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Object-Oriented Design Principles

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The Pillars of the Paradigm

- Abstraction
- Encapsulation
- Hierarchy
  - Association, Aggregation
  - Inheritance
- Polymorphism

What’s OO?

- Is it using Objects?
- Is it using C++, Java, C#, Smalltalk?
- No, its got to be using UML?! ☺

- What makes a program OO?
- How do you measure good design?

Measuring Quality of an Abstraction

Designing Classes & Objects

- An incremental, iterative process
- Difficult to design right the first time

cs for class design

- Coupling
  - inheritance Vs. coupling
  - Strong coupling complicates a system
  - design for weakest possible coupling
- Cohesion
  - degree of connectivity among the elements of a single module/class
  - coincidental cohesion: all elements related undesirable
  - Functional cohesion: work together to provide well-bounded behavior

Law of Demeter

"Methods of a class should not depend in any way on the structure of any class, except the immediate structure of their own class. Further, each method should send messages to objects belonging to a very limited set of classes only."

Bad design

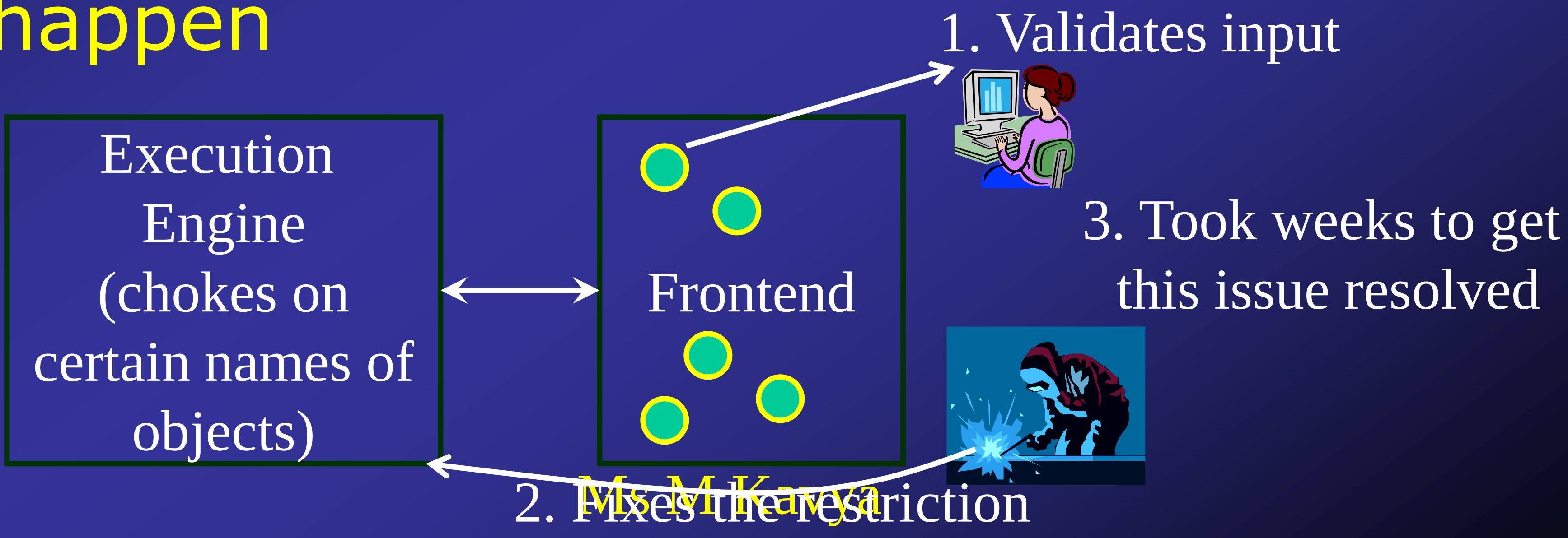
- Perils of a bad design
  - Rigidity
    - Hard to change, results in cascade of changes
  - Fragility
    - Breaks easily and often
  - Immobility
    - Hard to reuse (due to coupling)
  - Viscosity
    - Easy to do wrong things, hard to do right things
  - Needless Complexity
    - Complicated class design, overly generalized
  - Needless Repetition
    - Copy and Paste away
  - Opacity
    - Hard to understand

Principles

- Guiding Principles that help develop better systems
- Use principles only where they apply
- You must see the symptoms to apply them
- If you apply arbitrarily, the code ends up with *Needless Complexity*

DRY

- Don't Repeat Yourself
- "Every Piece of Knowledge must have a single, unambiguous, authoritative representation within a system"
- One of the most difficult, but most seen
- How many times have you see this happen



1. Validates input

Execution Engine (chokes on certain names of objects)

Frontend

3. Took weeks to get this issue resolved

2. Fixes the restriction

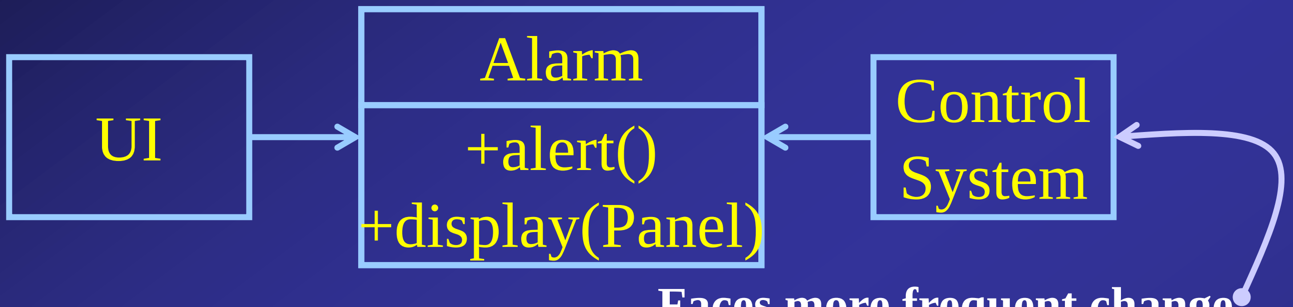
DRY

- Some times hard to realize this
- It is much easier to copy, paste and modify code to get it working the way you want it, isn't it
- Duplicating code results in
  - Poor maintainability
  - Expensive to fix bugs/errors
  - Hard to keep up with change

SRP

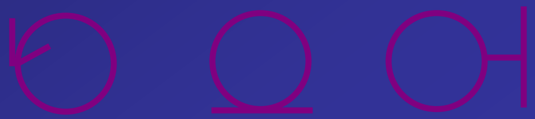
- Single-Responsibility Principle
- What metric comes to mind?
- “A class should have only one reason to change”
- Some C++ books promoted bad design
  - Overloading input/output operators!
- What if you do not want to display on a terminal any more?
  - GUI based, or web based?

