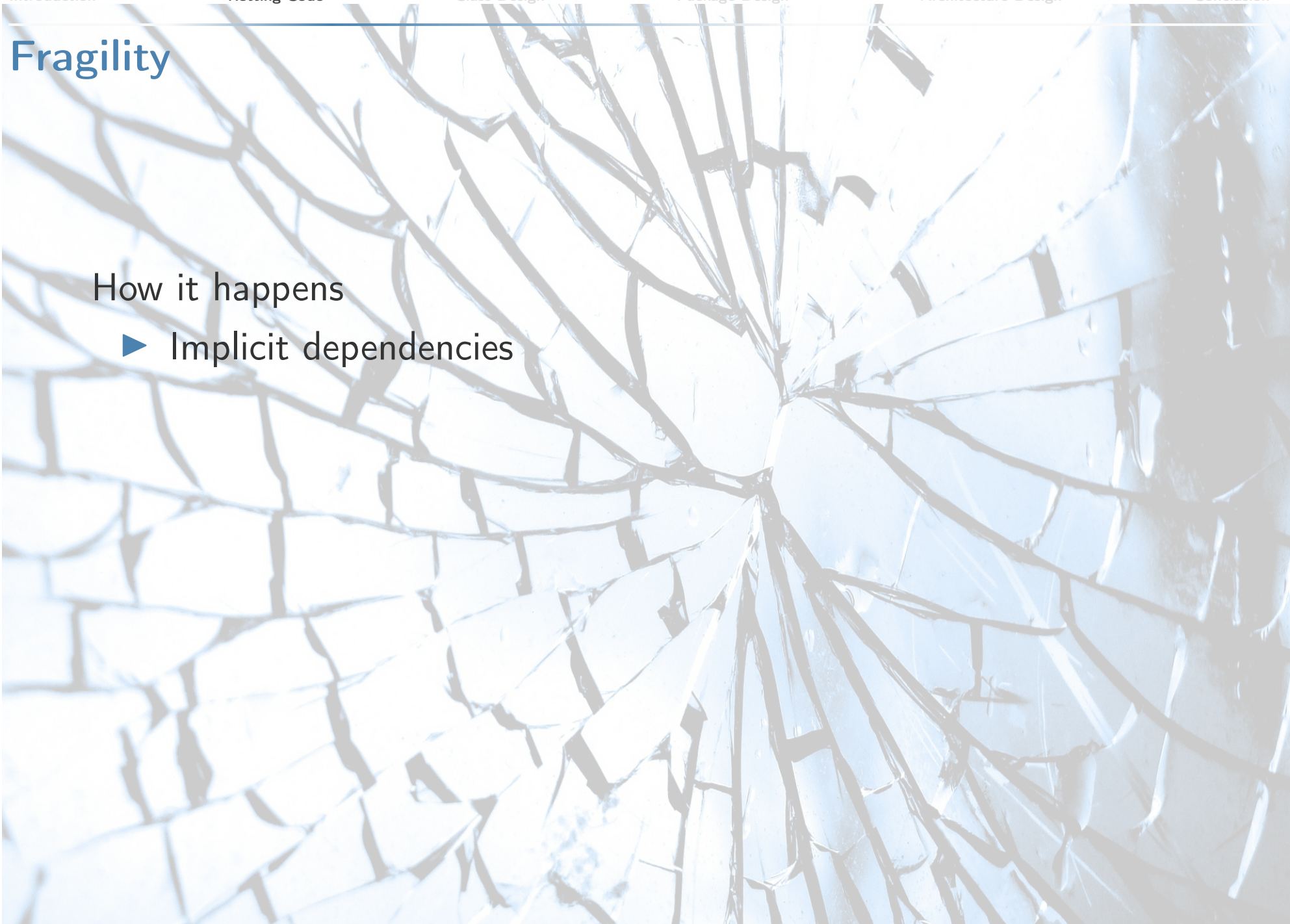
How it happens



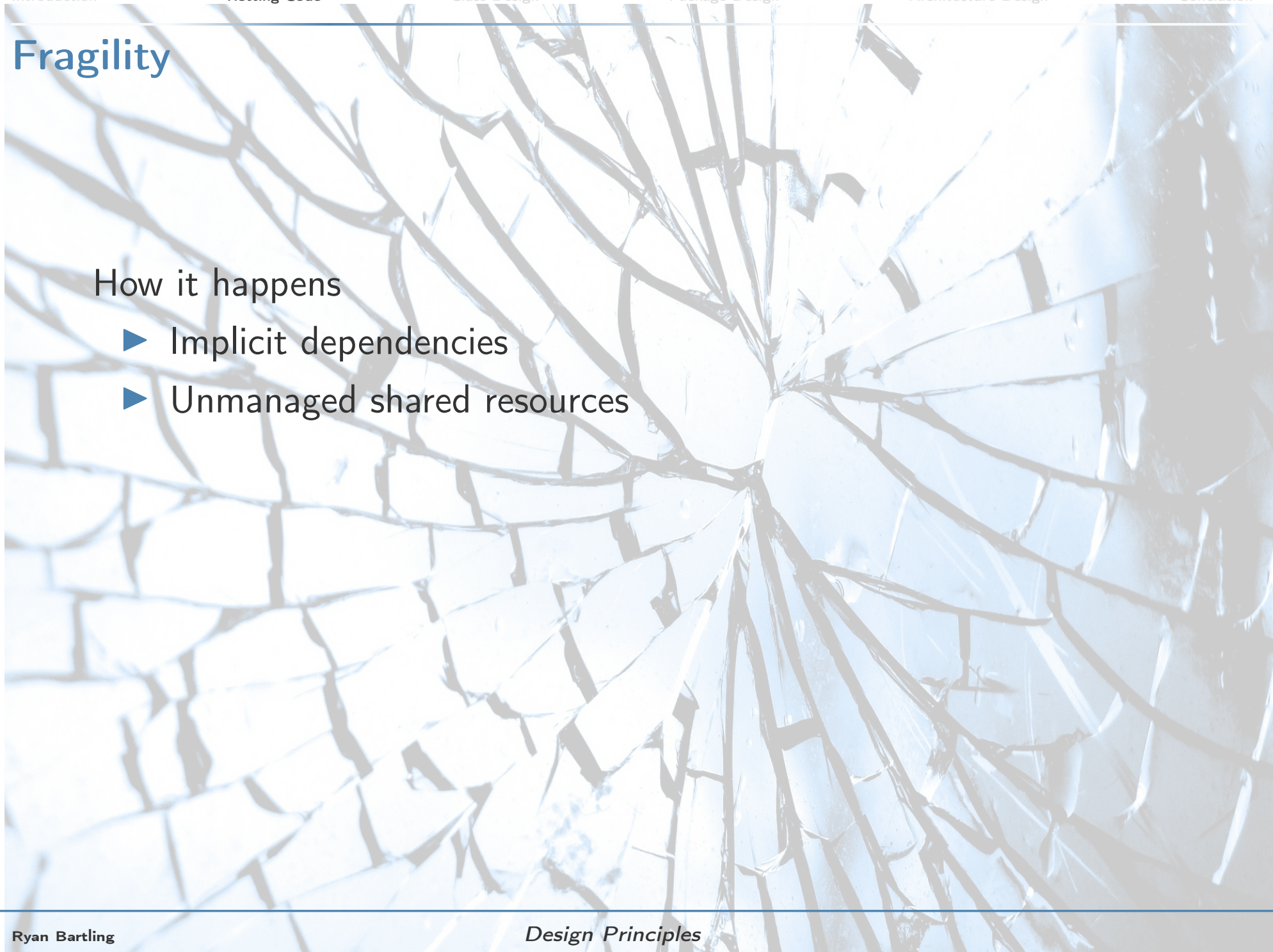
Fragility

How it happens

- Implicit dependencies



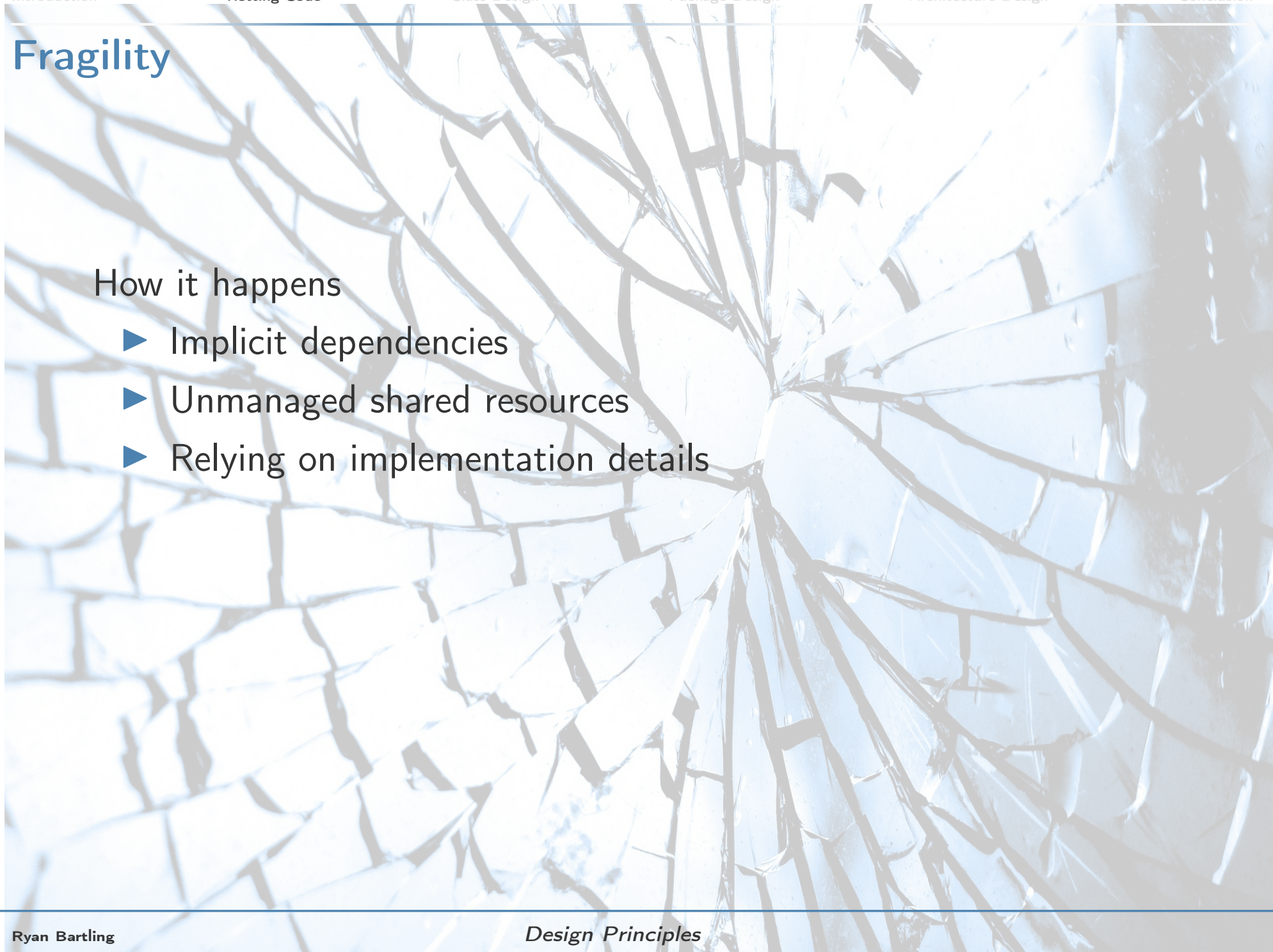
Fragility



How it happens

- Implicit dependencies
- Unmanaged shared resources

Fragility



How it happens

- Implicit dependencies
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- Relying on implementation details

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Fragility

How it happens

- Implicit dependencies
- Unmanaged shared resources
- Relying on implementation details
- Relying upon side effects of operations
- Reaching past abstraction layers
- Unmanaged complexity

Fragility

```
1  void
2  sdcard_init(void) {
3      spi_init(mode_0, card_cs_pin);
4      fat_init();
5  }
6
7  void
8  sensor_init(void) {
9      spi_init(mode_0, sensor_cs_pin);
10     spi_write(SENSOR_CONFIGURATION, sensor_cs_pin);
11 }
```

Fragility

Changing the sensor to use mode 1...

```
1  void
2  sdcard_init(void) {
3      spi_init(mode_0, card_cs_pin);
