CSE 331
Software Design & Implementation

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User Interfaces & Event-Driven Programs

Administrivia

- HW7 out now
  - has a lot of things to do
  - start early!

Graphical User Interfaces (GUIs)

- Large and important class of event-driven programs
  - waits for user-interaction events
  - mouse clicks, button presses, etc.

- Java, Android, Web, etc. provide libraries to write these
  - each of these use callbacks & events
  - examples of "event-driven programs"

- Using these libraries decreases bugs
  - also gives users a familiar experience

GUI terminology

window: A first-class citizen of the graphical desktop

- also called a *top-level container*
- Examples: *frame* (window), dialog box

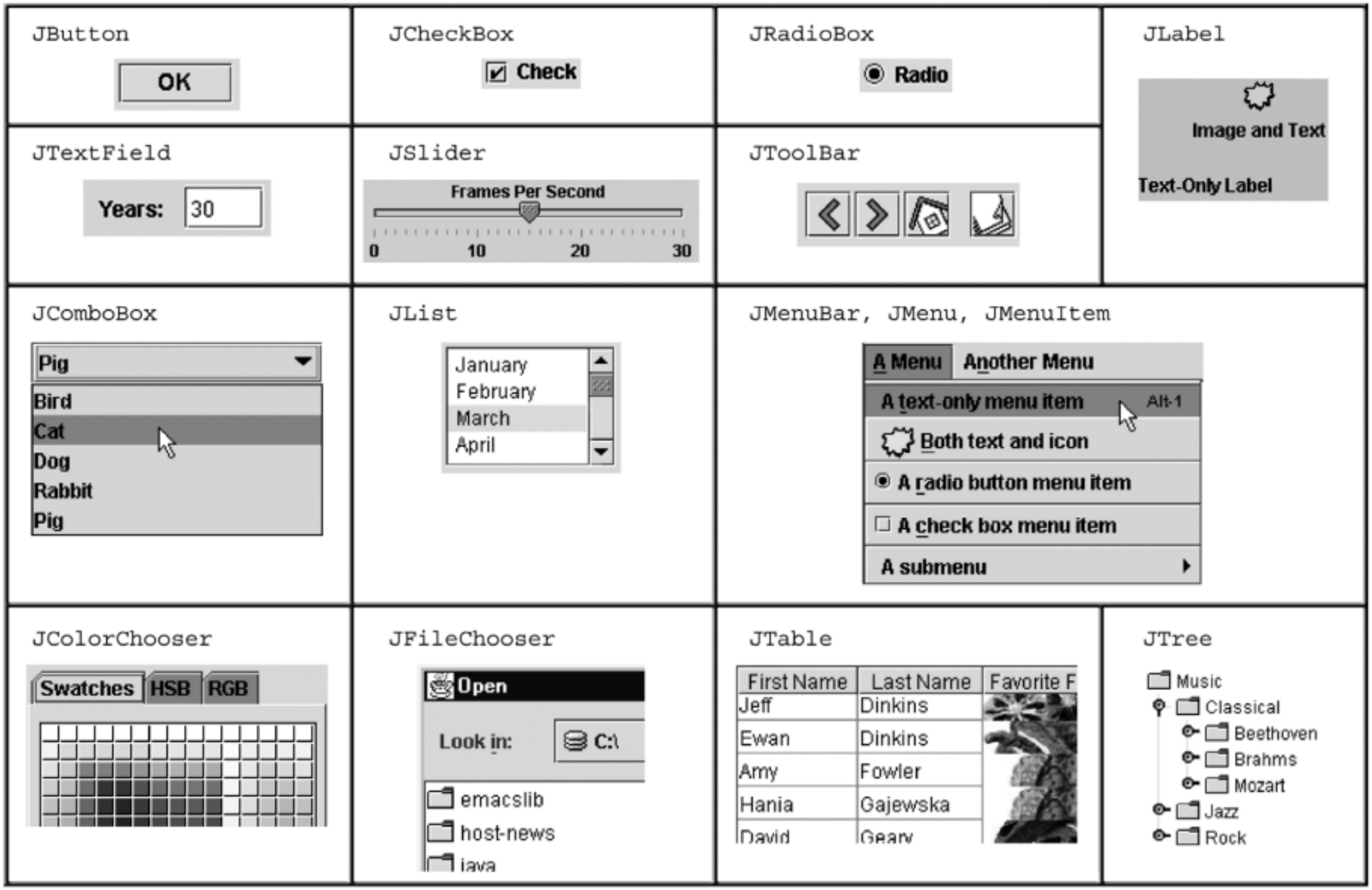
component: A GUI *widget* that resides in a window