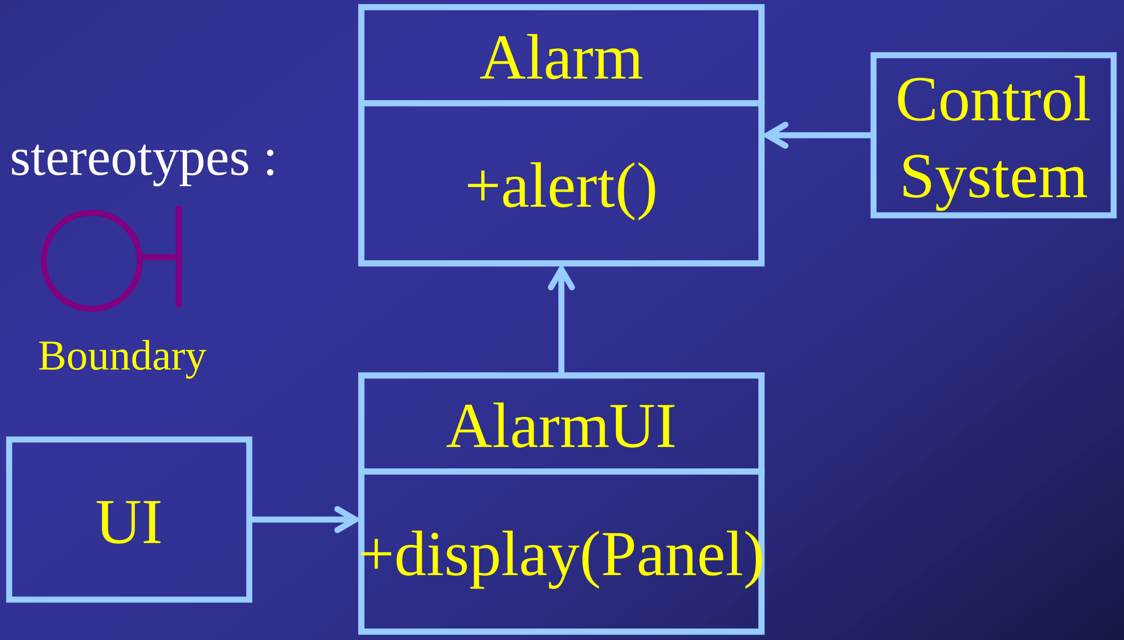
SRP…



Faces more frequent change
Has greater dependency (to UI related stuff)

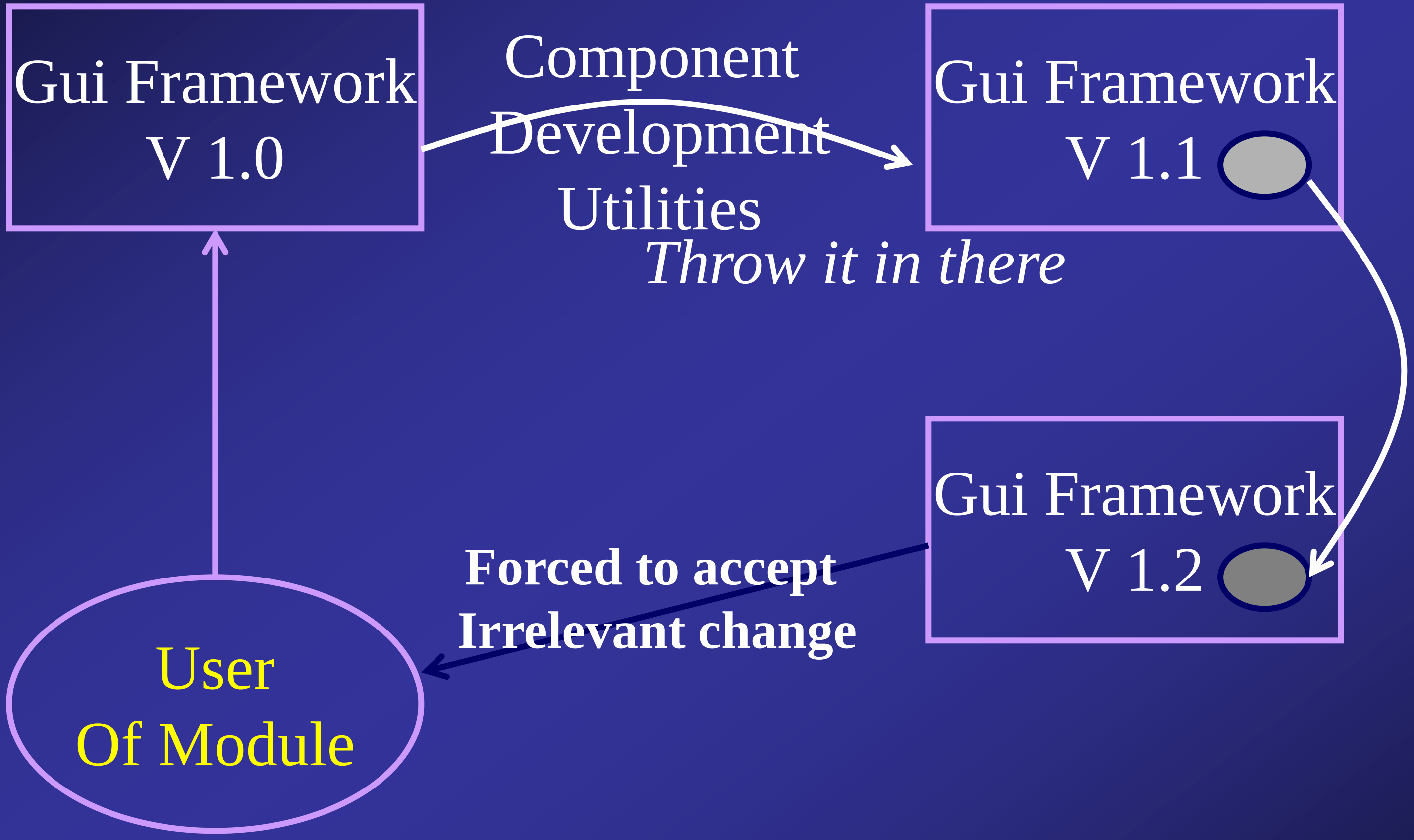
Related topics:
MVC
Analysis model stereotypes :





SRP at Module Level

- Can be extended to module level as well



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SRP affects Reuse

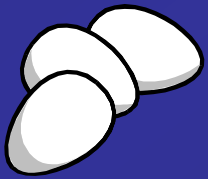
- Lower cohesion results in poor reuse
  - My brother just bought a new DVD and a big screen TV!
  - He offers to give me his VCR!
  - I have a great TV and all I need is a VCR
  - Here is what I found when I went to pickup!