4      fat_init();
5  }
6
7  void
8  sensor_init(void) {
9      spi_init(mode_1, sensor_cs_pin); // Breaks the sd card
10     spi_write(SENSOR_CONFIGURATION, sensor_cs_pin);
11 }
```

...Breaks the sd card (when sensor is initialized after the sd card)

Fragility

We can fix it with dynamic resource allocation...

```
1  void
2  sdcard_init(void) {
3      if(spi_success != spi_acquire(mode_0, card_cs_pin)) { return; }
4      fat_init();
5      spi_release();
6  }
7
8  void
9  sensor_init(void) {
10     if(spi_success != spi_acquire(mode_1, sensor_cs_pin)) { return; }
11     spi_write(SENSOR_CONFIGURATION, sensor_cs_pin);
12     spi_release();
13 }
```

Fragility

If multi threaded, we could spin lock...

```
1  void
2  sdcard_init(void) {
3      while(spi_success != spi_acquire(mode_0, card_cs_pin)) {}
4      fat_init();
5      spi_release();
6  }
7
8  void
9  sensor_init(void) {
10     while(spi_success != spi_acquire(mode_1, sensor_cs_pin)) {}
11     spi_write(SENSOR_CONFIGURATION, sensor_cs_pin);
12     spi_release();
13 }
```

