Lecture 6 — Events, Polling vs. Interrupts

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Be able to program for systems which use event-based models (eg Android).

Random Request

In 10 minutes, please remind me that I’m supposed to do something.

Relevance of OO to Android: Events

What happens when you press this?

What happens when you press this?

Android sends an event to the event listener.

An *event* is a notification of a change to the state of your system.

About event-based programming

Reactive, not proactive.

Event Listeners

- To receive click events:

  the application registers an event listener with the object representing the button.

- When the user clicks the button:

  the system executes the click event listener.

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  ```
  go.setOnClickListener(...);
  ```

- When the user clicks the button:

  the system executes the click event listener.

Implementing Event Listeners (painfully)

We need to pass something to `setOnClickListener()`. What?

This method takes a `View.OnClickListener` object.

You could declare one:

```
class MyClickListener
      extends View.OnClickListener {
  public void onClick(View v) {
    Log.d("A2", "clicked!");
  }
}

...
go.setOnClickListener(new MyClickListener());
```

```
go.setOnClickListener(new View.OnClickListener() {
  public void onClick(View v) {
    Log.d("A2", "clicked!");
  }
  });
```

This is called an inner class.

```
class MainActivity {
  int i;

  @Override
  protected void onCreate(Bundle savedInstanceState) {
    Button go = (Button) findViewById(R.id.go);
    final int j = 2;
    go.setOnClickListener(new View.OnClickListener() {
      public void onClick(View v) {
        Log.d("A2", "i is "+i+" and j is "+j);
      }
      });
  }
}
```

- They don't litter your code with one-time-use classes.
- They can access fields and (final) local variables.

You have another option. From the Android documentation[1]:

```
<Button
    android:layout_height="wrap_content"
    android:layout_width="wrap_content"
    android:text="@string/self_destruct"
    android:onClick="selfDestruct" />
```

Then, in your activity, you must include the method:

```
public void selfDestruct(View view) {
    // Kaboom
}
```

[1] http://developer.android.com/reference/android/widget/Button.html

We've been programming with callback methods.

This is also known as "inversion of control".

Key idea: system (user) decides what happens when.

Leveraging callback methods

You can also structure your program with callback methods. Say you have a time-consuming task (TCT).

1. register a callback upon completion of TCT;
2. spawn the TCT in another thread, don't wait for it;
3. continue normally.

Once the TCT finishes, the callback notifies the main application, which collects results.

Also known as asynchronous, or non-blocking, execution.

Synchronous versus Asynchronous Execution

ECE150: Synchronous, or sequential, programs:

- all instructions execute in sequence;
- an instruction only executes after its predecessor completes.

Also true for function calls.

ECE155, ECE254: Asynchronous, or concurrent, programs:

- most instructions execute in sequence; but
- main program may spawn a function to run concurrently with it.
- Communication via shared memory or via events.

Permits higher performance on multicores, or more relevant structuring. Callbacks are a tool.

Where do events come from?

Digression: Priorities

Imagine the following situation:

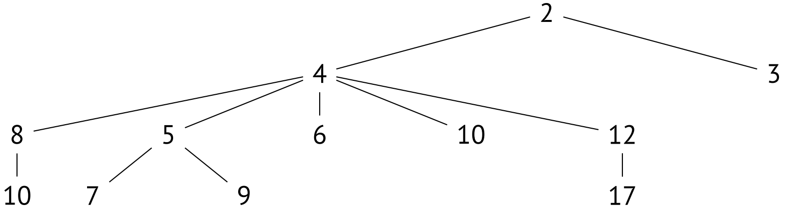
- your mom calls;
- supper is burning;
- laundry is done.

What do you do?

Implementing Priorities

Associate a priority with each event.

Use a *priority queue* data structure to get the highest-priority event.



Remember: reactive, not proactive.

How can the application do what it wants?

Use Finite-State Machines!

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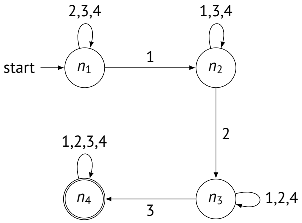
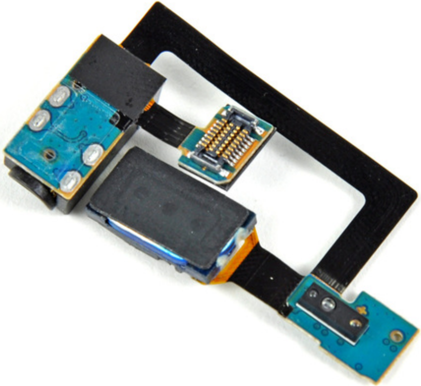
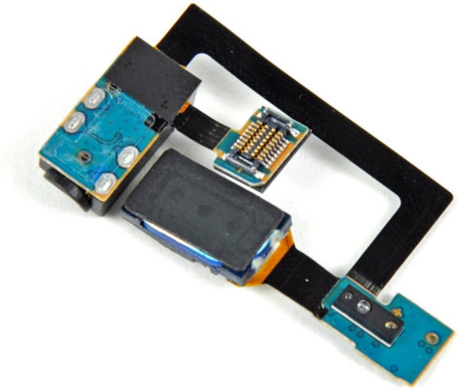
Use Finite-State Machines!



Where Events Come From



Where Events Come From



Analog-to-Digital Converter. Then what?

“Are we there yet?”

"Are we there yet?"

— example of polling.

Polling

Polling: processor requests readings from the device at its convenience.

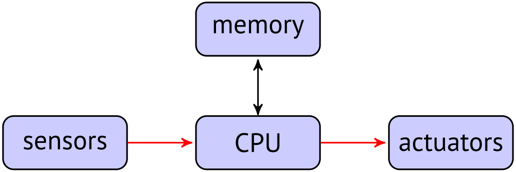
“What is the current light level?”

(also known as “passive synchronization”)

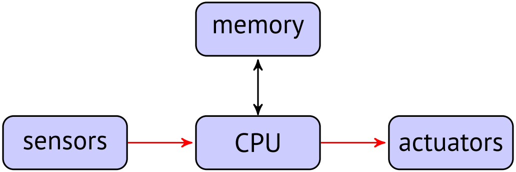
When to Poll?

It depends:

- whenever convenient (occasional polling);
- at fixed time intervals (periodic polling); or
- constantly (tight polling).



What’s the mechanism?



What's the mechanism?

- port-mapped I/O; or,
- memory-mapped I/O

Port-mapped I/O: Special CPU Instructions

The Intel ia32 processors provide special I/O instructions:

```
outb   ax, 0x3f8
inw    dx, ax
```

May use a special bus, or set a specific signal on the bus.

CPU just reads and writes to “memory”.

```
while (statusRegister == 0x0000) {
   // Do nothing until statusRegister changes value
}
// Read data that has changed from a dataRegister
// and store in memory
incomingData = dataRegister;
```

Devices listen on the bus and respond.

Memory-mapped I/O Example

```
while (statusRegister == 0x0000) {
   // Do nothing until statusRegister changes value
}
// Read data that has changed from a dataRegister
// and store in memory
incomingData = dataRegister;
```

This is a *tight polling loop*.

- Expect the hardware specification to promise that statusRegister eventually changes due to an external event.
- Data exchange occurs once device is ready: polling synchronization.

Interrupts: an alternative to polling

So far: processor controls when to read data from a device.

Instead: device may tell the processor when device is ready, using an interrupt.

This constitutes active synchronization.

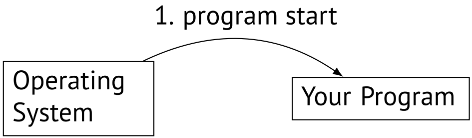
How Interrupts Work

Interrupt tells the processor: “Something’s happening!”

Upon receipt of an interrupt, the processor:

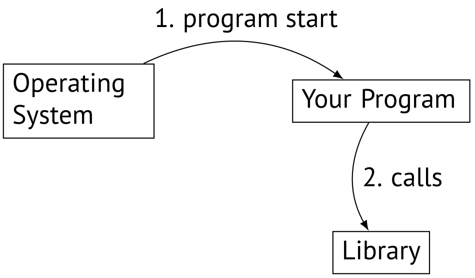
- stops what it’s currently doing and saves its state;
- starts executing pre-defined interrupt handler, which:
  - reads the event information; and
  - stores it somewhere accessible.
- upon return from handler, resumes previous state.

Old ECE150 paradigm:



Inversion of Control: Without It

Old ECE150 paradigm:



