11 Design Patterns for Multimedia Programs

11.1 Specific Design Patterns for Multimedia Software

11.2 Classical Design Patterns Applied to Multimedia

Literature:

R. Nystrom: Game Programming Patterns, genever banning 2014,
See also http://gameprogrammingpatterns.com/

Erich Gamma, Richard Helm, Ralph Johnson, John Vlissides,
Design Patterns, Addison-Wesley 1994

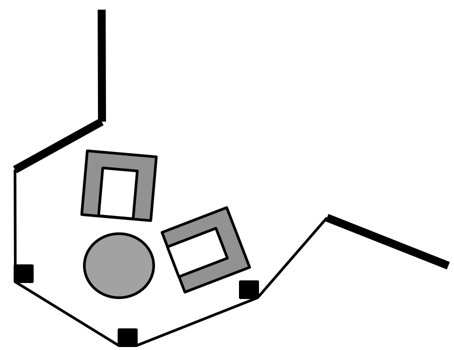
Design Patterns

- A *design pattern* is a generic solution for a class of recurring programming problems
  - Helpful idea for programming
  - No need to adopt literally when applied
- Origin:
  - Famous book by Gamma/Helm/Johnson/Vlissides ("Gang of Four", "GoF")
    - » List of standard design patterns for object-oriented programming
    - » Mainly oriented towards graphical user interface frameworks
    - » Examples: Observer, Composite, Abstract Factory
- Frequently used in all areas of software design
- Basic guidelines:
  - Patterns are not invented but recovered from existing code
  - Pattern description follows standard outline
    - » E.g.: Name, problem, solution, examples

Window Place: Architectural Pattern

Christopher Alexander et al., A Pattern Language, 1977
(quoted in Buschmann et al. 1996)

- **Problem:** In a room with a window and a sitting opportunity users have to decide whether to have a look or to sit.
- **Solution:**
At least one window of the room shall provide a sitting place.
- **Structure:**



Each pattern describes a problem which occurs over and over again in our environment, and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice.

Christopher Alexander et al., A Pattern Language

Description of a Design Pattern

- Name
- Problem
  - Motivation
  - Application area
- Solution
  - Structure (class diagram)
  - Participants (usually class, association und operation names):
    - » Role name, i.e. place holders for parts of implementation
    - » Fixed parts of implementaton
  - Collaboration (sequence of events, possibly diagrams)
- Discussion
  - Pros and cons
  - Dependencies, restrictions
  - Special cases
- Known uses

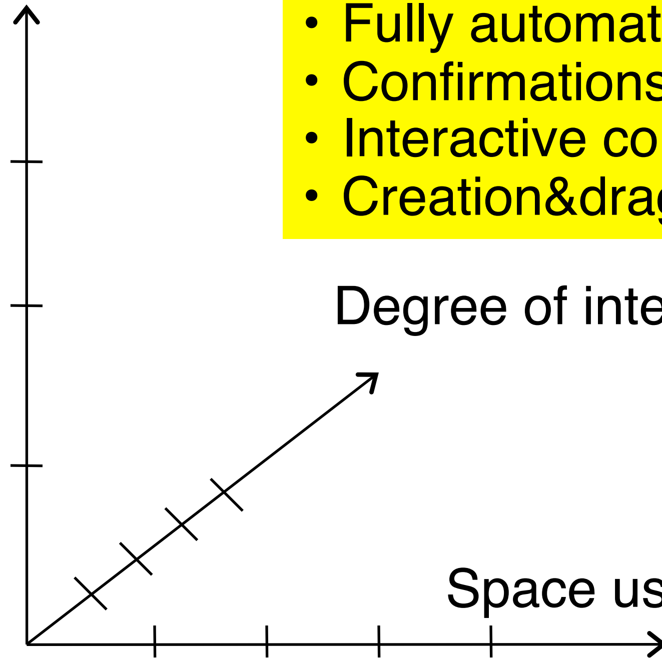
Patterns for Multimedia Software

- The following examples of patterns are not taken from literature, but derived from the material in this lecture
  - Based on various platforms, also older ones
- Types of patterns:
  - Cross-platform patterns
  - Patterns specific for a certain platform

Classification Space

Time usage:
- Still picture
- Linear progress
- Interaction dependent progress

Interactivity:
- Fully automatic (passive)
- Confirmations & questions (reactive)
- Interactive controls (proactive)
- Creation&dragging of objects (directive)



Space usage:
- Static layout
- Scenes
- Scenes & objects
- Fully dynamic

Aleem, T. A. (1998). A Taxonomy of Multimedia Interactivity.(Doctoral Dissertation, The Union Institute, 1998).

Cross-Platform Multimedia Pattern: Clockwork

- The current properties of presentation elements are derived from the current value of a “clock” ticking at regular time intervals
- Time usage: Linear progress
- Limited interactivity: Automatic or confirmations&questions
- Usually combined with static layout or scenes and objects
- Examples:
  - Timeline in Flash, Director, JavaFX
  - EnterFrame-Events in Flash ActionScript
  - Ticking scripts in Squeak
  - Clock class in PyGame
  - Scheduler in Cocos2d-x

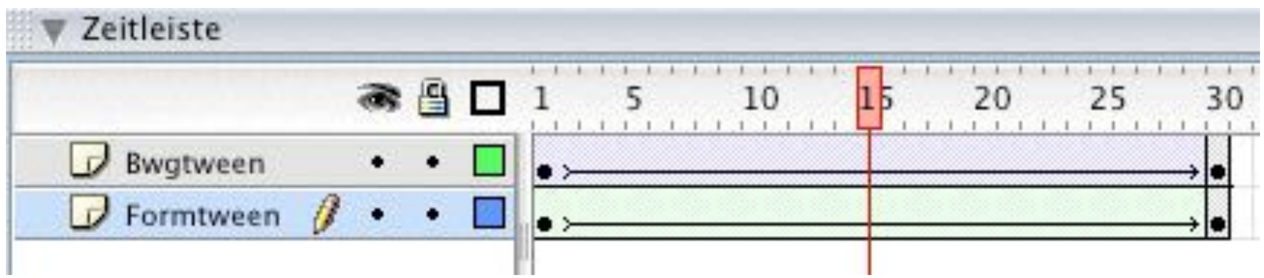
University of Maryland
“Piccolo” framework
(see cs.umd.edu/hcil/piccolo)

```
PActivity flash =
        new PActivity(-1, 500, currentTime + 5000) {

        protected void activityStep(long elapsedTime) {
        … }
```