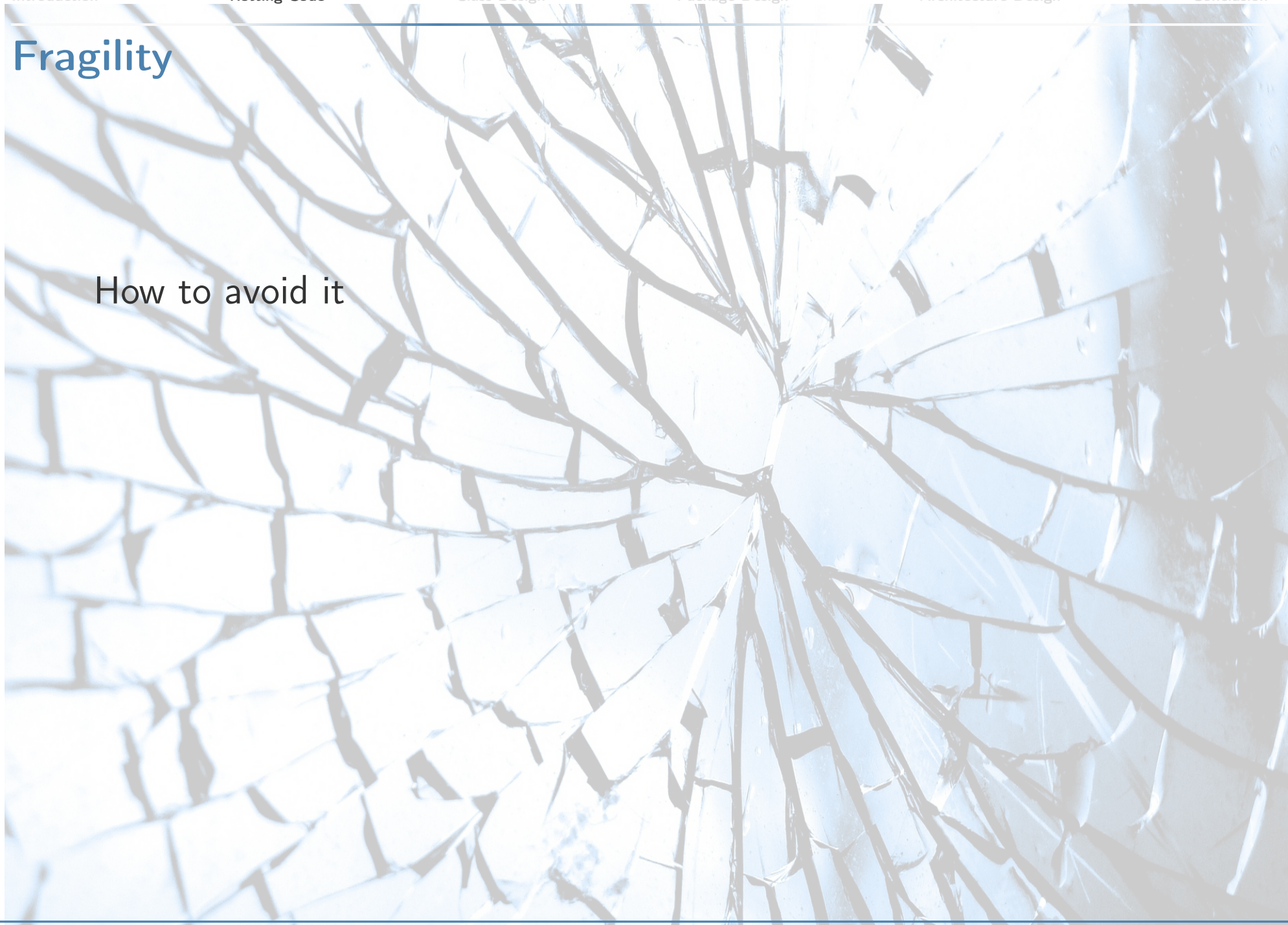
Fragility

We could also have a common allocation and assert correctness...

```
1  void
2  sys_init(void) {
3      spi_init(mode_0);
4  }
5
6  void
7  sdcard_init(void) {
8      assert(mode_0 == spi_mode_get() && "Wrong spi mode for sdcard");
9      fat_init();
10 }
11
12 void
13 sensor_init(void) {
14     assert(mode_0 == spi_mode_get() && "Wrong spi mode for sensor");
15     spi_write(SENSOR_CONFIGURATION, sensor_cs_pin);
16 }
```

Fragility

How to avoid it



Fragility

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- Rely on the published API

Fragility

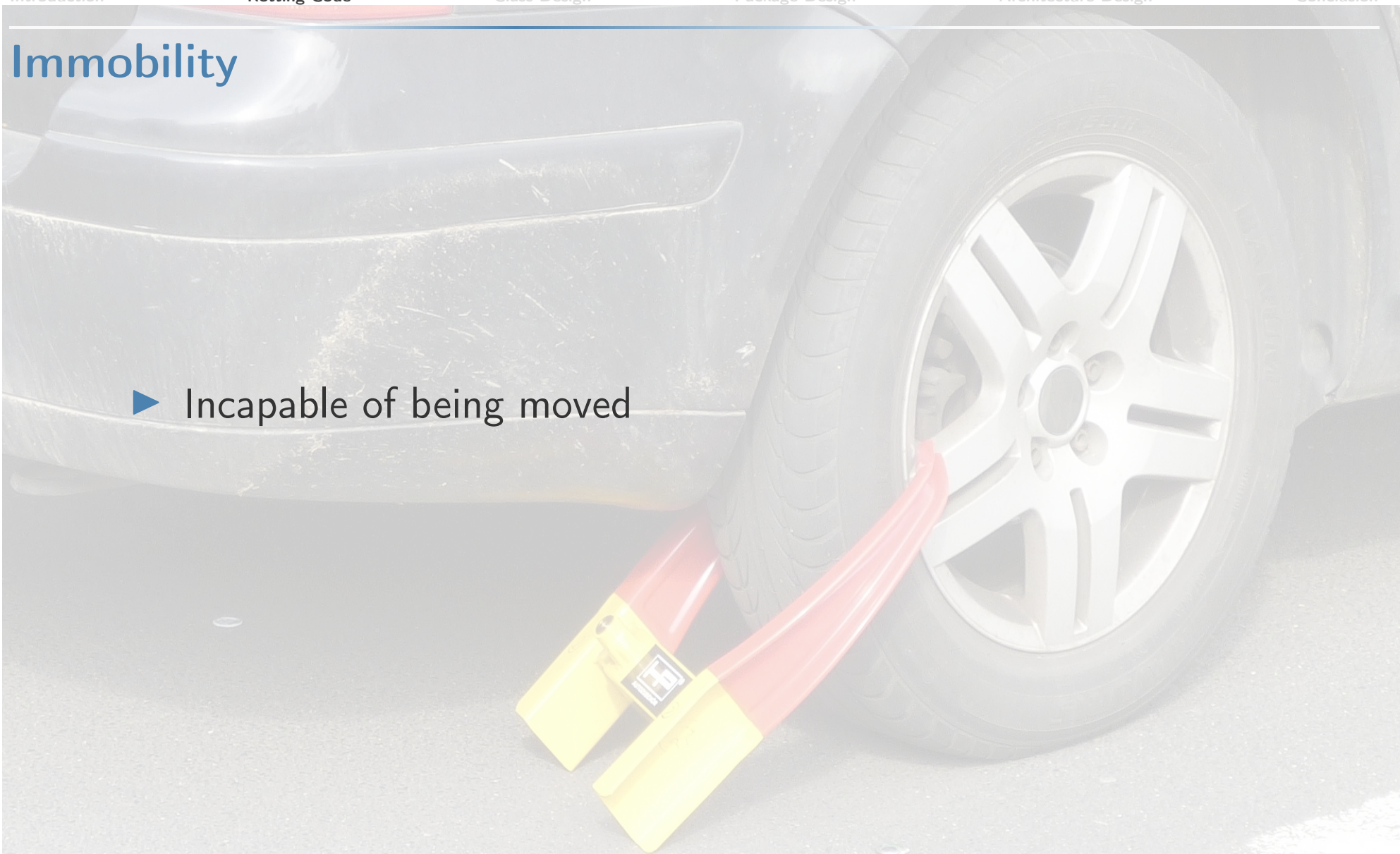
How to avoid it

- Explicit dependencies
- Law of Demeter: principle of least knowledge
- Avoid side effects, and don't rely on the side effects of other modules
- Rely on the published API
- Invent and **simplify**