Tight coupling
Poor Cohesion
Bad for resuse

Disclaimer: This slide not intended to say anything about the brand of product shown here as an example!

Nature of code

- “Software Systems change during their life time”
- Both better designs and poor designs have to face the changes; good designs are stable



OCP…

Bertrand Meyer:

"Software Entities (Classes, Modules, Functions, etc.) should be open for extension, but closed for modification"

OCP…

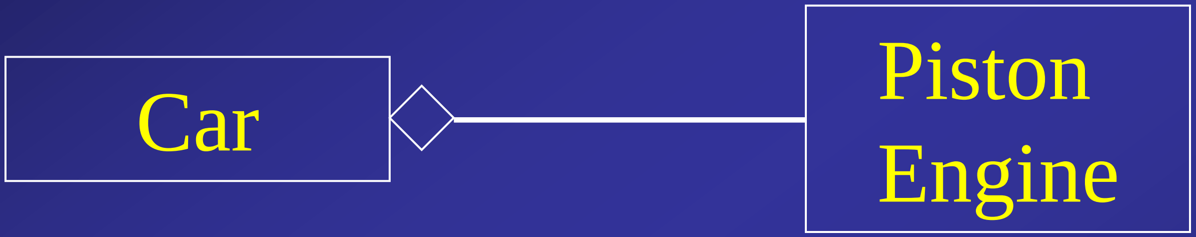
- Characteristics of a poor design:
  - Single change results in cascade of changes
  - Program is fragile, rigid and unpredictable

- Characteristics of good design:
  - Modules never change
  - Extend Module’s behavior by adding new code, not changing existing code

OCP…

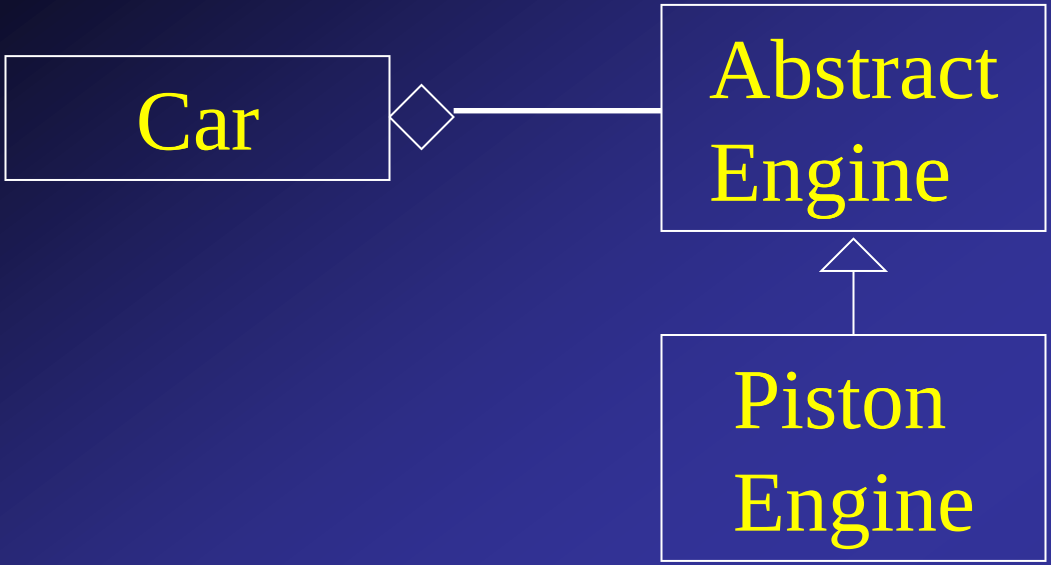
- Software Modules must
  - be open for extension
    - module’s behavior can be extended
  - closed for modification
    - source code for the module must not be changed

OCP…



- How to make the Car run efficiently with Turbo Engine ?
- Only by changing Car in the above design

OCP…



Abstraction & Polymorphism are the Key

- ***A class must not depend on a Concrete class; it must depend on an abstract class***

OCP…

Strategic Closure:

No program can be 100% closed

There will always be changes against which the module is not closed

Closure is not complete - it is strategic

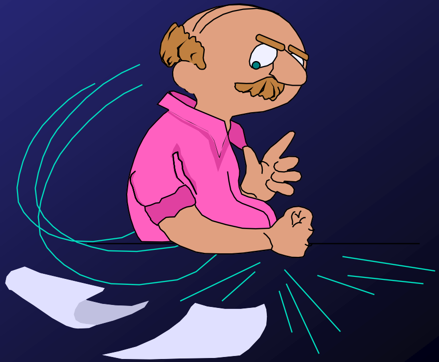
Designer must decide what kinds of changes to close the design for.