Cross-Platform Multimedia Pattern: Interpolation

- A parameter (usually regarding a graphical property) is assumed to change its value continuously dependent of another parameter (e.g. time). The dependency can follow a linear or other rules of computation.
  - Fixed values for the dependent parameter are given for certain values of the base parameter.
  - Intermediate values of the dependent parameter are computed by interpolation.
- Space usage: scenes&objects mainly
- Time usage: Linear progress only
- Usually combined with low interactivity (on this level)
- Examples:
  - Tweening in Flash
  - Actions in Cocos2d-x
  - JavaFX transitions

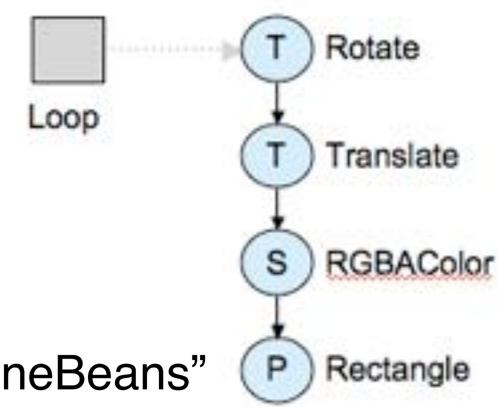


Piccolo

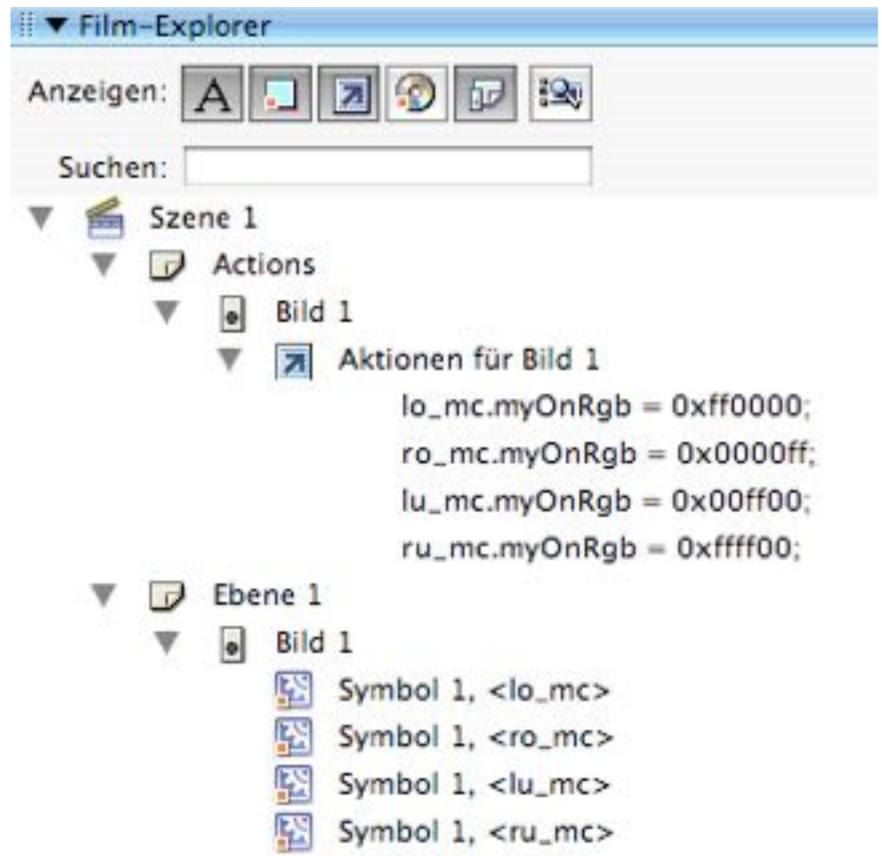
```
PActivity a1 =
     aNode.animateToPositionScaleRotation(0, 0, 0.5, 0, 5000);
```

Cross-Platform Multimedia Pattern: Scene Graph

- Graph structure for all represented objects
- Space usage: Scenes&objects or fully dynamic
- Time usage: Linear progress or interaction dependent
- Examples:
  - Scene graph of Cocos2d-x, JavaFX
  - Scene graph of Piccolo
  - Implicit: Film Explorer view in Flash



“SceneBeans”



Cross-Platform Pattern: Time Container Algebra

- Presentation is built from atomic parts (processes) each of which is executed in a *time container*.
- Time containers are composed by algebraic operations: sequential composition, parallel composition, repetition, mutual exclusion, synchronization options
- Time usage: Linear progress
- Space usage: Scenes or scenes&objects
- Low interactivity
- Examples:
  – SMIL body: seq, par, excl
  – Cocos2-x actions: Sequence, Spawn, Repeat
  – Animations class of “JGoodies” animation framework for Java
  – Sequence of frames and parallelism of layers in Flash

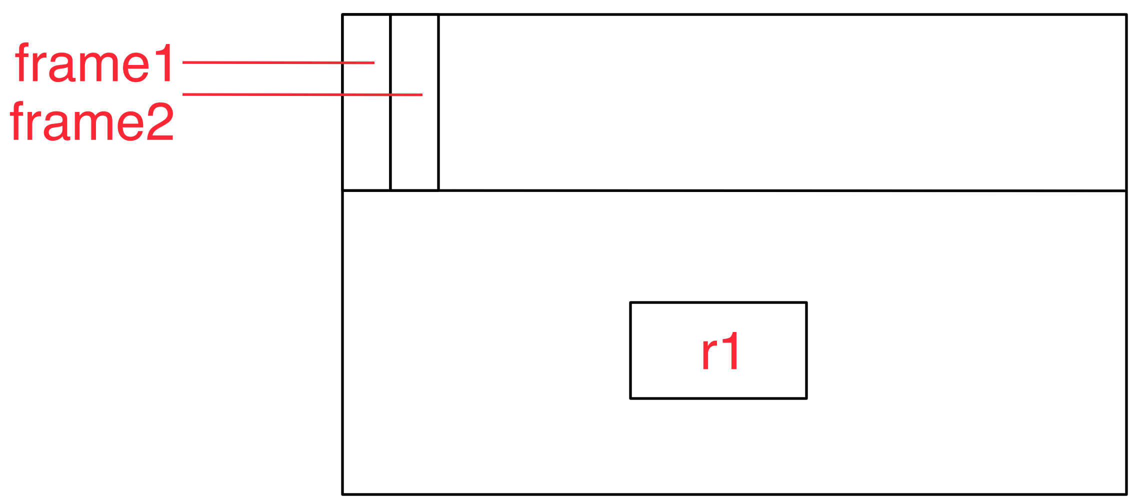
Various Syntactical Representations for a Single Concept

```
<layout>
  <region id=“r1” ...>
</layout>
<body>
  <seq>
     ...frame1
     ...frame2
  </seq>
</body>
```