Immobility

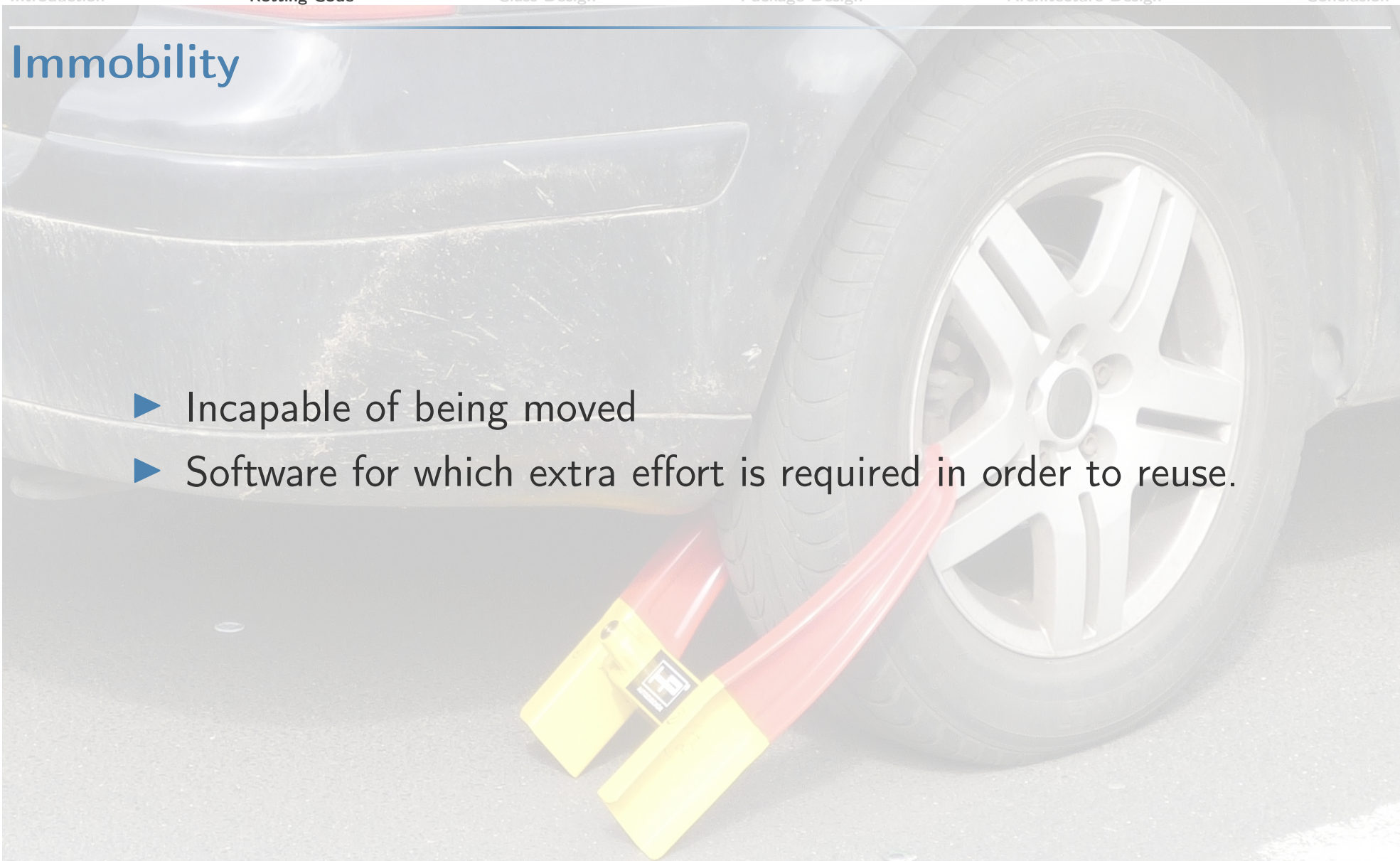
Immobility

Immobility



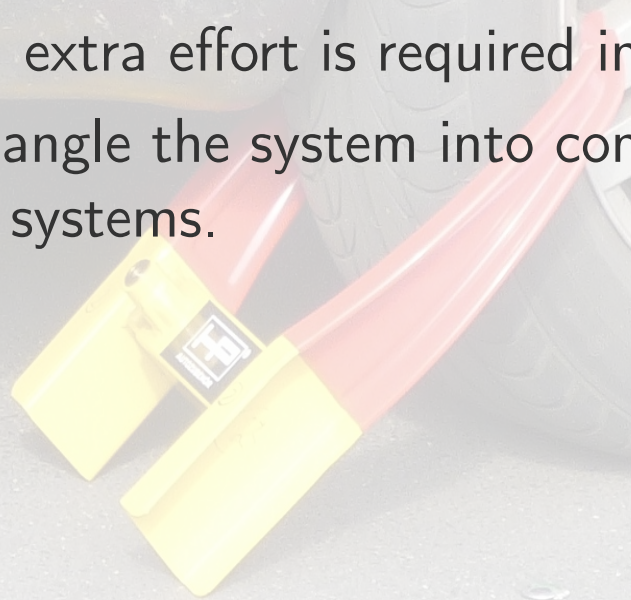
- Incapable of being moved

Immobility



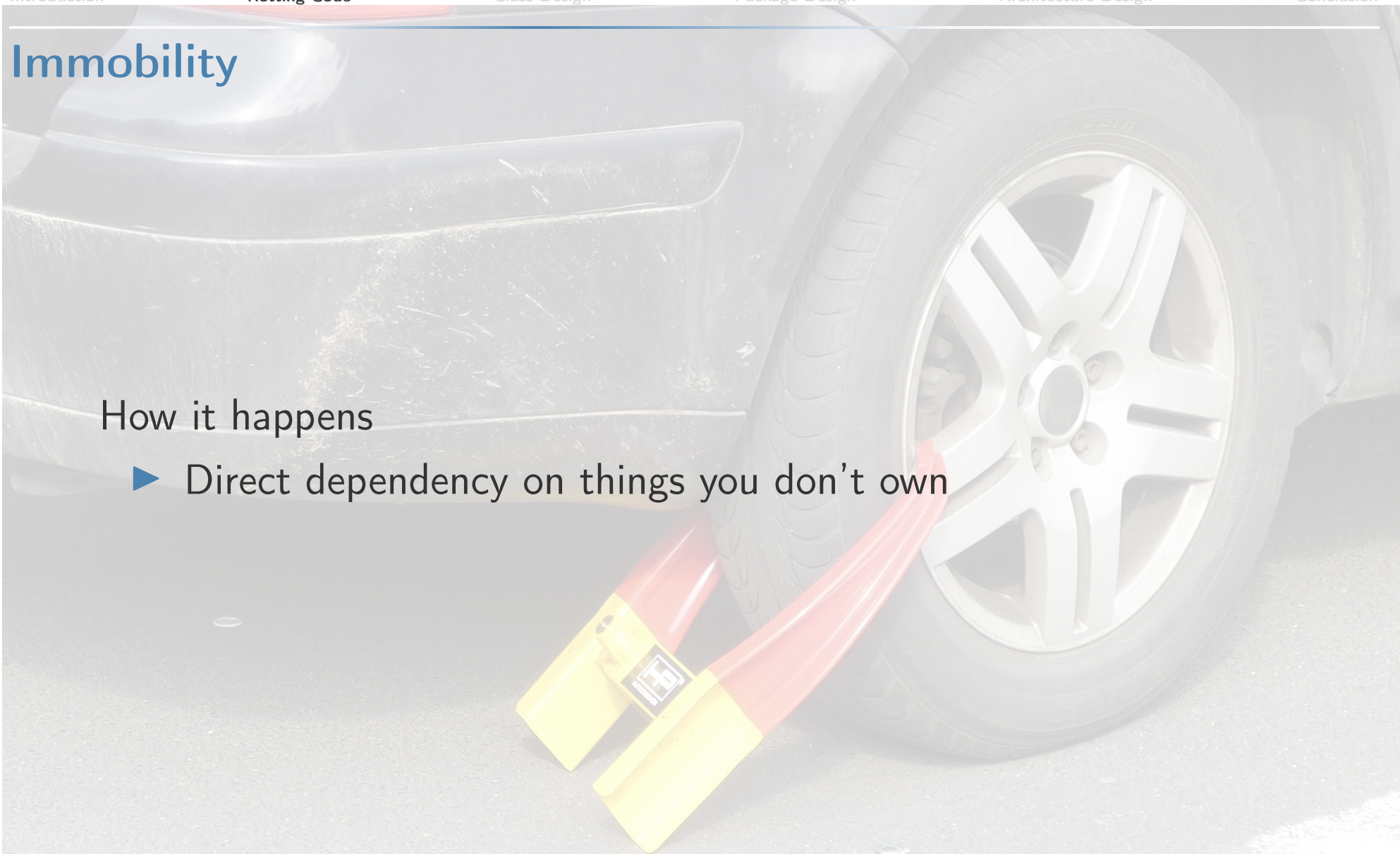
- Incapable of being moved
- Software for which extra effort is required in order to reuse.