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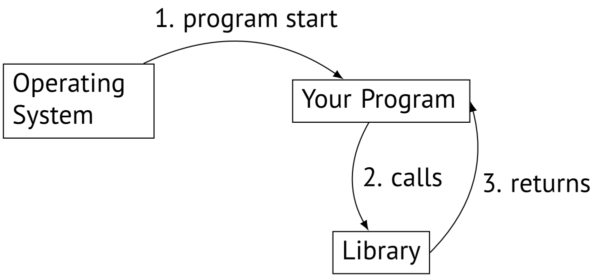

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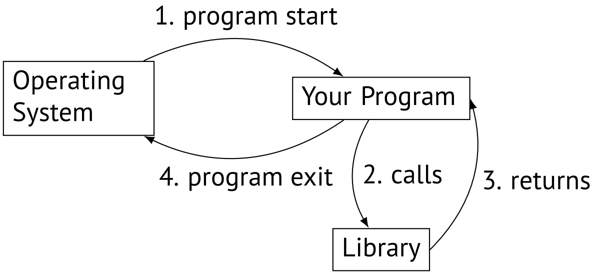
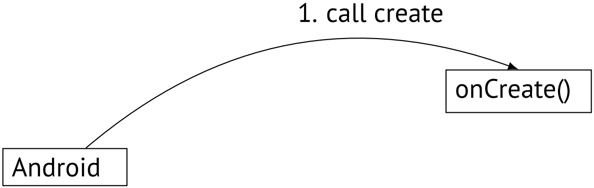


New event-driven ECE155 paradigm:



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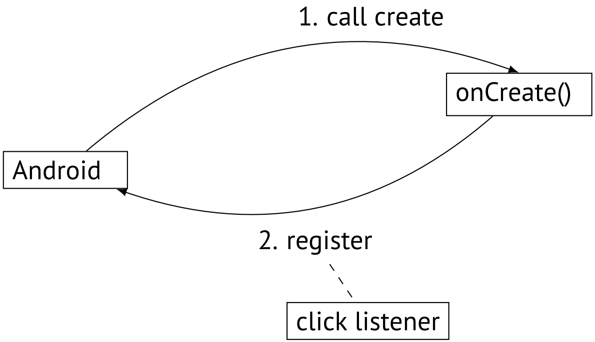

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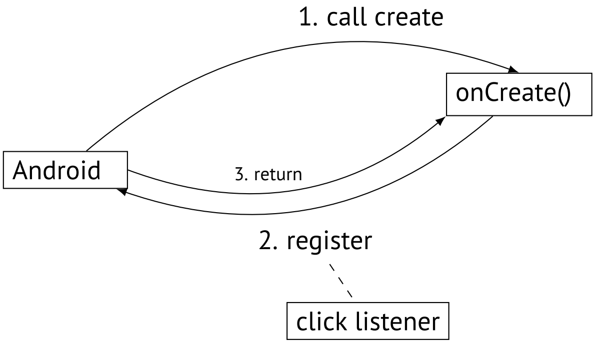

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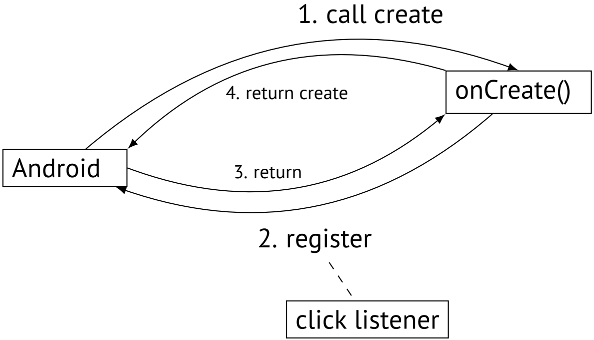

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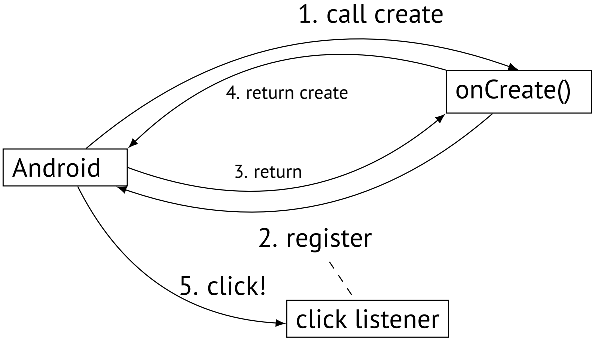

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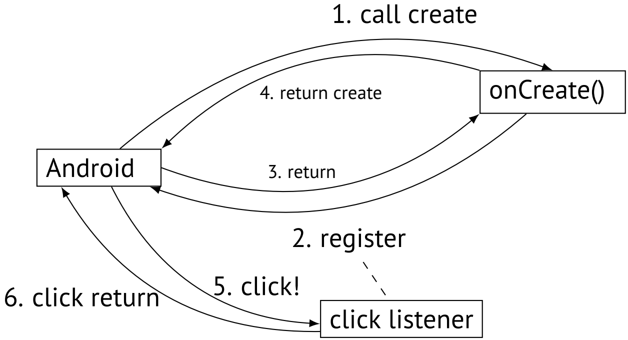

Behind the Scenes for Inversion of Control

Android is running an event loop for each thread:

```
while (!done) {
 r <- fetch Runnable from Queue
 dispatch r
}
```

This is a polling loop: in particular, a tight polling loop, but which goes to sleep waiting for the next event (in fetch).

Miscellaneous: Real-Time Systems

Must respond to an external event in a fixed amount of time.

This fixed amount of time is not necessarily small.

- may potentially be fixed and large.

Many embedded systems must satisfy real-time constraints.

In upper-year courses, you'll see both embedded systems and real-time systems in more detail.

Real-Time System Example

(credit `digitaljournal.com`, from flickr)

Blu-Ray player must:

- read compressed video data from a media disk;
- decompress the video; and
- output it to a HDMI interface,

all within a fixed amount of time, to avoid a degradation of video quality.