This is where the experience and problem domain knowledge of the designer comes in

OCP…

Heuristics and Conventions that arise from OCP

- Make all member variables private
  - encapsulation: All classes/code that depend on my class are closed from change to the variable names or their implementation within my class. Member functions of my class are never closed from these changes
  - Further, if this were public, no class will be closed against improper changes made by any other class
- No global variables



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OCP…

Heuristics and Conventions that arise from OCP…

- RTTI is ugly and dangerous
  - If a module tries to dynamically cast a base class pointer to several derived classes, any time you extend the inheritance hierarchy, you need to change the module

Not all these situations violate OCP all the time

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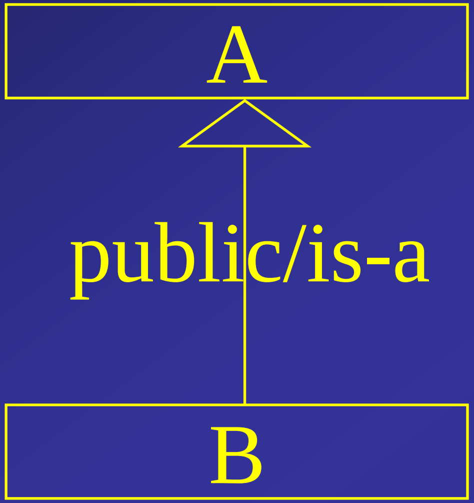
v Substitution Principle

- Inheritance is used to realize Abstraction and Polymorphism which are key to OCP
- How do we measure the quality of inheritance?
- LSP:

"Functions that use pointers or references to base classes must be able to use objects of derived classes without knowing it"

eritance



B publicly inherits from (*“is-a”*) A means:

- every object of type B is also object of type A
- whats true of object of A is also of object of B
- A represents a more general concept than B
- B represents more specialized concept than A
- **anywhere an object of A can be used, an object of B can be used**

Behavior

Advertised Behavior of an object

- Advertised Requirements (Pre-Condition)
- Advertised Promise (Post Condition)

Stack and eStack example

Design by Contract

Design by Contract

Advertised Behavior of the

Derived class is Substitutable for that of the Base class

Substitutability: Derived class Services Require no more and promise no less than the specifications of the corresponding services in the base class

LSP

"Any Derived class object must be substitutable where ever a Base class object is used, without the need for the user to know the difference"

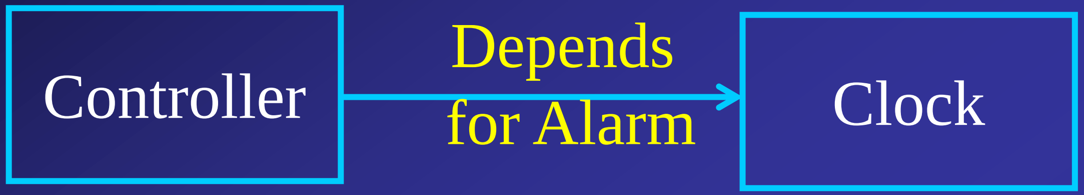
LSP in Java?

- LSP is being used in Java at least in two places
- Overriding methods can not throw new unrelated exceptions
- Overriding method’s access can’t be more restrictive than the overridden method
  - for instance you can’t override a public method as protected or private in derived class

ature of Bad Design

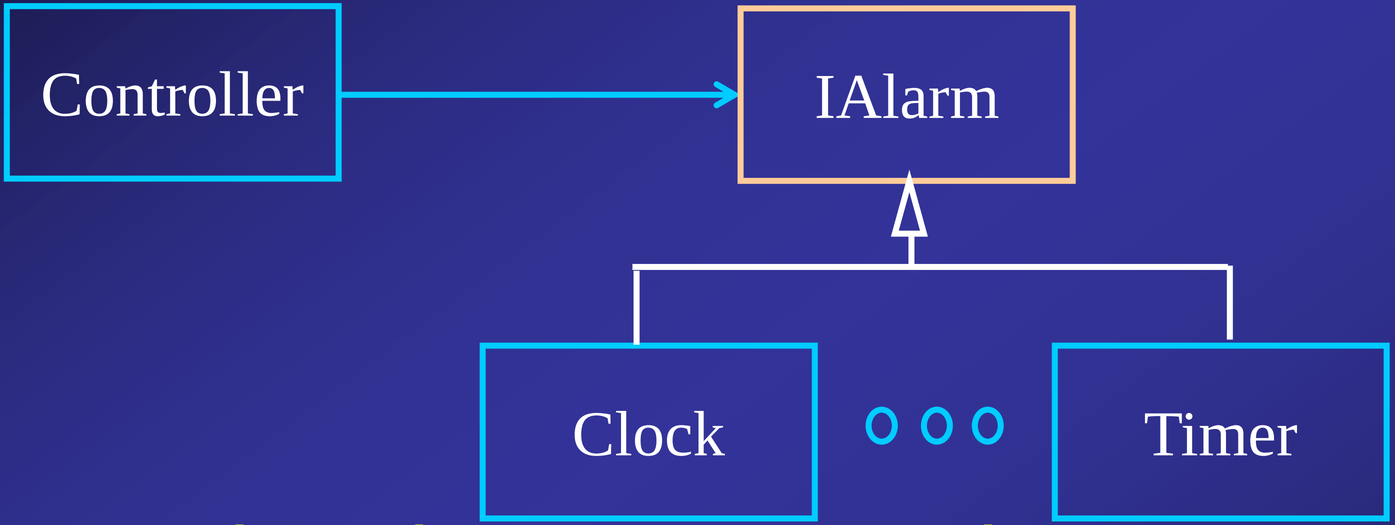
- Bad Design is one that is
  - Rigid - hard to change since changes affect too many parts
  - Fragile - unexpected parts break upon change
  - Immobile - hard to separate from current application for reuse in another

Ramifications



- Controller needs an alarm
- Clock has it, so why not use it?
- Concrete Controller depends on concrete Clock
- Changes to Clock affect Controller
- Hard to make Controller use different alarm (fails OCP)
- Clock has multiple responsibilities (fails SRP)

Alternate Design



- Dependency has been inverted
- Both Controller and Clock depend on Abstraction (IAlarm)
- Changes to Clock does not affect Controller
- Better reuse results as well

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DIP

- Dependency Inversion Principle

"High level modules should not depend upon low level modules. Both should depend upon abstractions."

"**Abstractions should not depend upon details**.

Details should depend upon abstractions."