Immobility



- Incapable of being moved
- Software for which extra effort is required in order to reuse.
- It is hard to disentangle the system into components that can be reused in other systems.

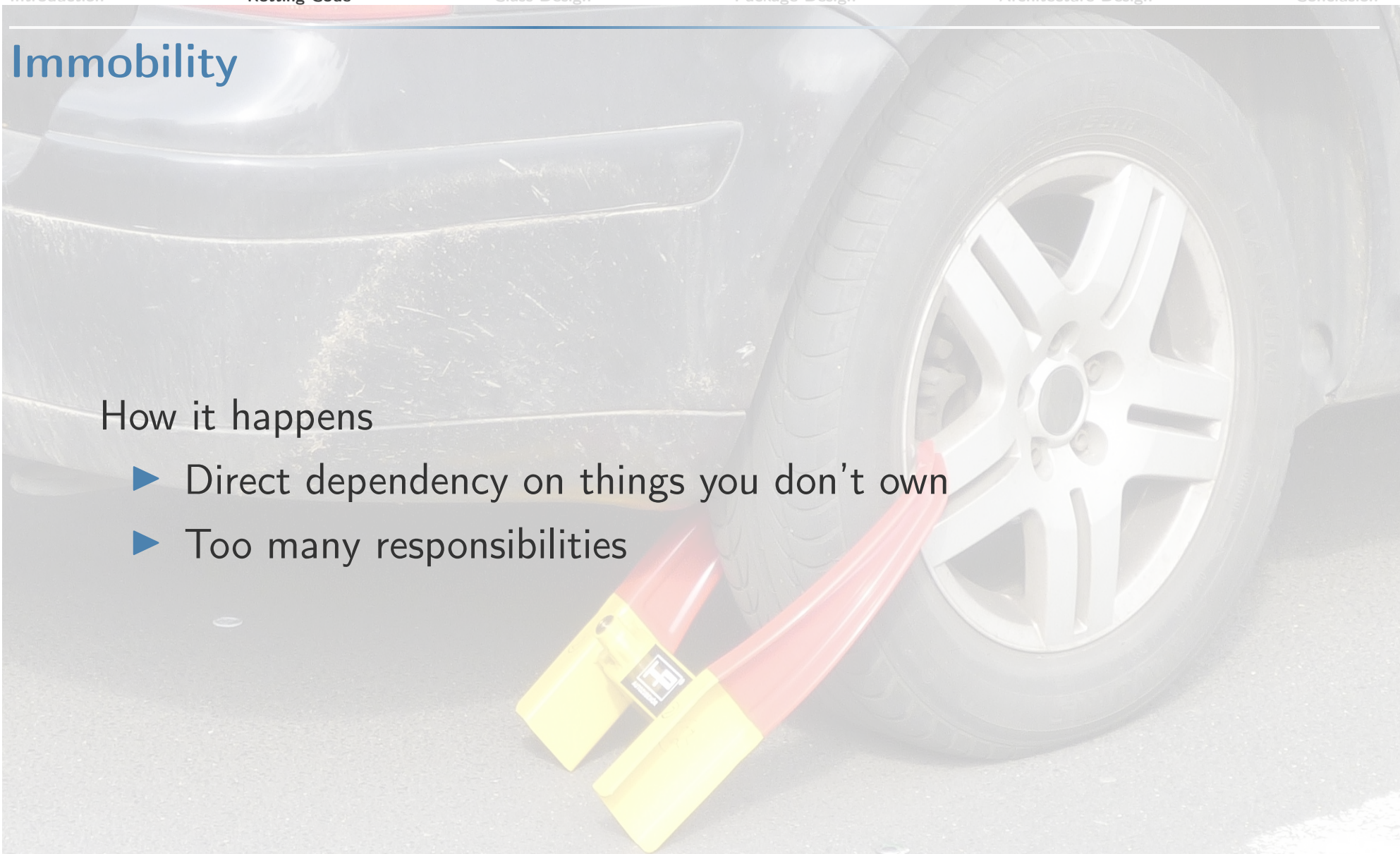
Immobility



How it happens

- Direct dependency on things you don't own

Immobility



How it happens

- Direct dependency on things you don't own
- Too many responsibilities

Immobility

```
1  #include "temperature_sensor.h"
2
3  #include <mcu.h>
4  #include <stdint.h>
5
6  uint16_t
7  oven_temperature(void) {
8      adccon |= 1 << 3;              // Start adc conversion
9      while(!(adccon & (1 << 0))) {} // While not done
10     return ((adcsamp * 53) / 7);
11 }
```

Immobility

```
1  #include "temperature_sensor.h"
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3  #include <mcu.h>
4  #include <stdint.h>
5
6  uint16_t
7  oven_temperature(void) {
8      ADC1_start_conversion();
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Immobility

```
1  #include "temperature_sensor.h"
2
3  #include <mcu.h>
4  #include <stdint.h>
5
6  // TPS = Temperature Sensor
7
8  static uint16_t const
9  TPS_get_adc_sample(void) {
10     ADC1_start_conversion();
11     while(!ADC1_done()) {}
12     return ADC1_sample_get();
13 }
14
15 static uint16_t const
16 TPS_adc_counts_to_F(uint16_t const adc_sample) {
17     return ((ADC1_sample_get() * 53) / 7);
18 }
19
20 uint16_t
21 TPS_oven_temperature_F(void) {
22     uint16_t sample = TPS_get_adc_sample();
23     return TPS_adc_counts_to_F(sample);
24 }
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Immobility

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9  TPS_get_adc_sample(void) {
10     ADC1_start_conversion();
11     while(!ADC1_done()) {}
12     return ADC1_sample_get();
13 }
14
15 static int const
16 TPS_adc_counts_to_F(uint16_t const adc_sample) {
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18 }
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20 int
21 TPS_temperature_F(void) {
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20 int
21 TPS_temperature_F(void) {
22     uint16_t sample = TPS_get_adc_sample();
23     return TPS_adc_counts_to_F(sample);
24 }
25
26 int
27 TPS_temperature_C(void) {
28     int temperature_F = TPS_temperature_F();
29     return ((temperature_F - 32) * 5) / 9
30 }
```

Immobility