XML

```
Sprite* imageSprite r1;
auto act1 = … frame1;
auto act2 = … frame2;
r1->runAction(
  Sequence::create(act1, act2, NULL));
```

Cocos2d-x



Authoring Tool (Flash-like)

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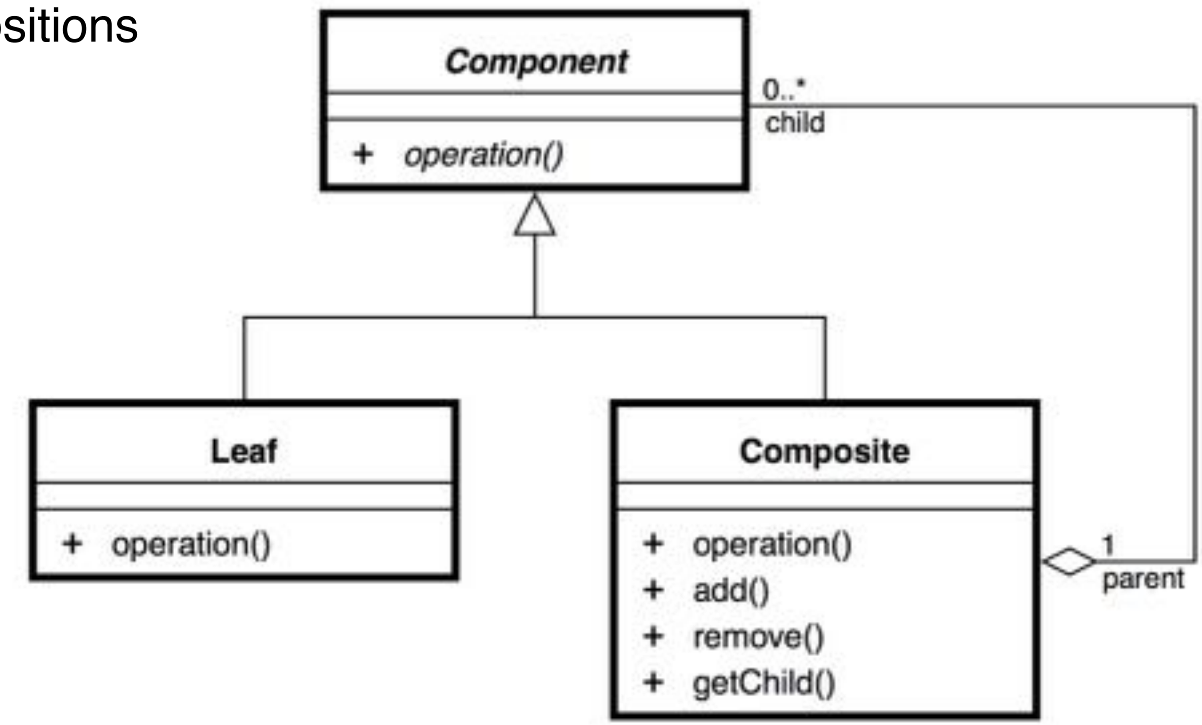
GoF Structural Pattern: Composite

- Situation:
  - Complex tree-structured objects
- Motivation:
  - Use homogeneous interface for objects and compositions thereof



Exercise (Cocos2d-x):
Compare with classes
- Node
- Scene
- Layer
- Sprite
- DrawNode