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The Founding Principles

- The three principles are closely related
- Violating either LSP or DIP invariably results in violating OCP
- It is important to keep in mind these principles to get the most out of OO development

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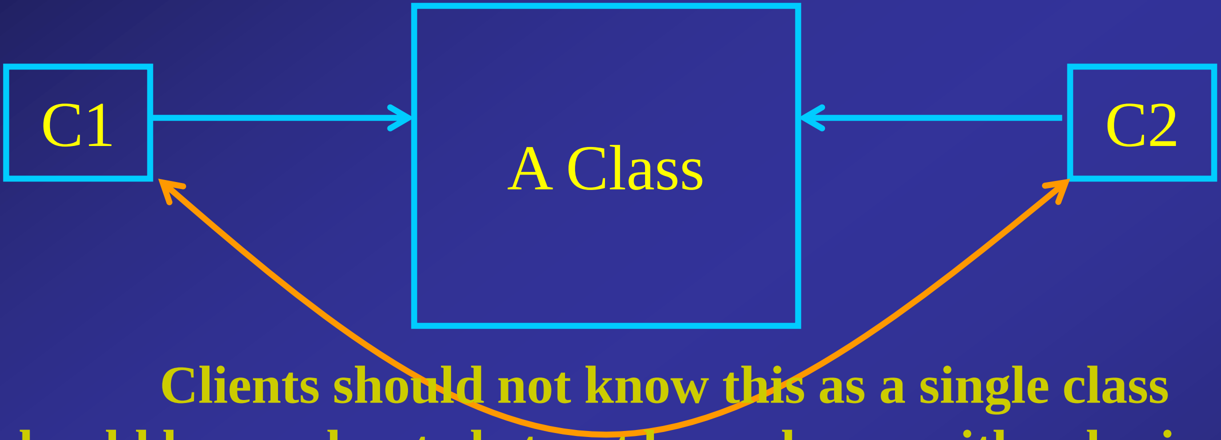
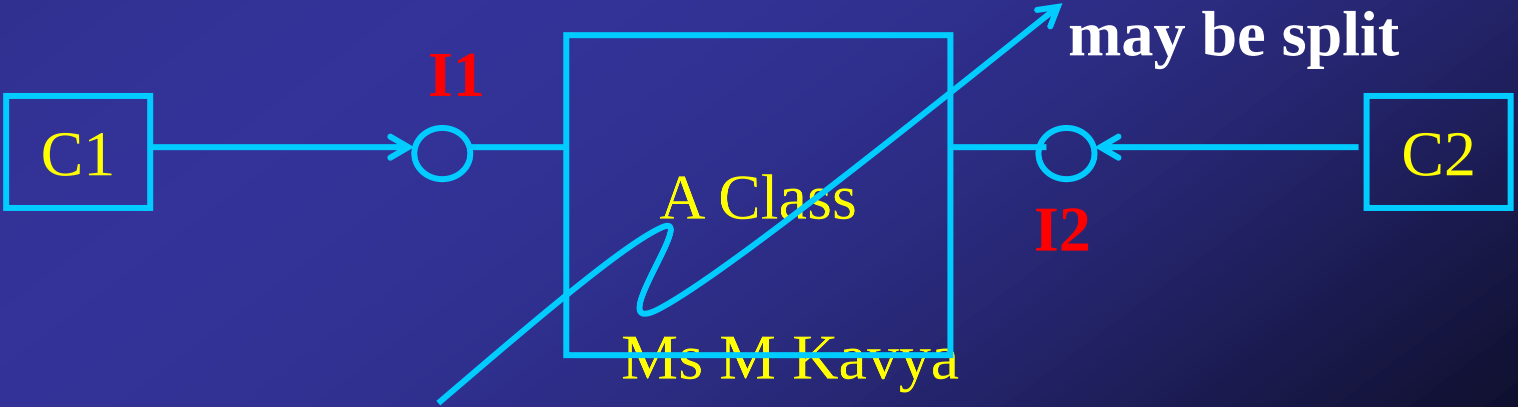
Fat Interfaces

- Classes tend to grow into fat interfaces
- Examples of this can been seen in several APIs
- Less cohesive (fails SRP)



Clients should not know this as a single class
They should know about abstract base classes with cohesive interfaces



Interface of the class may be split

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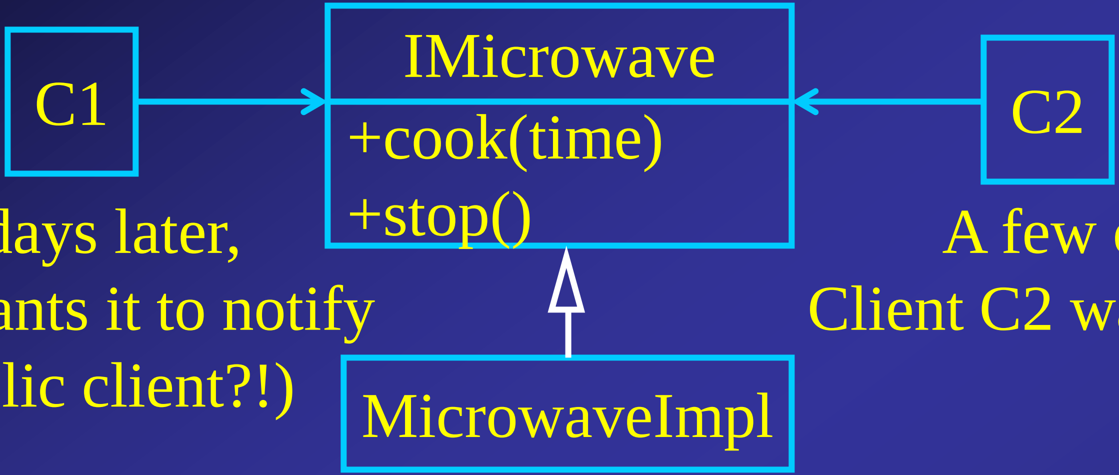
Growth of an interface



C1

IMicrowave

+cook(time)