```
1  #include "temperature_sensor.h"
2
3  // TPS = Temperature Sensor
4
5  static int const
6  TPS_adc_counts_to_F(int const adc_sample) {
7      return ((ADC1_sample_get() * 53) / 7);
8  }
9
10 static int const
11 TPS_F_to_C(int const temperature_F) {
12     return ((temperature_F - 32) * 5) / 9;
13 }
14
15 int
16 TPS_temperature_F(int const adc_sample) {
17     return TPS_adc_counts_to_F(adc_sample);
18 }
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20 int
21 TPS_temperature_C(int const adc_sample) {
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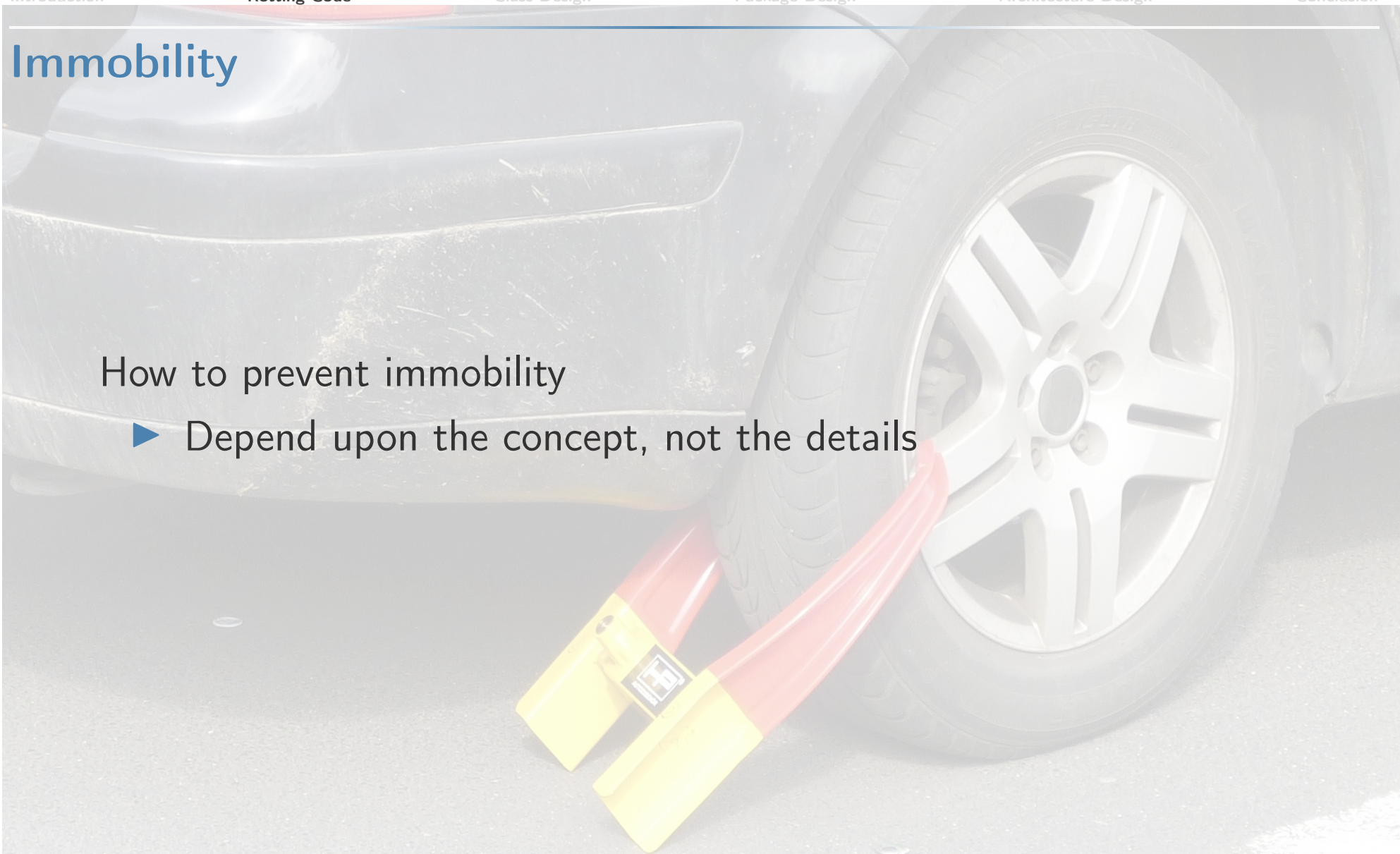
Immobility



How to prevent immobility

- Depend upon the concept, not the details

Immobility

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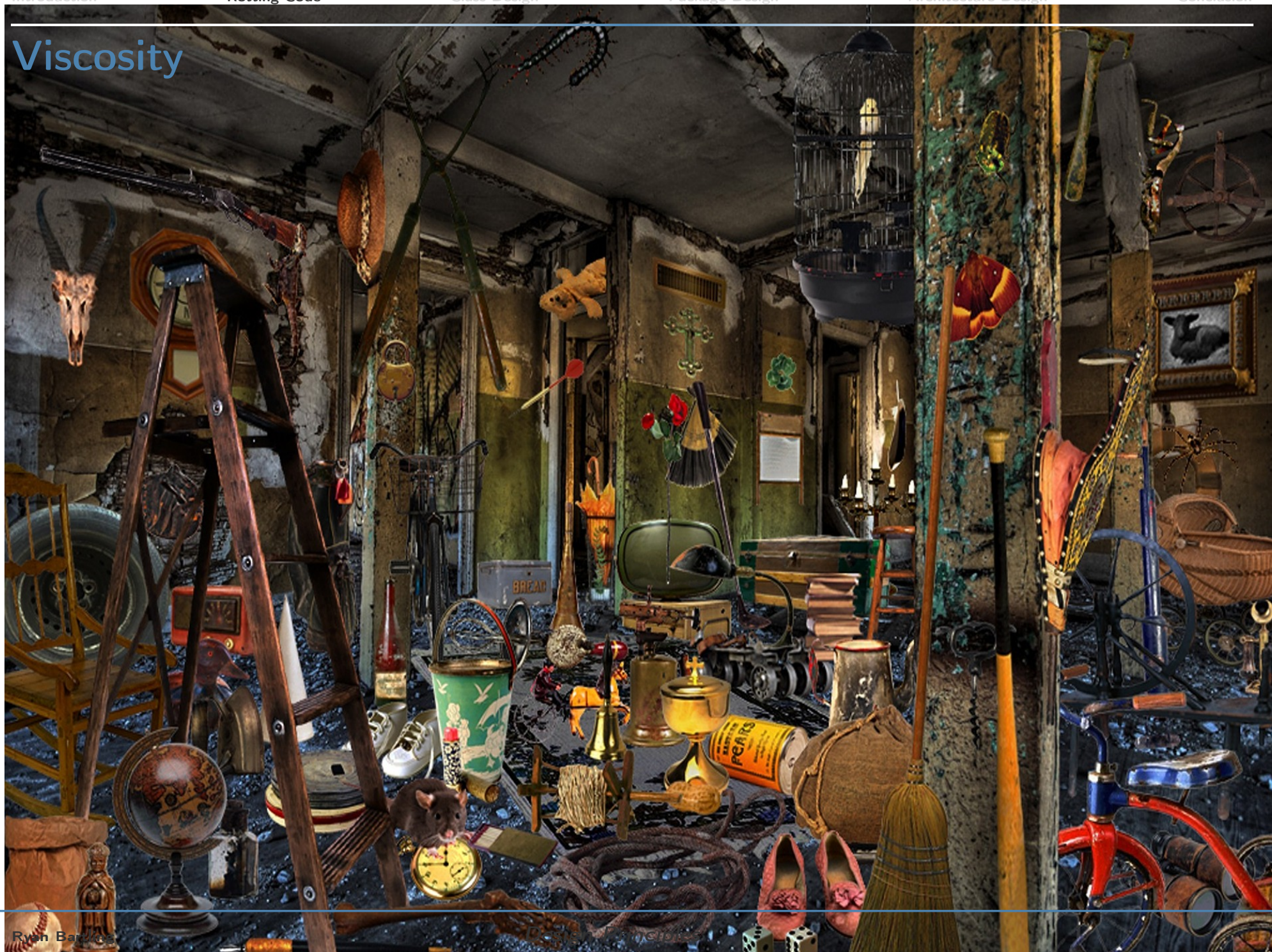
- Reduce responsibilities to solve distinct problems

Immobility

How to prevent immobility

- Depend upon the concept, not the details
- Reduce responsibilities to solve distinct problems
- Write unit tests for the module at the time that you write the module.

