CMSC 131
Object-Oriented Programming I

Dynamic Systems and State-Transition Diagrams

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This material is based on material provided by Ben Bederson, Bonnie Dorr, Fawzi Emad, David Mount, Jan Plane

Overview

- Dynamic Systems
- State-Transition Diagrams

Dynamic Systems

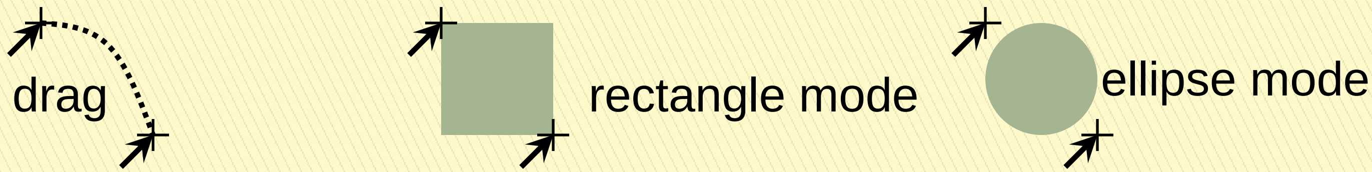
- **Dynamic Systems:** Systems that change dynamically over time. Such systems arise naturally when writing programs involving **graphical user interfaces** (video games, interactive graphics). Some issues:
  - How does the system respond to external events or stimuli? Called **reactive** or **event-driven** systems
  - **State transition**: Most dynamic systems are defined in terms of information called its **state**
    - What are the **possible states** the system can be in?
    - What sorts of **state transitions** are possible, and under what circumstances do transitions occur?
    - What **actions** are performed in each state?

Dynamic Systems

- **Examples**:

  DVD Player/Recorder: Behavior to remote control commands varies depending on the operating state: recording, playback, idle .

  Figure drawing program: (e.g. Paint) The meaning of mouse actions depends on the drawing state: line, curve, ellipse, rectangle, polygon.



  Video game: The meaning of user inputs depends on the current context in which the game is operating

  Digital watch: Has various modes (clock, stop watch, timer) and the meaning of buttons varies with the mode

- How do we **design programs** for such event-driven systems?

State Transition Systems

- These systems have a number of elements in common:
  - **Events**: Inputs/Stimuli come in the form of events (rather than traditional text prompt + text input)
  - **State**: The behavior depends on **internal information** (which the user cannot see) called the system's **state** or **context**
  - **Transitions**: Events can cause changes in the context and other state information
  - **Actions**: Actions (which the user may or may not see) are performed in response to each event/transition
  - **(Spontaneous actions)**: Some actions take place without any user input. (Example: animation in a video game.) These can be modeled as responses to system-generated events, like timer events

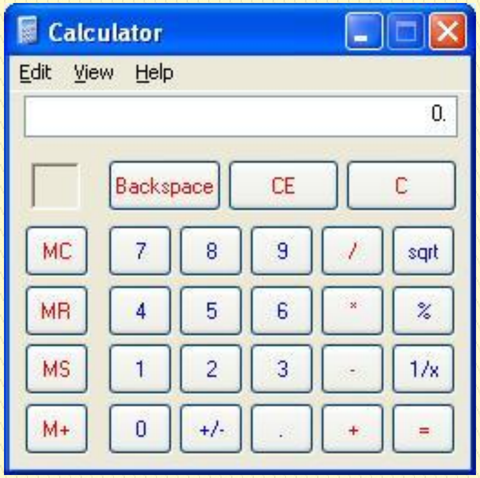
Calculator

- Let us consider the case of a simple **interactive calculator**

  Events: occur when user hits the keys

  State: Operands, memory, internal state of the computation (more about this later)

  Actions: Perform calculations, update the display



- What **internal state** information is needed?
- **Example**: " **3 4 + 5 6 =** "
  When the "**=**" is processed, the calculator has saved the following information internally:

  First operand: "**34**" (call this **v1**)

  Operator: "**+**" (call this **op**)

  Second operand: "**56**" (call this **v2**)
- It must also know **which operand** it is reading, first or second

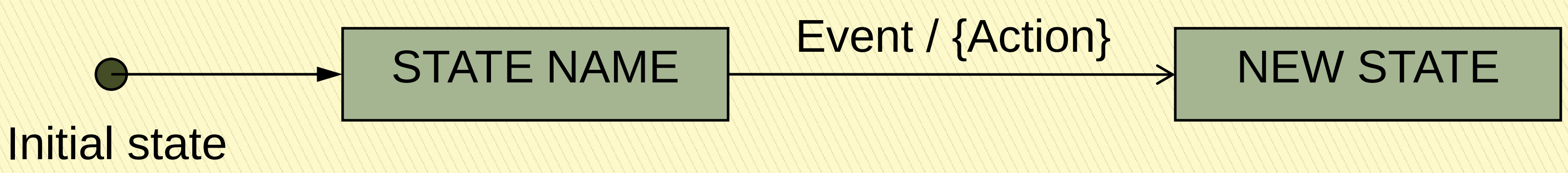
Calculator

- **Calculator**: Has three **states**, or **contexts**:
  - **Reading-First-Operand** (**RFO**): reading digits for the first operand
  - **Reading-Second-Operand** (**RSO**): reading digits for the second operand
  - **Error** (**ERR**): An error occurs (e.g., invalid operand or divide by 0).
- **Example**:

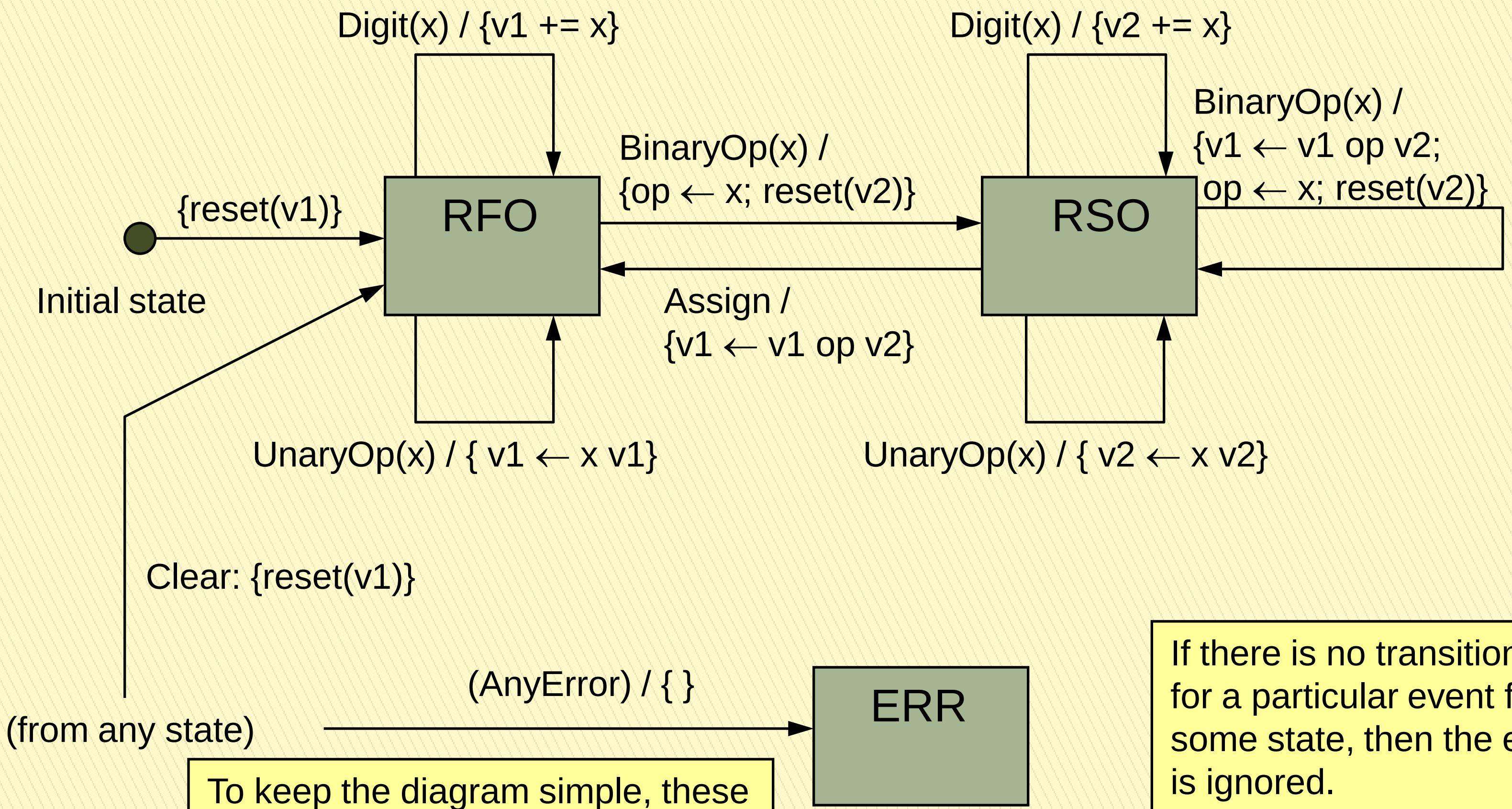
Input:	Context:	Action:	Display:
(init)	RFO	`reset(v1)`	0
3	RFO	`v1 += "3"`	3
4	RFO	`v1 += "4"`	34
+/-	RFO	`v1 ← procUnary: "34", "+/-"`	-34
+	RSO	`op ← "+"; reset(v2)`	-34
5	RSO	`v2 += "5"`	5
6	RSO	`v2 += "6"`	56
*	RSO	`v1 ← procBinary: "-34", "+", "56"` `reset(v2)`	22
2	RSO	`v2 += "2"`	2
1/x	RSO	`v2 ← procUnary: "2", "1/x"`	0.5
=	RFO	`v1 ← procBinary: "22", "*", "0.5"`	11

State-Transition Diagram

- How does the calculator know what operation to perform with each event? This is based on its state, or context (RFO, RSO, ERR)
- We can describe the behavior using a **state-transition diagram**
  - **Nodes**: represent possible **states** the system can be in. A black circle is the **initial or starting state**
  - **Arcs** or **Edges**: represent possible **transitions**. Each is labeled with a pair "**Event/Action**" where:
    - **Event**: event that triggers the transition
    - **Action**: action/computation performed as a result of the event



(Simplified) State-Transition Diagram



To keep the diagram simple, these two transitions are the same for all states.

If there is no transition for a particular event from some state, then the event is ignored.

Programming State-Transition Diagrams

- To programm state-transition diagrams you can use **if-the-else** and/or **switch** statements to control the processing. You can also use the state design pattern (advanced topic).
- **Example**:

```
if ( event == X ) {          // some event X encountered
    switch ( state ) {
    case STATE1:
            // processing for event X in state 1
            break;
    case STATE2:
            // processing for event X in state 2
           break;
    }
} else if ( event == Y ) {  // event Y encountered
    // same thing
} // etc…
```