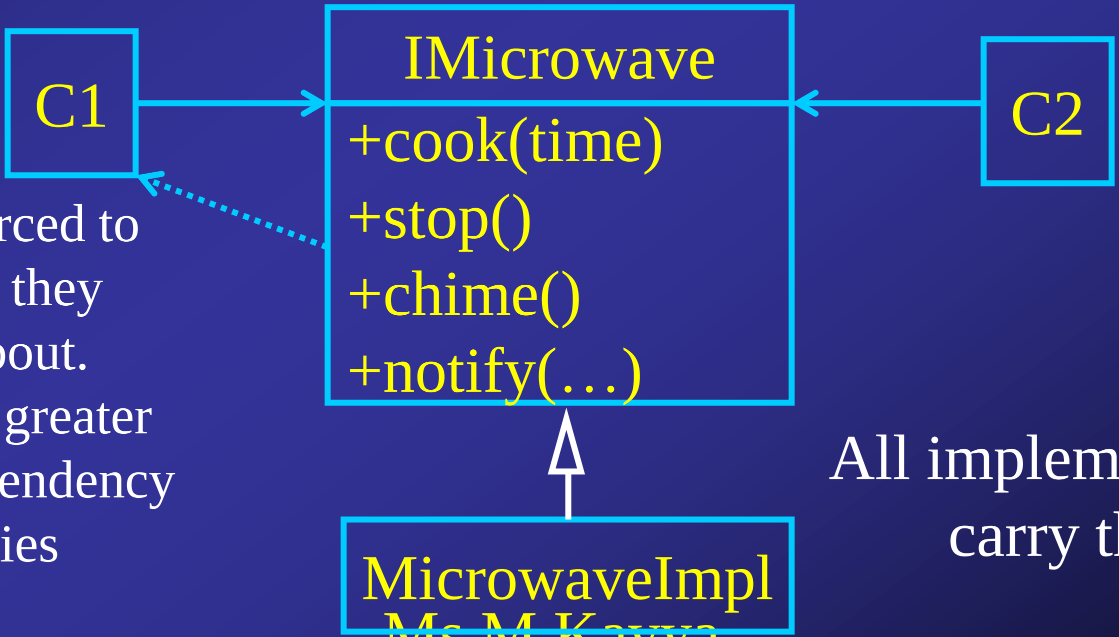
+stop()

C2

MicrowaveImpl

A few days later,
Client C1 wants it to notify
(workaholic client?!)

A few days later,
Client C2 wants it to chime



C1

IMicrowave

+cook(time)

+stop()

+chime()

+notify(…)

C2

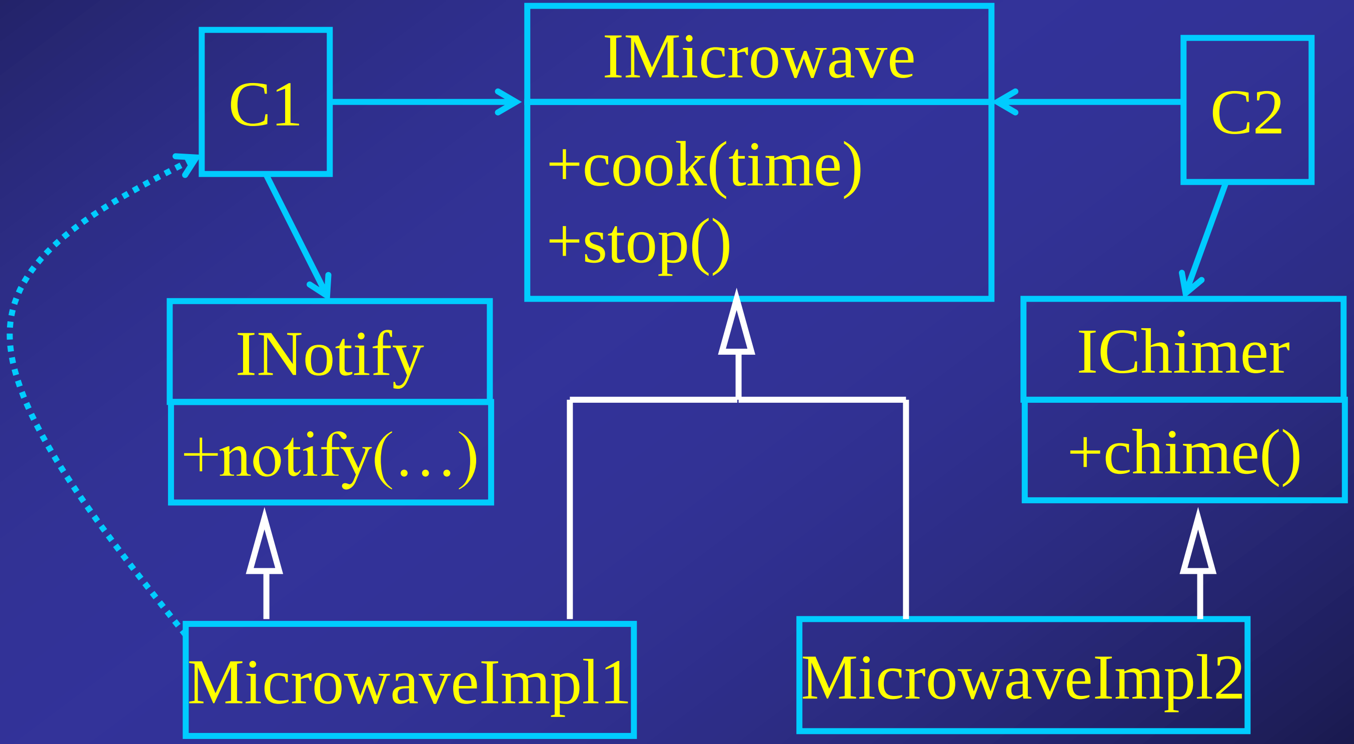
MicrowaveImpl

Clients are forced to use interfaces they do not care about. May result in greater coupling, dependency to more libraries

All implementations must carry the weights

ISP

- Interface Segregation Principle
- “Clients should not be forced to depend on methods that they do not use”



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Reuse/Release Equivalency Principle

"The granularity of reuse is the same as the granularity of release. Only components that are released through a tracking system can be effectively reused."

Reuse/Release Equivalency Principle

- Release
  - A class generally collaborates with other classes
  - For a class to be reused, you need also the classes that this class depends on
  - All related classes must be released together

Reuse/Release Equivalency Principle

- Tracking
  - A class being reused must not change in an uncontrolled manner
  - Code copying is a poor form of reuse

Software must be released in small chunks - components

Each chunk must have a version number

Reusers may decide on an appropriate time to use a newer version of a component release

Common Closure Principle

“Classes within a released component should share common closure. If one need to be changed, they all are likely to need to be changed. What affects one, affect all.”

Common Closure Principle…

- A change must not cause modification to all released components
- Change must affect smallest possible number of released components
- Classes within a component must be cohesive
- Given a particular kind of change, either all classes in a component must be modified or no class needs to be modified
- Reduces frequency of re-release of component

Common Reuse Principle

"Classes within a released component should be reused together. That is, it must be impossible to separate the component in order to reuse less than the total."