Viscosity



Viscosity

- Having or characterized by a high resistance to flow

Viscosity

- Having or characterized by a high resistance to flow
- Software projects in which design preserving changes are more difficult than hacks.

Viscosity

- Viscous Design

Viscosity

- Viscous Design
- Viscous Environment

Viscosity

- Viscous Design
  - When making changes, preserving the design is difficult
- Viscous Environment

Viscosity

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  - When making changes, preserving the design is difficult
  - When a more correct solution is not the easier solution
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  - When a more correct solution is not the easier solution
  - *"That is the right way to do this, but we can't do that in this project"*
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- Viscous Environment
  - Long builds can prevent people from making the appropriate change since it will trigger a longer build.
  - Slow/unreliable Tests *"I can't run these tests after each change, I'd get no work done. Besides, they always fail anyway."*
  - Slow/cumbersome tools (e.g. large complicated files may require longer static analysis)

Viscosity

- Viscous Policies
  - Management steps in to avoid the issues above

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  - Policies can remain long after the original problem was solved.
  - Process can also result in viscosity.
    - What code changes require stricter review?
    - What code changes require new or updated documentation?

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- Viscous Policies
  - Management steps in to avoid the issues above
  - *"We cannot afford to have anyone touch the Fobnicator stack, because too many things depend upon it"*
  - Policies can remain long after the original problem was solved.
  - Process can also result in viscosity.
    - What code changes require stricter review?
    - What code changes require new or updated documentation?
    - When does a code revision require upfront design?

Viscosity

Software develops along the path of least resistence. If hacks are easier, that's what your project will consist of.

Principles of Object Oriented Class Design

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SOLID Principles

Principles of Object Oriented Class Design

SOLID Principles

- **S***ingle Responsibility Principle* (SRP)

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- **D***ependency Inversion Principle* (DIP)

Single Responsibility Principle

Responsibility

Single Responsibility Principle

Responsibility

- Cohesion

Single Responsibility Principle

Responsibility

- Cohesion
- Reason to change

Single Responsibility Principle

Responsibility

- Cohesion
- Reason to change
- Axis of change

Single Responsibility Principle

```
1  class modem {
2  public:
3      void
4      dial();
5      void
6      hangup();
7      void
8      send();
9      void
10     rcv();
11 }
```

Single Responsibility Principle

```
1  class modem {
2  public:
3      void
4      dial(); // Connection management
5      void
6      hangup(); // Connection management
7      void
8      send();
9      void
10     rcv();
11 }
```

Single Responsibility Principle

```
1  class modem {
2  public:
3      void
4      dial();
5      void
6      hangup();
7      void
8      send(); // Data Management
9      void
10     rcv(); // Data Management
11 }
```

Single Responsibility Principle

```
1  class modem_connection {
2  public:
3      void
4      dial();
5      void
6      hangup();
7  }
8
9  class modem_data {
10 public:
11     void
12     send();
13     void
14     rcv();
15 }
16
17 class modem_impl {
18 private:
19     modem_connection connection;
20     modem_data       data;
21 }
```

Single Responsibility Principle

Caution:

Single Responsibility Principle

Caution:

- Too much splitting of modules can lead to an overly complicated design.

Single Responsibility Principle

Caution:

- Too much splitting of modules can lead to an overly complicated design.
- If the code does not change in a way that the two responsibilities change at different times, then there's no need to separate.

Open Closed Principle

Open Closed Principle

- "Open for Extension"

Open Closed Principle

- "Open for Extension"
  - Behavior of the module can be modified through extension

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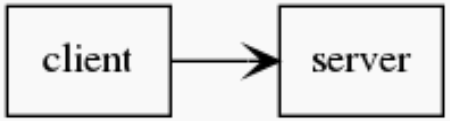
- "Closed for Modification"

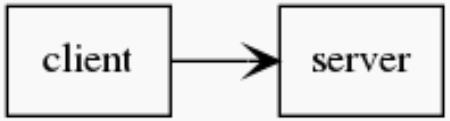
Open Closed Principle

- "Open for Extension"
  - Behavior of the module can be modified through extension
- "Closed for Modification"
  - Extending the behavior requires no change in source code or binary executables.

Open Closed Principle

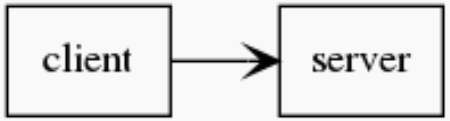


Open Closed Principle



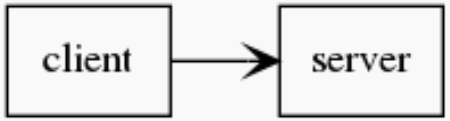
- Client depends on server

Open Closed Principle



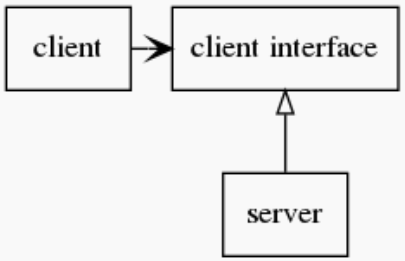
- Client depends on server
- Changing server requires modification of client

Open Closed Principle

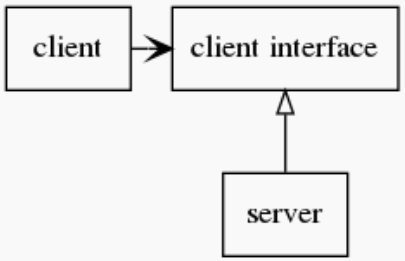


- Client depends on server
- Changing server requires modification of client
- Use of clients with different servers requires duplication of code

Open Closed Principle



Open Closed Principle



- Enables client implementations for multiple servers

Open Closed Principle

```
1  // shape.h ////////////////////////////////////////////////////////////////
2
3  enum shape_type_t { circle, square };
4  struct shape_s {
5      shape_type_t shape_type;
6  }
7  // circle.h ///////////////////////////////////////////////////////////////
8  #include "shape.h"
9  struct circle_s {
10     shape_type_t shape_type;
11     double       radius;
12     point        center;
13 }
14
15 void
16 drawCircle(struct circle_s *);
17
18 // square.h ///////////////////////////////////////////////////////////////
19 #include "shape.h"
20 struct square_s {
21     shape_type_t shape_type;
22     double       side;
23     point        top_left;
24 }
25
26 void
27 drawSquare(struct square_s *);
```

Open Closed Principle

```
1  // shape.h ////////////////////////////////////////////////////////////////
2  // Adding a new shape, requires modification of enum
3  enum shape_type_t { circle, square };
4  struct shape_s {
5      shape_type_t shape_type;
6  }
7  // circle.h ///////////////////////////////////////////////////////////////
8  #include "shape.h"
9  struct circle_s {
10     shape_type_t shape_type;
11     double       radius;
12     point        center;
13 }
14
15 void
16 drawCircle(struct circle_s *);
17
18 // square.h ///////////////////////////////////////////////////////////////
19 #include "shape.h"
20 struct square_s {
21     shape_type_t shape_type;
22     double       side;
23     point        top_left;
24 }
25
26 void
27 drawSquare(struct square_s *);
```

Open Closed Principle

```
1  // draw_all_shapes.c ////////////////////////////////////////////////////////
2
3  typedef struct shape_t *shape_pointer_t;
4
5  void
6  DrawAllShapes(shape_pointer_t *shapes, int n) {
7      for(int i = 0; i < nl i++) {
8          struct shape_s *s = shapes[i];
9          switch(shape->shape_type) {
10         case circle: drawCircle((struce circle_s *)shape); break;
11         case square: drawSquare((struce square_s *)shape); break;
12         }
13     }
14 }
```

