Design

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What is design?

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- Includes many things:
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  - The components of the system
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  - How they interact
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} architecture
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  - The interfaces & abstractions they expose (or hide!)
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What is an abstraction?
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Server server{port};
while (true) {
    auto incoming = server.receive();
    ...
    server.send(outgoing);
}
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Is design UML?
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Is design UML?

Is UML design?
Why does design matter?
Why does design matter?

- Translating requirements and stories to code

```cpp
#include <unistd.h>
#include "ChatWindow.h"
#include "Client.h"

int main(int argc, char* argv[]) {
    if (argc < 3) {
        printf("Usage:
%s <ip address> <port>
e.g. %s localhost 4002
", argv[0], argv[0]);
        return 1;
    }
    networking::Client client{argv[1], argv[2]};
    bool done = false;
    auto onTextEntry = [&done, &client] (std::string text) {
        if ("exit" == text || "quit" == text) {
            done = true;
        } else {
            client.send(text);
        }
    };
    ChatWindow chatWindow(onTextEntry);
    while (!done && !client.isDisconnected()) {
        try {
            client.update();
        } catch (std::exception& e) {
            chatWindow.displayText("Exception from Client update:");
            chatWindow.displayText(e.what());
            done = true;
        }
        auto response = client.receive();
        if (!response.empty()) {
            chatWindow.displayText(response);
            chatWindow.update();
        }
    }
    return 0;
}
```
Why does design matter?

- Translating requirements and stories to code
- Understandability
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- Translating requirements and stories to code
- Understandability

How much time do professional programmers spend reading code?
Why does design matter?

- Translating requirements and stories to code
- Understandability
- Performance & reliability
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- Performance & reliability
- Reusability
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- Determines ease & risk for change.
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  - Understanding of requirements will change
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Determines ease & risk for *change*.
- Understanding of requirements will change
- **Requirements** will change
Why does design matter?

- Translating requirements and stories to code
- Understandability
- Performance & reliability
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  - Understanding of requirements will change
  - Requirements will change
  - Your code may outlast your time at a company
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- Determines ease & risk for change.
  - Understanding of requirements will change
  - Requirements will change
  - Your code may outlast your time at a company
- Once software is too complex to reason about, it is too late
What makes a design bad?

- Too many possible ways to design poorly to list
What makes a design bad?

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- Common attributes of a bad design: [Ousterhout 2018]
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- Common attributes of a bad design: [Ousterhout 2018]
  - *Change Amplification*
    - An apparently simple change requires modifying many locations
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- Common attributes of a bad design: [Ousterhout 2018]
  - *Change Amplification*
    An apparently simple change requires modifying many locations
  - *Cognitive Load*
    The developer needs to know a great deal in order to complete a task
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  - Unknown unknowns
    Potions of code to modify for a task may be hard to identify
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These are symptoms of complexity.
What makes a design good?

- It identifies & manages complexity
  - *Inherent* (essential) complexity
What makes a design good?

- It identifies & manages complexity
  - *Inherent* (essential) complexity
  - *Incidental* (accidental) complexity
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hide

minimize
What makes a design good?

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  - Inherent (essential) complexity
  - Incidental (accidental) complexity

- What is complexity?
What makes a design good?

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  - Incidental (accidental) complexity

- What is complexity?
  - No agreed upon universal definition; many variants
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- What is complexity?
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  - Grows as entities/concepts in project are connected/woven together
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[Watch “Simple Made Easy” for one interesting perspective]
What makes a design good?

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- What is complexity?
  - No agreed upon universal definition; many variants
  - Grows as entities/concepts in project are connected/woven together
    [Watch “Simple Made Easy” for one interesting perspective]
  - One other heuristic is risk of change
What makes a design good?

Broadly

- Divides the system into independent components
What makes a design good?

Broadly

- Divides the system into independent components
- Makes it easy for developers to get their jobs done
What makes a design good?

- Not clever
What makes a design good?

- Not clever!

```c
int x = foo(bar(baz(bam(a), b), c), d);
```
What makes a design good?

- Not clever!!

```c
int x = foo(bar(baz(bam(a), b), c), d);

// this subroutine is called thousands of times.
// use longjmp instead of loops to increase speed.

void
calculate(struct salesinfo* sales){
    jmp_buf buffer;
    int i=setjmp(buffer);
    if (!(i<sales->count)) RETURN_NOTHING;
    addvaluetosubtotal(sales->values[i]);
    if (i<sales->count) longjmp(buffer,i+1);
}
```

http://thedailywtf.com/articles/Longjmp--FOR-SPEED!!!
What makes a design good?

- Not clever!!!
What makes a design good?

- Not clever
- Loose coupling
What makes a design good?

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- Loose coupling
  - Content (accessing implementation of another component)
What makes a design good?

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  - Content (accessing implementation of another component)
  - Common global data
  - Subclassing
  - Temporal
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  - Passing data to/from each other
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  - Content (accessing implementation of another component)
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  - Subclassing
  - Temporal
  - Passing data to/from each other
  - Independence
What makes a design good?

- Not clever
- Loose coupling
- High fan in / low fan out
What makes a design good?

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- Loose coupling
- High fan in / low fan out

Do you agree? Why?
What makes a design good?

- Not clever
- Loose coupling
- High fan in / low fan out
- Layers / Stratification

& a consistent, self contained view per level
What makes a design good?

- Not clever
- Loose coupling
- High fan in / low fan out
- Layers / Stratification
What makes a design good?

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- Loose coupling
- High fan in / low fan out
- Layers / Stratification
What makes a design good?

- Not clever
- Loose coupling
- High fan in / low fan out
- Layers / Stratification
- Cohesion
- ...

VS
What makes a design good?