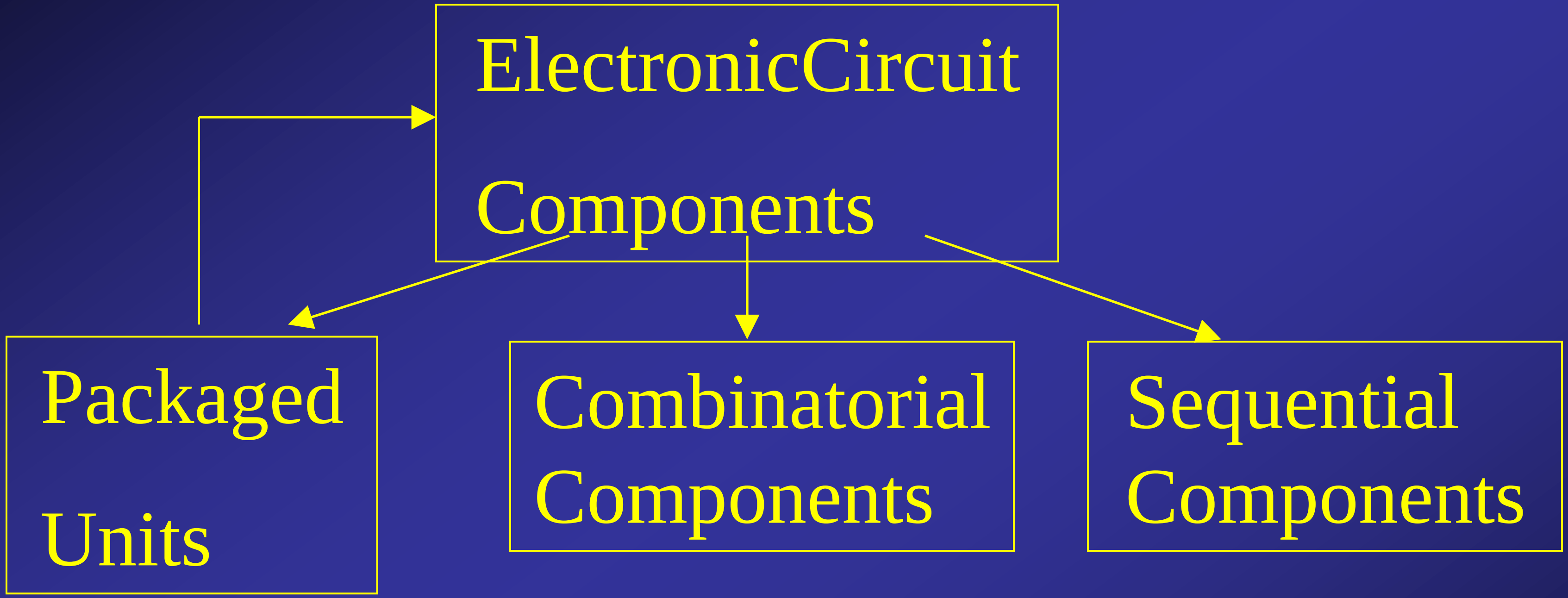
Common Reuse Principle…

- Components must be focused
- Component must not contain classes that an user is not likely to reuse
  - user may be forced to accept a new release due to changes to unused classes
- Component must be narrow

Acyclic Dependency Principle

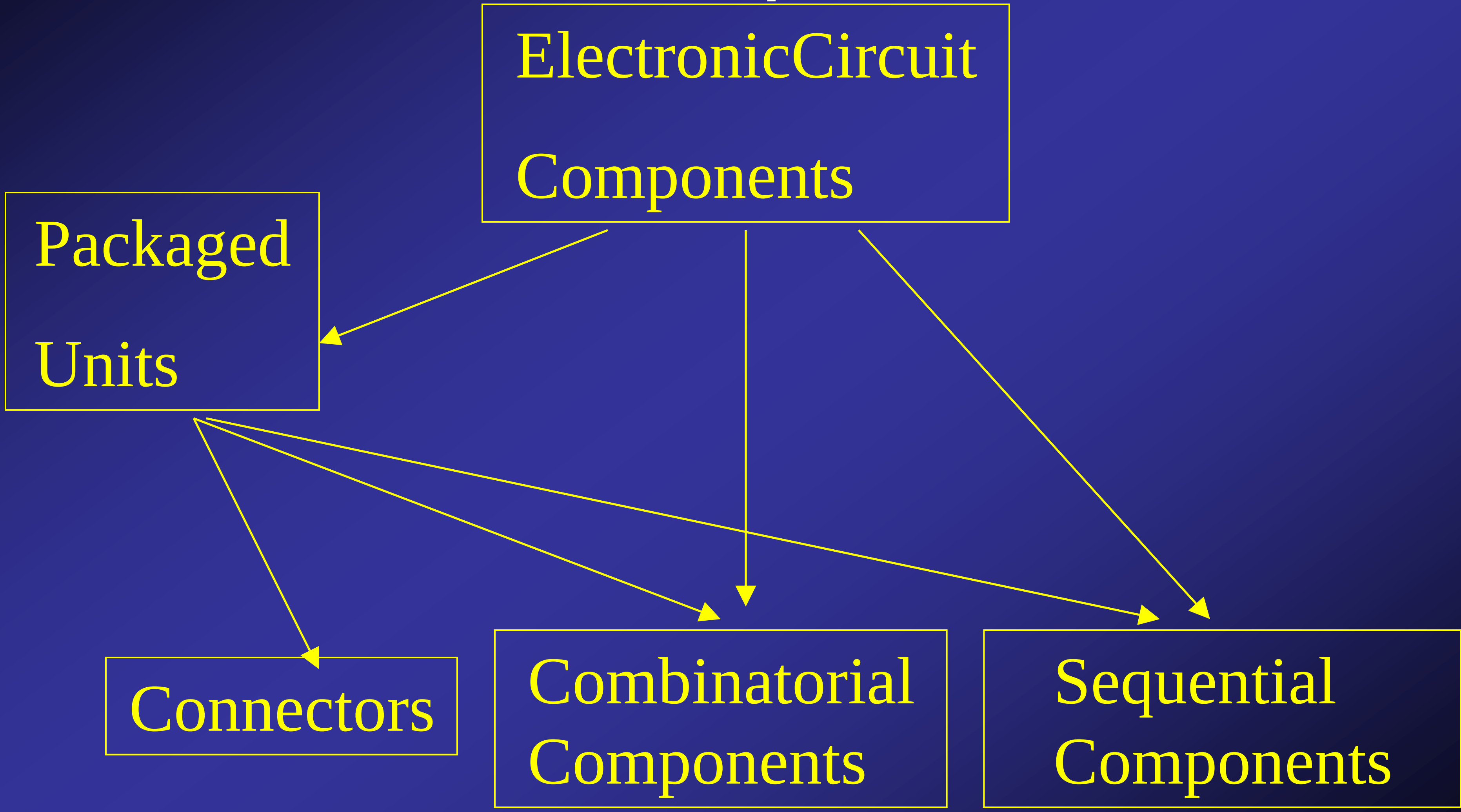
"The dependency structure for released component must be a Directed Acyclic Graph. There can be no cycles."