Open Closed Principle

```
1  // shape.h ////////////////////////////////////////////////////////////////
2  enum shape_type_t { circle, square };
3  void (*DrawFunction)(void *);
4  struct shape_s {
5      DrawFunction draw;
6  } void
7  DrawShape(void *);
8
9  // shape.c ////////////////////////////////////////////////////////////////
10 void
11 DrawShape(void *shape_in) {
12     shape = (struct shape_s *)shape_in;
13     shape.draw(shape_in);
14 }
15
16 // circle.h ///////////////////////////////////////////////////////////////
17 struct circle_s {
18     DrawFunction draw;
19     double       radius;
20     point        center;
21 }
22
23 void
24 drawCircle(struct circle_s *);
25
26 // square.h ///////////////////////////////////////////////////////////////
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33 void
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Open Closed Principle

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1  // draw_all_shapes.c ////////////////////////////////////////////////////////
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3  typedef struct shape_t *shape_pointer_t;
4
5  void
6  DrawAllShapes(shape_pointer_t *shapes, int n) {
7      for(int i = 0; i < nl i++) {
8          struct shape_s *shape = shapes[i];
9          DrawShape(shape);
10     }
11 }
```

Liskov Substitution Principle

Interface Segregation Principle

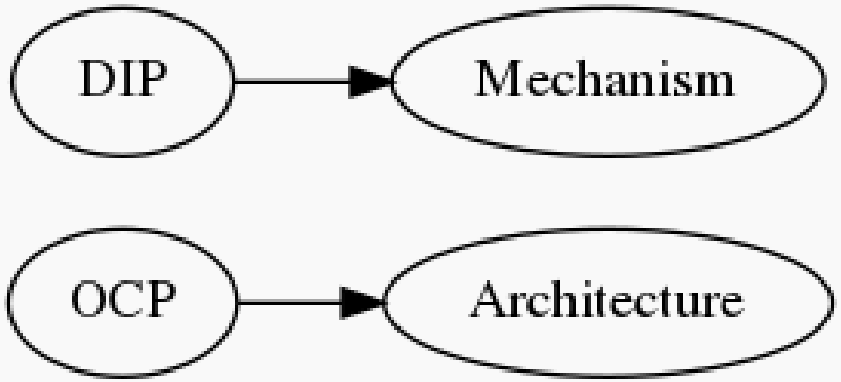
Dependency Inversion Principle

Depend upon abstractions.

Dependency Inversion Principle

Depend upon abstractions. Do not depend upon concretions.

Dependency Inversion Principle



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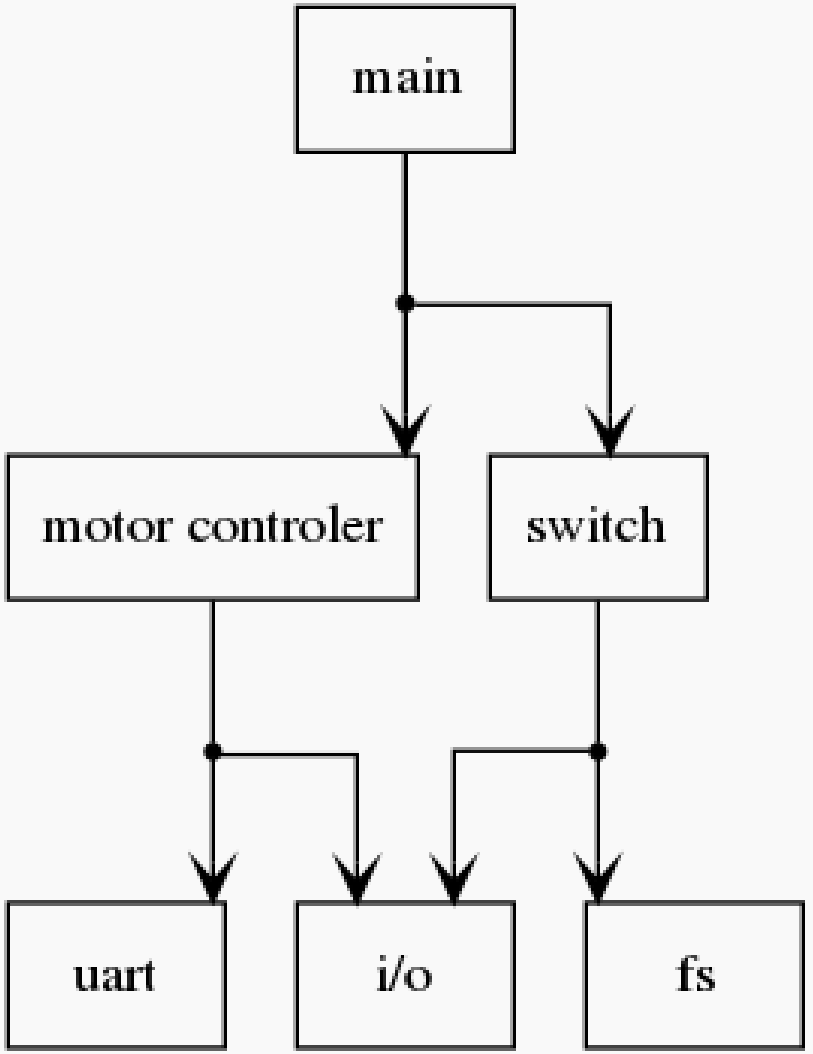
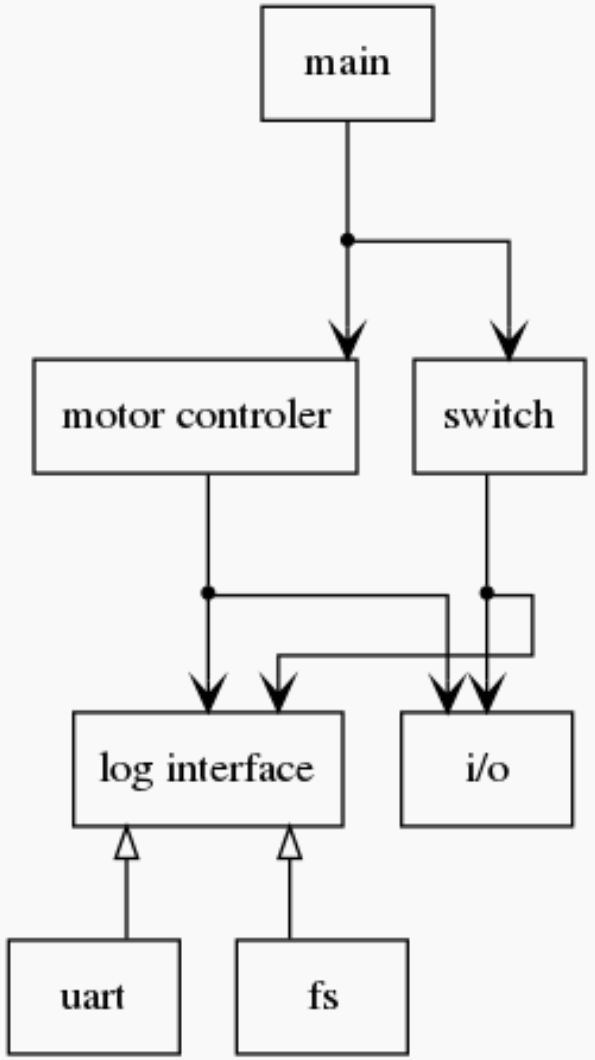


Dependency Inversion Principle



Package Design

Principles of Package Architecture

Package Principles

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Package Principles

- Package Cohesion

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- Package Coupling

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  - Stable Dependencies Principle (SDP)
  - Stable Abstractions Principle (SAP)

Dependency Inversion Principle

Architecture Design

Principles of Package Architecture

Conclusion

Principles of Package Architecture

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Questions