- Not clever
- Loose coupling
- High fan in / low fan out
- Layers / Stratification
- Cohesion
- ...

But these are the ends, not the means
Revisiting Complexity

- We can characterize *causes* of complex designs [Ousterhout 2018]
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- Dependencies
  Code cannot be understood in isolation because of relationships to other code.
Revisiting Complexity

- We can characterize *causes* of complex designs [Ousterhout 2018]
  - *Dependencies*
    Code cannot be understood in isolation because of relationships to other code.
  - *Obscurity*
    Important information about code is not obvious.
Revisiting Complexity

- We can characterize *causes* of complex designs [Ousterhout 2018]
  - **Dependencies**
    Code cannot be understood in isolation because of relationships to other code.
  - **Obscurity**
    Important information about code is not obvious.

These directly relate to the qualities of good code we just saw.
Consider a design
Consider a design

User Interface

Graphics

Data Storage

Business Logic

Enterprise Backbone

Is this simple? Why?
Consider a design

- What if you want to *modify* the business logic?
Consider a design

- What if you want to **modify** the business logic?
- What if you want to **reuse** the business logic?
Consider a design

- What if you want to *modify* the business logic?
- What if you want to *reuse* the business logic?
- What if you want to *replace* the display?
Consider a design

- What if you want to *modify* the business logic?
- What if you want to *reuse* the business logic?
- What if you want to *replace* the display?

Like a basket woven together, you get everything or nothing.
Consider a design:

- User Interface
- Graphics
- Business Logic
- Data Storage
- Enterprise Backbone
Consider a design

Is this simpler? Why?
Consider a design

User Interface → Graphics
Data Storage → Business Logic
Enterprise Backbone → Data Storage

Is this simpler? Why?
What is still complex? Why?
Consider a design

- The fewer connected or conflated concepts, the better
Consider a function

```cpp
bool isFasterThanSound(double speed) {
    return speed > MACH1;
}
```
Consider a function

```c
bool
isFasterThanSound(double speed) {
    return speed > MACH1;
}
```

Is this simple or complex? Why?
Consider a function

```cpp
bool isFasterThanSound(double speed) {
    return speed > MACH1;
}
```

```cpp
(double speed, double angle) {
    ...
}
```

Is this simple or complex? Why?
Consider a function

```c
bool isFasterThanSound(double speed) {
    return speed > MACH1;
}
```

A good design should be hard to misuse.
Consider a class

```cpp
class Student {
public:

    ID getID() const;
    Name getName() const;
    Address getAddress() const;

    void storeToDatabase() const;
    static Student readFromDatabase();

    bool canApplyForCoOp();
    bool meetsDegreeRequirements();
};
```
What is **good** about this class?
Consider a class

class Student {
public:
    ... 
    ID getID() const;
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    void storeToDatabase() const;
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    bool canApplyForCoOp();
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};
What are our simplifying tools?

- Metaphors – identify “real world” objects & relations
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Be careful. This can be a good place to start, but a poor place to end.
What are our simplifying tools?

- Metaphors – identify “real world” objects & relations
- Abstraction – use high level concepts
What are our simplifying tools?

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- Abstraction – use high level concepts
- Encapsulation – hide the details

This is the Code Complete definition, not a universal one!
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Deeply tied to information hiding
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  - In small, constrained doses
  - Ideally through interfaces
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Use especially for:
1) likely/risky to change code
2) frequently used code
Key Strategy: Mitigate change

- Identify potential areas of change

```cpp
class Student {
public:
    ... 
    int getID() const;
    ...
};
```
Key Strategy: Mitigate change

- Identify potential areas of change

```cpp
class Student {
public:
    ...
    ...
    int getID() const;
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Key Strategy: Mitigate change

- Identify potential areas of change
- Separate them structurally

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Key Strategy: Mitigate change

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    ...  
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    ...  
};
```

```cpp
class Student {
public:
    ...  
    ID getID() const;  
    ...  
};
```
Key Strategy: Mitigate change

- Identify potential areas of change
- Separate them structurally
- Isolate their impact through interfaces
Key Strategy: Mitigate change

- Identify potential areas of change
- Separate them structurally
- Isolate their impact through interfaces

class IDCreator {
public:
    ...
    ...  
    virtual ID createID() = 0;
    ...
};
Key Strategy: Mitigate change

...  
ID studentID = student.getID();
...

How might this hinder change?
Key Strategy: Mitigate change

... ID studentID = student.getID(); ...

How might this hinder change?

How can it be resolved?
Key Strategy: Mitigate change

... 

ID studentID = student.getID();
...

How might this hinder change?

How can it be resolved?

What are the trade offs?
Constant Vigilance

- Avoiding complexity requires a planned process
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  - Code review everything
    [metaphors, abstraction, encapsulation, consistency, inheritance]
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- Know when & where you make bad decisions
  - *technical debt*
Constant Vigilance

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  - Code review everything
    [metaphors, abstraction, encapsulation, consistency, inheritance]
  - Write tests (simple code is easier to test)

- Know when & where you make bad decisions
  - *technical debt*
    - You end up paying it back!
A design smell is a clue that better design is needed.
Design Smells

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- Such as: (adapted from John Ousterhout)
  - Thin components
    - Is it really hiding an implementation?
    - Is complexity arising from having to many small classes?
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    - Can I see the implementation details? (unintentional interface)
    - Repeated similar code
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    - Is it really hiding an implementation?
    - Is complexity arising from having too many small classes?
  - Information leaks
    - Can I see the implementation details? (unintentional interface)
    - Repeated similar code
  - Difficulty making a change
Experience

- Experience hones your sense of design.
  - Hopefully, our discussions this semester will help you be aware of it.