Acyclic Dependency Principle...



- Cannot release application in pieces

Acyclic Dependency Principle



ElectronicCircuit Components

Packaged Units

Connectors

Combinatorial Components

Sequential Components

- Break cyclic dependency into subcomponents

Stable Dependency Principle

“Dependencies between released components must run in the direction of stability. The dependee must be more stable than the depender.”

Stable Dependency Principle

- A component can never be more stable than the one it depends upon
- Instability $I = C_e / (C_a + C_e)$,

where

C_a - # of classes outside that depend upon this class

C_e - # of classes outside that this class depends upon

- $0 \leq I \leq 1$
- ***0 - ultimately stable; 1 - ultimately unstable***

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Stable Dependency Principle...

Components should be arranged such that components with a high **I** *metrics should depend upon component with low* **I** *metrics*

Stable Abstraction Principle

"The more stable a component is, the more it must consist of abstract classes. A completely stable category should consist of nothing but abstract classes."

Stable Abstraction Principle

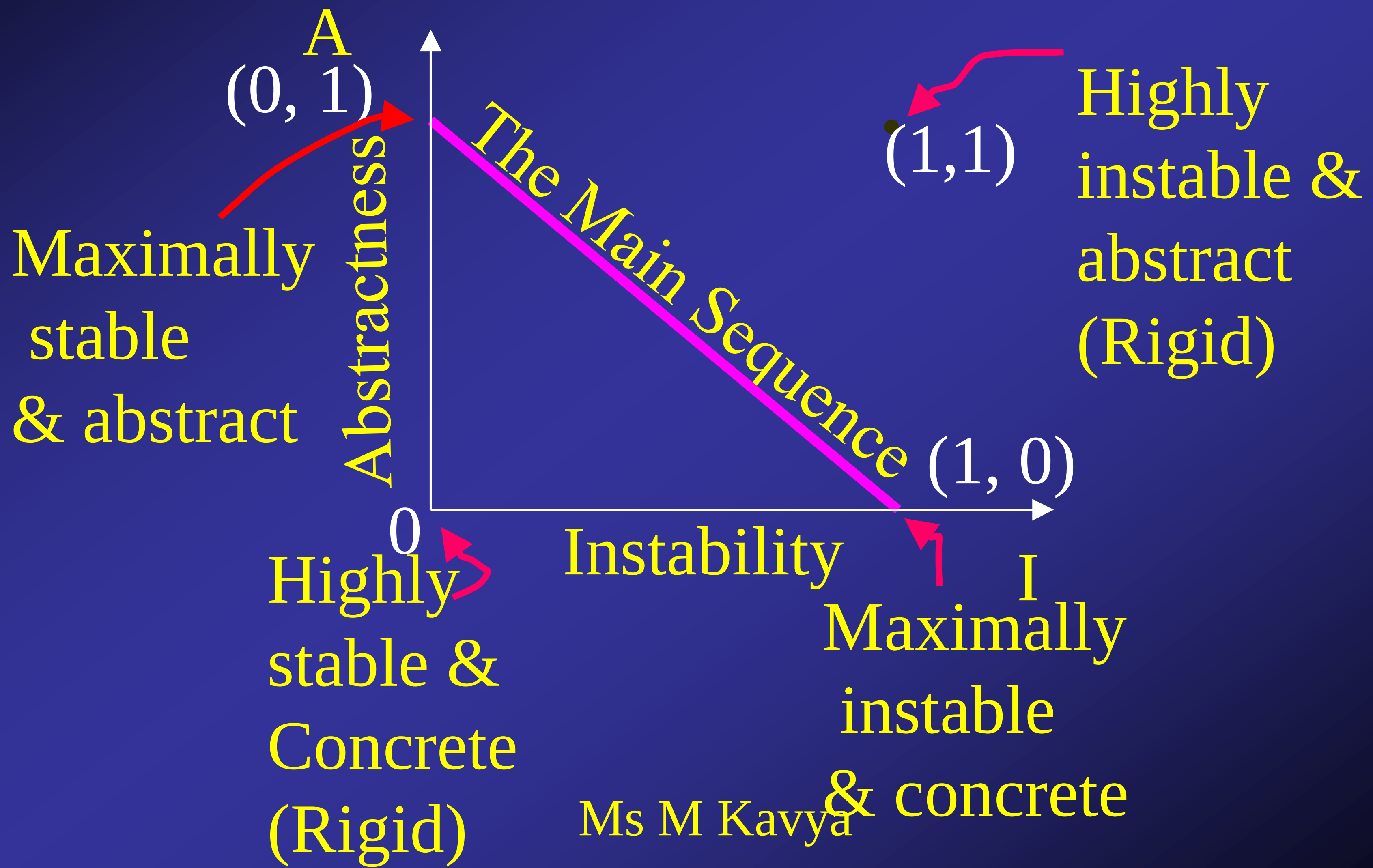
- Implementation of methods change more often than the interface
- Interfaces have more intrinsic stability than executable code
- Abstraction of a Component

  A = (# of abstract classes) / (# of classes)

$0 \leq A \leq 1$

- 0 - no abstract classes; 1 - all abstract classes

ity Vs. Abstractness



stance from the main sequence

- $D = |(A + I - 1) / \sqrt{2}\ |$

- $0 \leq D \leq 0.707$; *Desirable value of D is closed to 0*

- Normalized form $D' = |(A + I - 1)|$

- Calculate D value for each component
- Component whose D value is not near Zero can be reexamined and restructured

Applying the Principles

- Developing with OO is more than
  - Using a certain language
  - Creating objects
  - Drawing UML
- It tends to elude even experienced developers
- Following the principles while developing code helps attain agility
- Use of each principle should be justified at each occurrence, however