- called *controls* in many other languages
- Examples: button, text box, label

container: A component that hosts (holds) & lays out components

- Examples: frame, *panel*, box

More components…



This lecture

- Brief survey of Desktop, Mobile, and Web
  - discuss how each handles key issues
  - (no need to memorize anything)

- Next lectures
  - go deeper into languages used for Web apps
  - improved UI libraries available for Web apps

GUI Libraries

- Core parts of these applications:
  - stores some data for the user
  - displays that data for the user
  - allows the user to change the data
    - causes the app to re-display

- Early apps required a lot of code to implement these

- More recent improvements have made this easier
  - highly valuable
    - your time is important
  - less code (usually) means fewer bugs

GUI Libraries

- AWT & Swing are the native Java libraries for writing GUIs
  - Android apps are also GUIs and written in Java

- Core parts of these applications:
  - stores some data for the user
  - displays that data for the user
  - allows the user to change the data
    - causes the app to re-display

- Library helps with the latter two parts
  - components used to display data
  - components allow *listeners* that are notified of interaction

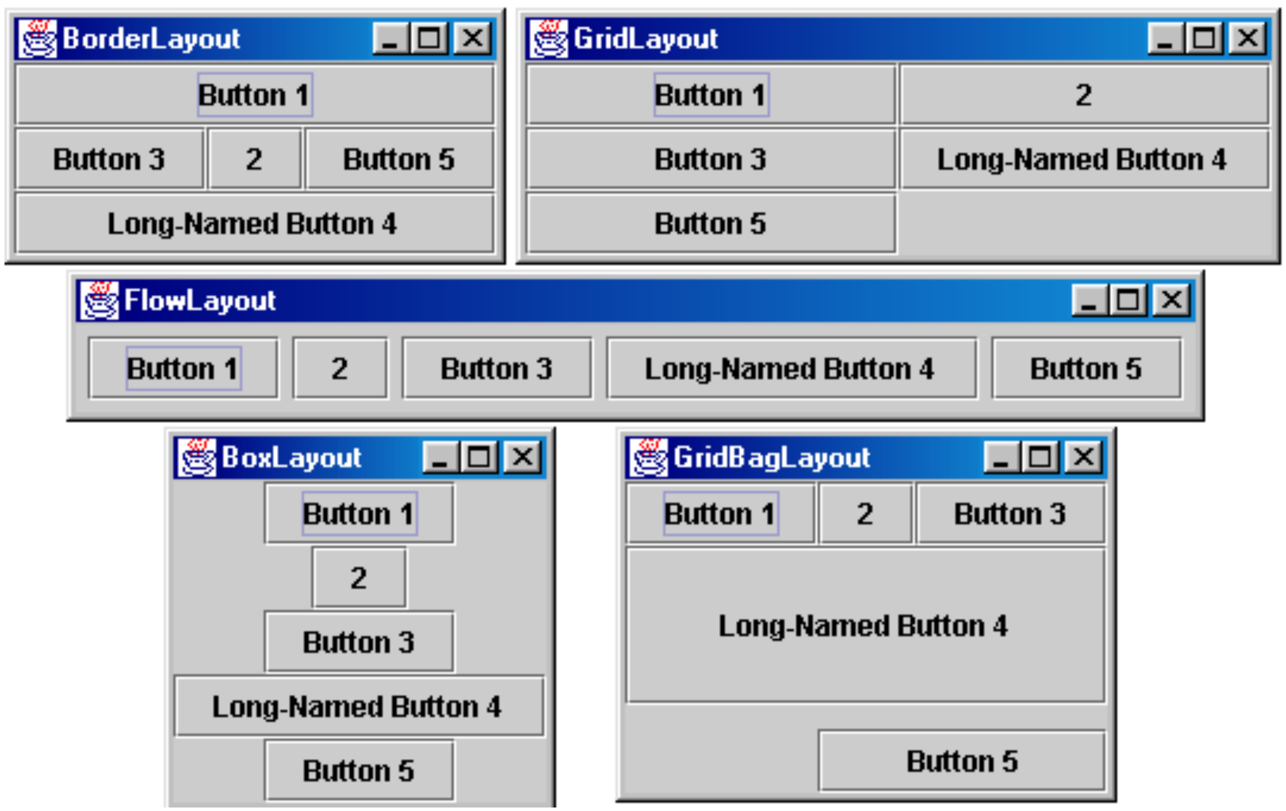
AWT / Swing Example 1

SimpleFieldDemo.java

Containers and layout

- Container needs to position (lay out) the child components
- You need to tell it how you want them arranged

- In AWT / Swing, each container has a *layout manager*



AWT / Swing Examples

- Default is a flow layout
  - components placed next to each other
  - wrap around when out of space on the line
- Can change to a 2 x 2 grid layout