GoF Patterns: Observer, Template Method, Façade

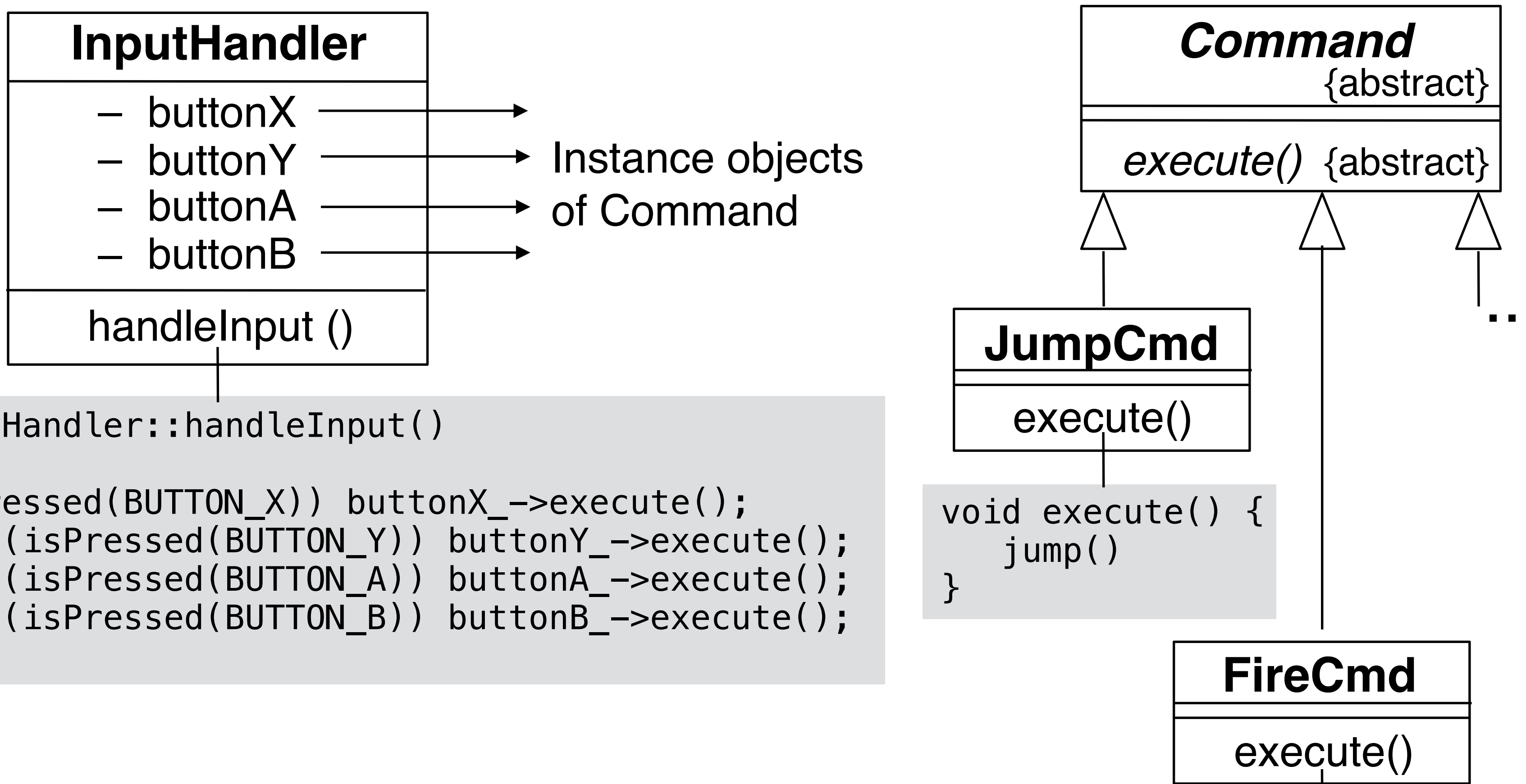
- Observer (behavioral):
  - Decoupling event handling from event sources
  - Notification interface for observers, registration functions for subjects
  - ***Basic principle of all event handling mechanisms***
    Built into most GUI and multimedia frameworks
- Template Method (behavioral):
  - Modifying detailed steps in an algorithm keeping its general structure
  - Program skeleton with calls to abstract methods (detail steps)
  - Subclasses specialize the abstract methods
  - ***Basis for inversion of control in frameworks***
    (e.g. `createScene()` and `init()` methods in Cocos2d-x)
- Façade (structural):
  - Maintaining a simple interface object to a large body of code
  - Used e.g. in Cocos2d-x in the `Director` object for game setup

GoF Behavioral Pattern: Command (1)

- Command:
  - Encapsulate a request as an object, alternative to callbacks
- Example:


```
void InputHandler::handleInput()
{
  if (isPressed(BUTTON_X)) jump();
  else if (isPressed(BUTTON_Y)) fireGun();
  else if (isPressed(BUTTON_A)) swapWeapon();
  else if (isPressed(BUTTON_B)) lurchIneffectively();
}
```

GoF Behavioral Pattern: Command (2)




```
void InputHandler::handleInput()
{
  if (isPressed(BUTTON_X)) buttonX_->execute();
  else if (isPressed(BUTTON_Y)) buttonY_->execute();
  else if (isPressed(BUTTON_A)) buttonA_->execute();
  else if (isPressed(BUTTON_B)) buttonB_->execute();
}
```

```
void execute() {
   jump()
}
```

```
void execute() {
   fire()
}
```

What are potential advantages of this restructuring?

Generalizing Command

- Commands may be parameterized
  - Example: Actors

```
class JumpCommand : public Command {
    public:
        void execute(GameActor& actor) {
            actor.jump();
        }
}
```

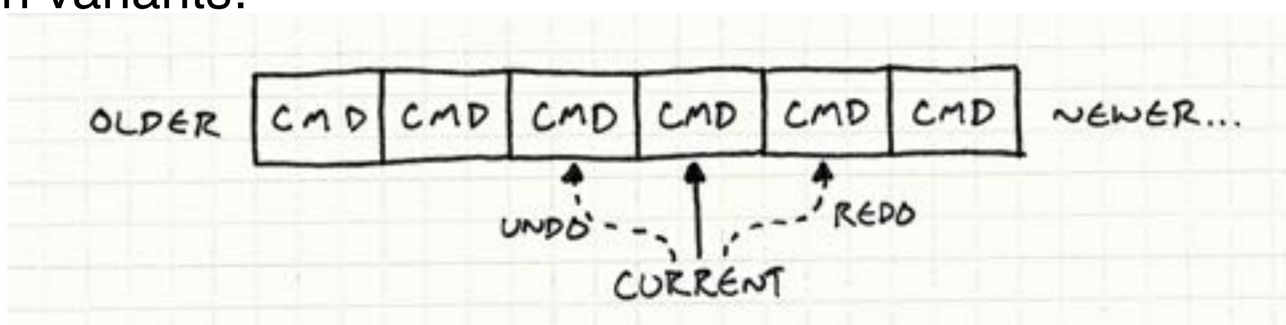
- Application example:
  - Defining Non-Player Characters (NPCs)
  - Typically based on "AI" (Artificial Intelligence)
  - AI code emits Command objects

Using Command for Undo Functionality

- Undo/Redo:
  - Generally important for all software – basic ingredient for good usability
  - Games: Important mainly in game creation, e.g. Level Design Software
- Extend Command by inverse to `execute()` method:

Command {abstract}
execute() {abstract} *undo()* {abstract}

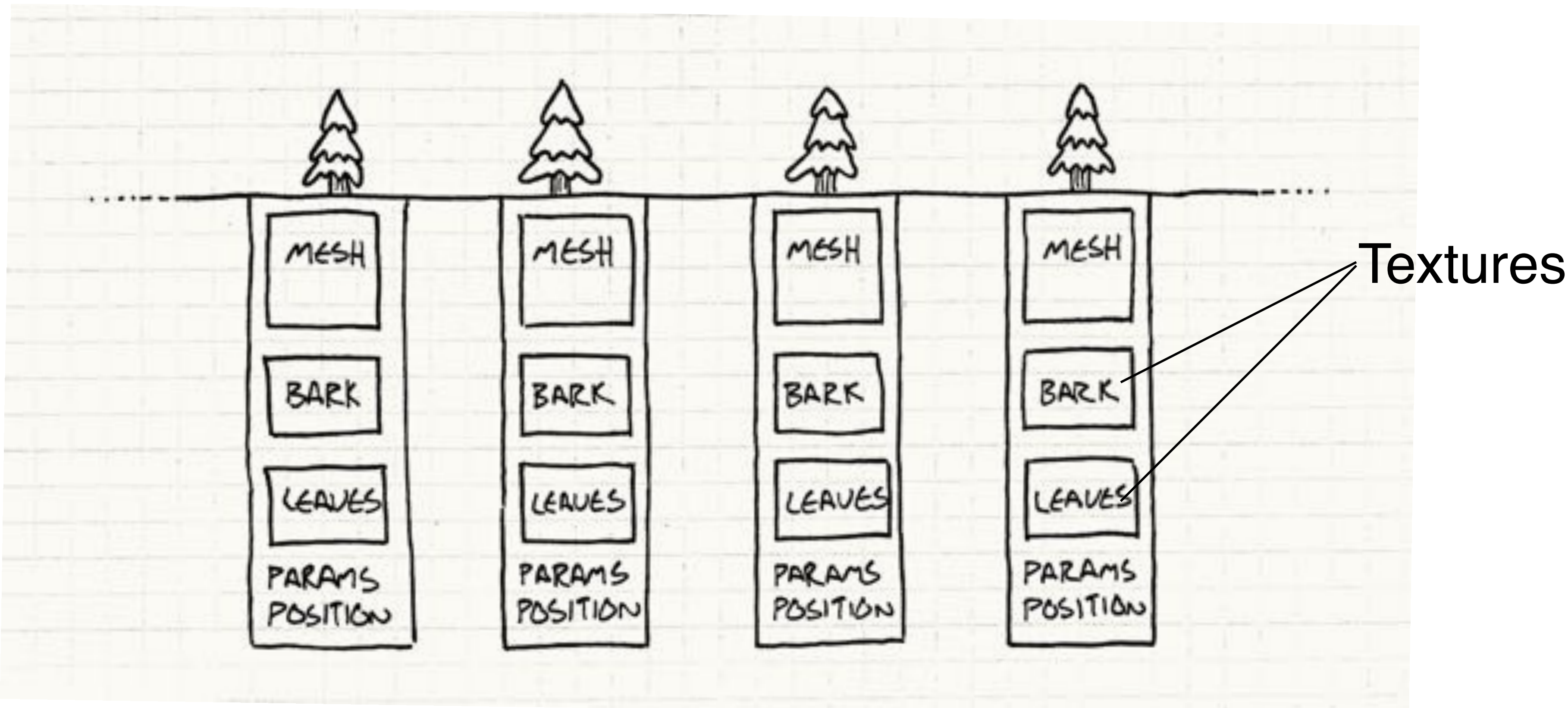
- Various application variants:
  - Including game replay



GoF Structural Pattern: Flyweight (1)

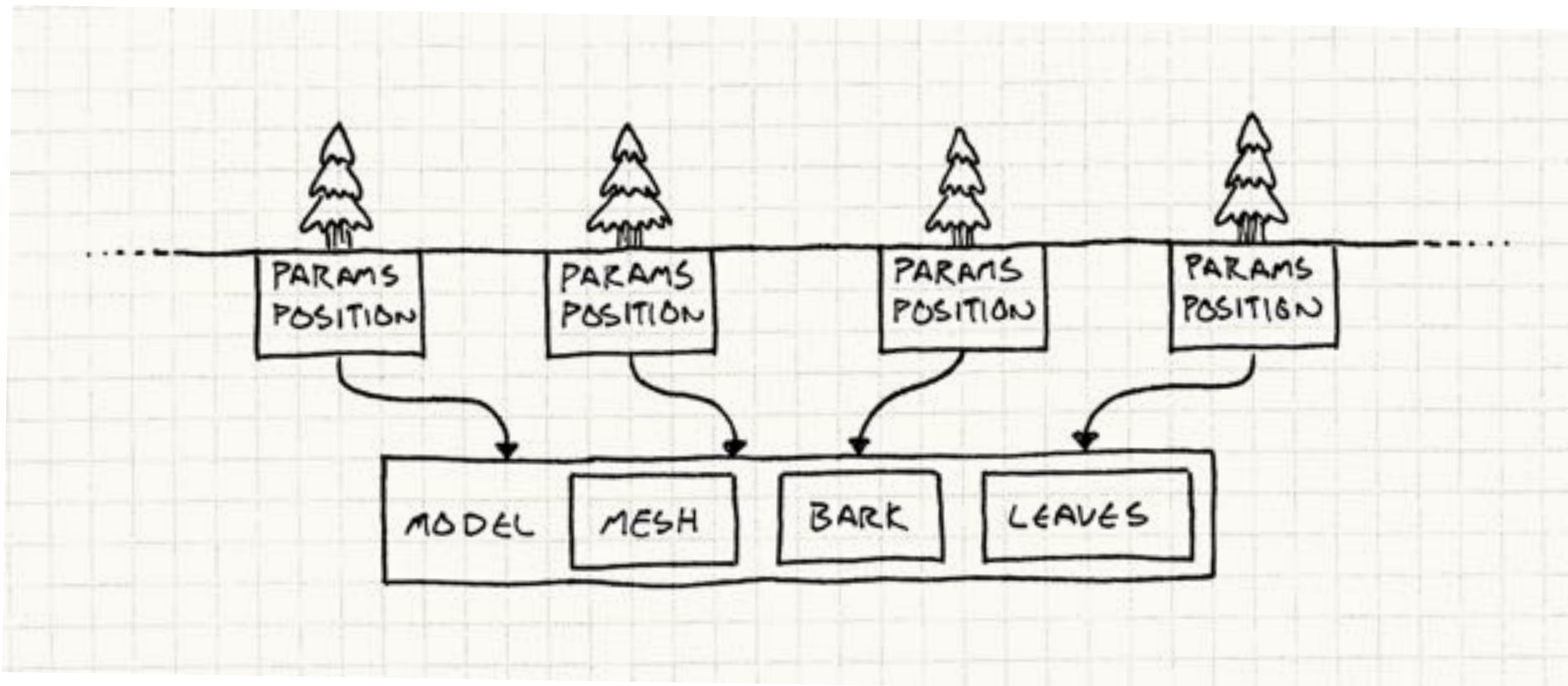
"Use sharing to support large numbers of fine-grained objects efficiently."
(GoF Book)

- Think about a majestic old growth forest
  - Consisting of individual trees…
  - Enormous amount of resource needs!



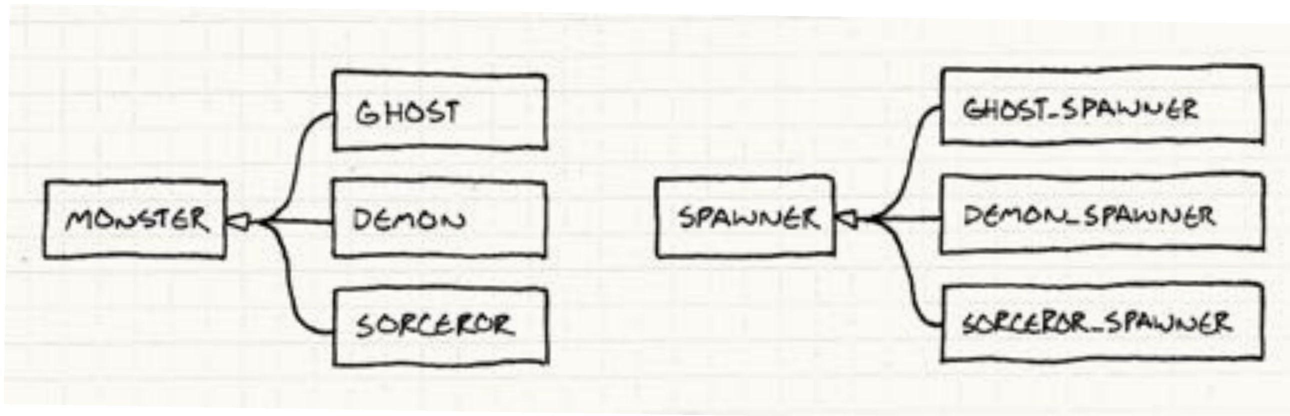
GoF Structural Pattern: Flyweight (2)

- Basic idea: Separate between
  - Data shared by many instances
  - Data specific for a single instance
- Goal: Memory and time efficiency, only



GoF Creational Pattern: Prototype (1)

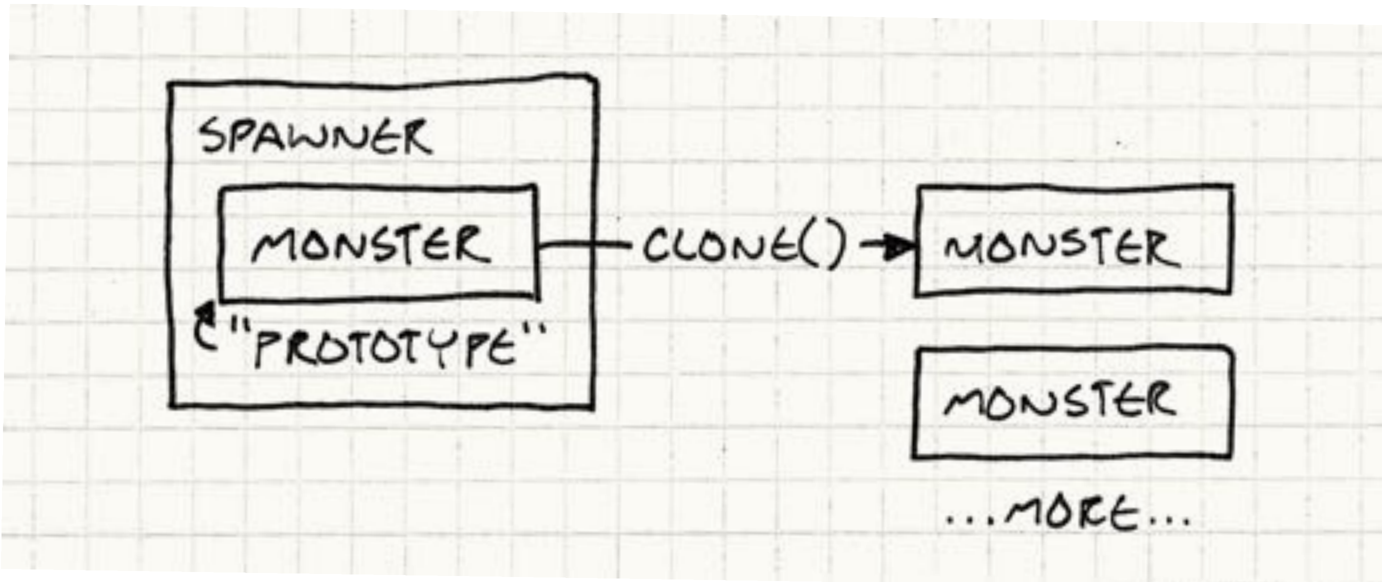
- Assuming we need many instances of a few types of objects:



- Extending the root class with a `clone()` method:

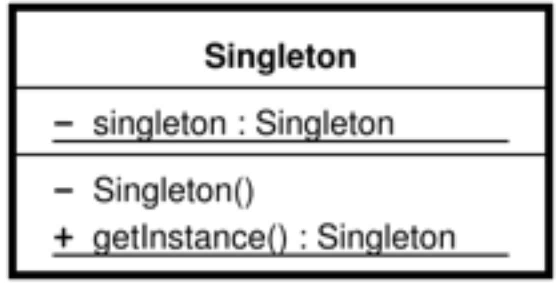
Monster
– speed – health – …
… clone()

GoF Creational Pattern: Prototype (2)



- Generic "spawner" (creator) object
  - Holds a local "prototype"
  - Creates on request copies of the prototype
- Spawner clones not only structure but also state!
  - May be used to differentiate more fine-grained than class hierarchy