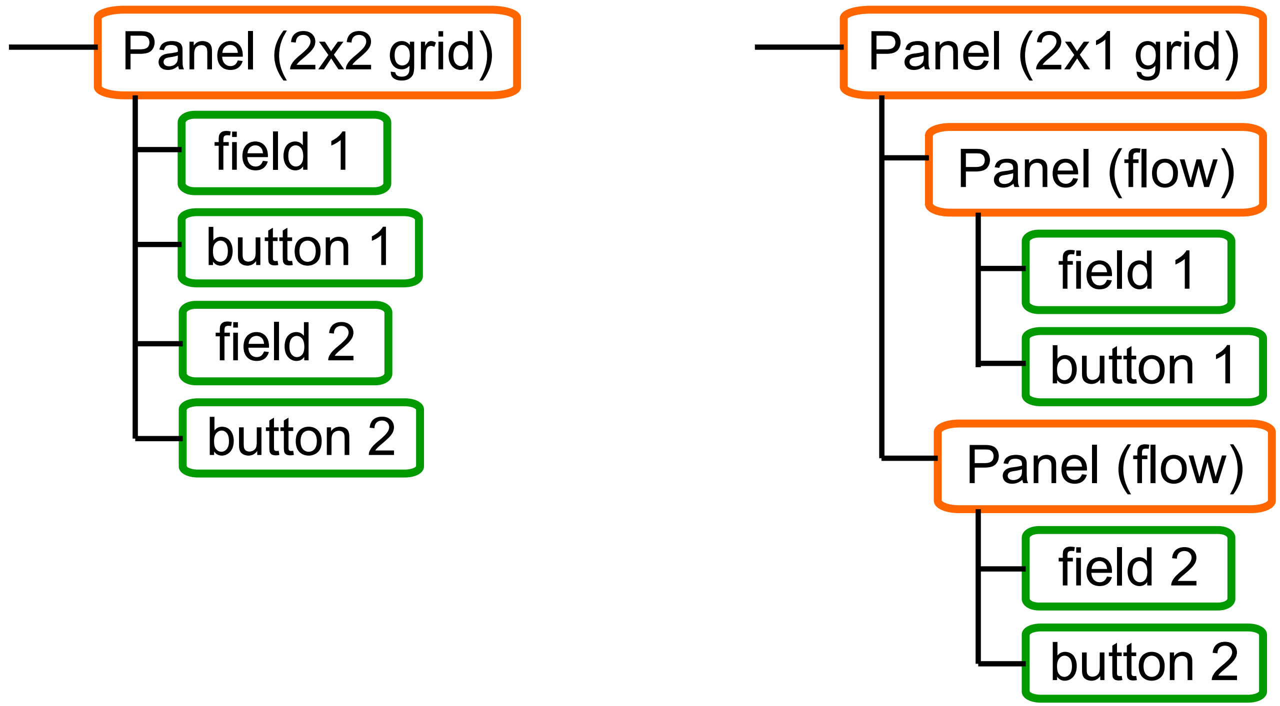
AWT / Swing Example 2

SimpleFieldDemo2.java

AWT / Swing Examples

- Does not look natural

- Instead try 2 rows (2 x 1 grid) and flow layout *within* the rows



AWT / Swing Example 3

SimpleFieldDemo3.java

Events in GUI Libraries

Most of the GUI widgets can generate events

- button clicks, menu picks, key press, etc.

Add a **listener** to be called back when those events occur

- component promises to call you in those circumstances
- passed an **event** object that provides info about the event

More examples of “callbacks” coming later…

Achievement unlocked: Callbacks

Callback: “Code” provided by client to be used by library

- In JS etc., pass a function as an argument
- In Java, pass an object with the “code” in a method

Examples: **`HashMap`** calls its client’s **`hashCode`**, **`equals`**

Synchronous callbacks:

- Useful when library needs the callback result immediately

Asynchronous callbacks:

- *Register* to indicate interest and where to call back
- Useful when the callback should be performed later, when some interesting event occurs

Event listeners / handlers

Event listeners must implement the proper interface. AWT/Swing:

`KeyListener` – handle key press

`ActionListener` – handle button press

`MouseListener` – handle mouse clicks

`MouseMotionListener` – handle mouse move/drag

When an event occurs

- the appropriate method specified in the interface is called: **`actionPerformed`**, **`keyPressed`**, **`mouseClicked`**, **`mouseDragged`**, …
- an event object is passed to the listener method

Interfaces are different in Android but all conceptually the same

Android similarities

- Events and listeners work in the same manner

```
Button btn = ...;
btn.setOnClickListener(new MyClickListener());

…