GoF Creational Pattern: Singleton



- Realization of "single-instance" classes:
  - Only one instance exists and is created if needed
  - Access is homogeneous, whether instance exists or not
- Attention: To be called in a mutually exclusive way in multi-threaded applications!
- Examples for application in games:
  - Director class in Cocos2d-x (`Cocos2::Director::getInstance()`)
  - Audio engine in various frameworks (`CocosDenshion::SimpleAudioEngine::getInstance()`)

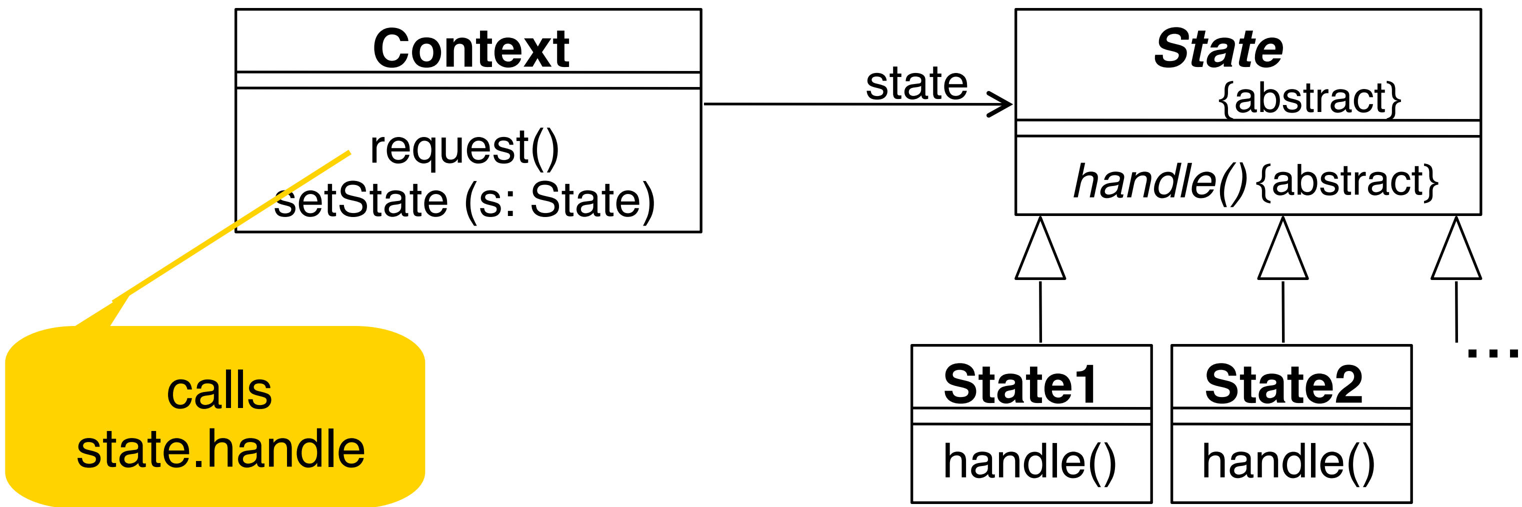
Criticism on Singleton Pattern

- Global state information:
  - Makes it difficult to reason about code locally (theoretical and practical aspects)
  - Introduces hidden coupling between code parts
  - Is not concurrency-friendly
- Multiple instances may be useful (e.g. for logging)
- Simple static methods of a static class may be more flexible

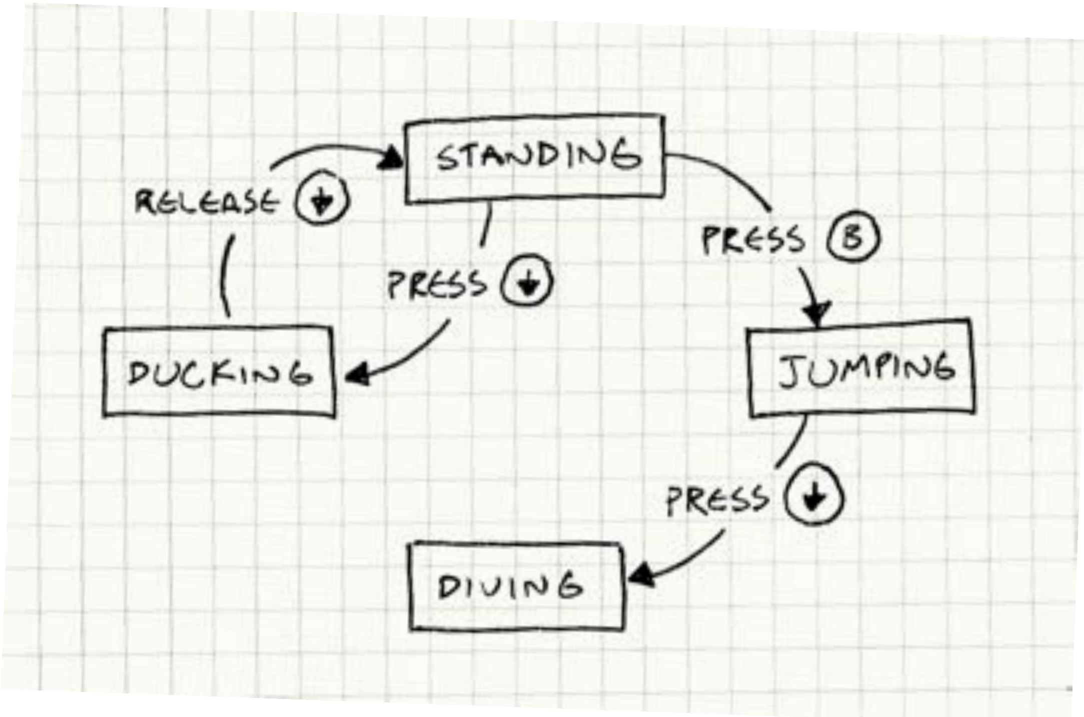
- General advice: Do not apply design patterns everywhere possible!
- Specific advice: Limit application to a few system-global assets

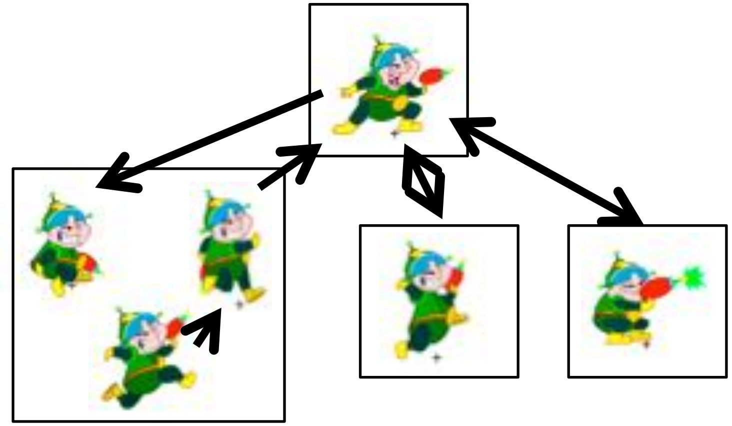
GoF Structural Pattern: State

- Name: **State**
- Problem:
  - Flexible and extensible technique to change the behavior of an object when its state changes.
- Solution :



Example for State (1)





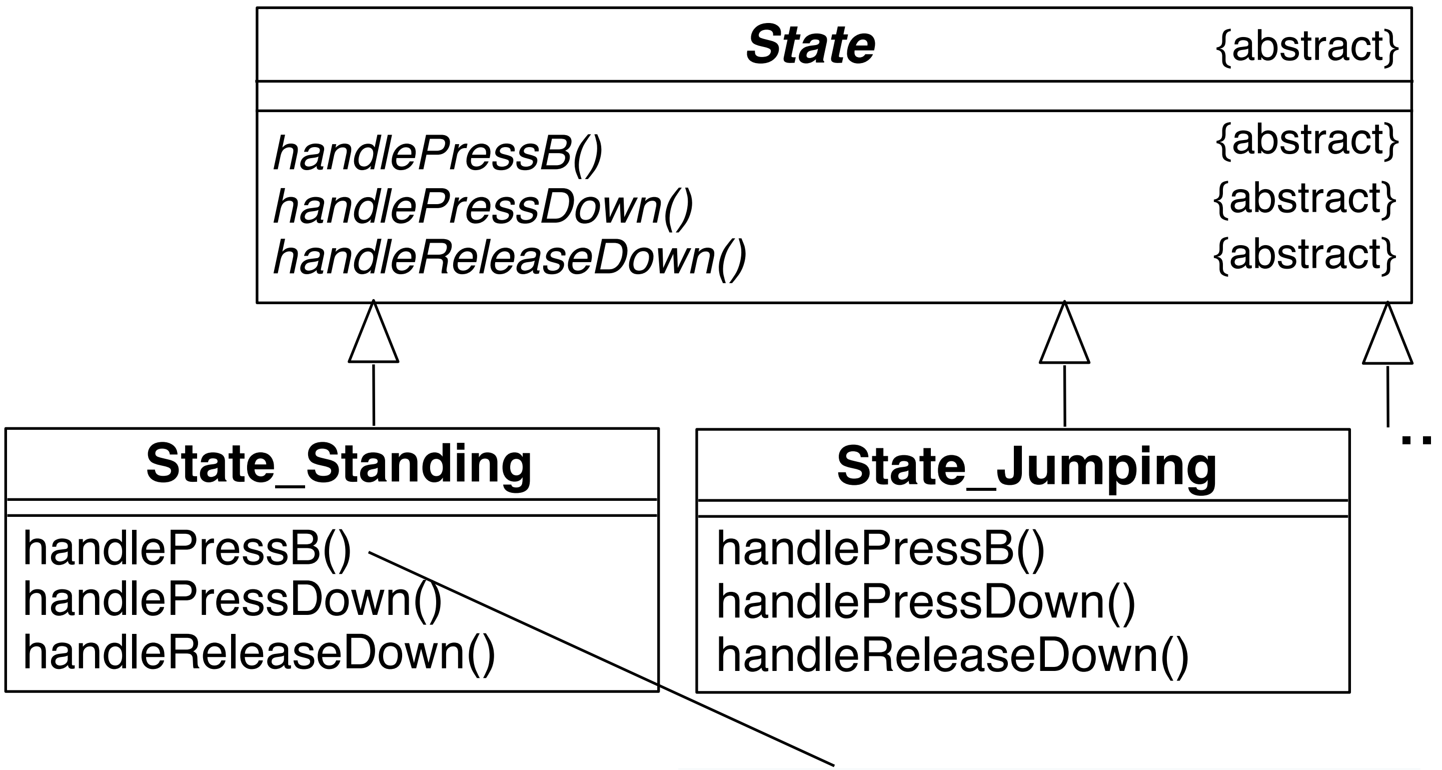
Classical implementation

```
void Heroine::handleInput(Input input) {
  switch (state_) {
    case STATE_STANDING:
      if (input == PRESS_B) {
          state_ = STATE_JUMPING;
          yVelocity_ = JUMP_VELOCITY;
          setGraphics(IMAGE_JUMP);
      }
      else if (input == PRESS_DOWN) {…}
      break;

    case STATE_JUMPING:
      if (input == PRESS_DOWN) {…}
      break;

    case STATE_DUCKING:
      if (input == RELEASE_DOWN) {…}
      break;
  }
}
```

Example for State (2)




```
… change state to State_Jumping …
yVelocity_ = JUMP_VELOCITY;
setGraphics(IMAGE_JUMP);
```

Changing States Through Context

- Context of state-changing object:
  - Keeps variable `currentState` of type `State`
  - Provides a static single instance for each of the the available states `e.g. stateStandingInstance, stateJumpingInstance`
  - May provide a special interface for updating the `currentState`
- In all State subclasses:
  - State change by somehow changing the context, e.g. `currentState = stateJumpingInstance`
  - Either access to global variable or usage of special interface
- Advantages:
  - Programming language & compiler check for coverage of all possible inputs in any state
  - Clear path for extension, protected by language/compiler checks

Test for Extensibility

- Adding a “pressA” input leading to a “paused” state
- First step: Change the *State* interface

  handlePressA()

  —> Compiler checks completeness of transitions
- All additional code is concentrated in one class = one file
  - for new state paused, e.g. class `State_Paused`
- Please note:
  - Transitions (e.g. commands through buttons, external events) are mapped to *State* interface
  - States (e.g. standing, ducking, jumping, diving, paused) are mapped to subclasses of *State*