public class MyClickListner
    implements ClickListener {
  @Override
  public void onClick(View v) {
    Log.d(“My Button”, “You pressed it”);
  }
});
```

Event objects

GUI event is represented by an *event object*

- passes information often needed by the handler

In AWT/Swing, the superclass is **`AWTEvent`**. Some subclasses are:

`ActionEvent` – GUI-button press

`KeyEvent` – keyboard

`MouseEvent` – mouse move/drag/click/button

In Android, the superclass is **`InputEvent`**.

Event objects contain

- UI object that triggered the event
- other information depending on event. Examples:

`ActionEvent` – text string from a button

`MouseEvent` – mouse coordinates

Achievement unlocked: Observers

This is the *observer pattern*

- Objects can be *observed* via *observers*/*listeners* that are *notified* via *callbacks* when an *event* (of interest) occurs
- Pattern: Something used over-and-over in software, worth recognizing when appropriate and using common terms
- Widely used in public libraries

More examples of “observers” coming later…

GUI Client Programming

- Clients sit around waiting for events like:
  - mouse move/drag/click, button press, button release
  - keyboard: key press or release, sometimes with modifiers like shift/control/alt/etc.
  - finger tap or drag on a touchscreen
  - window resize/minimize/restore/close
  - timer interrupt (including animations)
  - network activity or file I/O (start, done, error)
    - (we will see an example of this shortly)

Event-driven programming

An *event-driven* program is designed to wait for events:

- program initializes then enters the *event loop*
- abstractly:

```
do {
     e = getNextEvent();
     process event e;
} while (e != quit);
```

Contrast with most programs we have written so far

- they perform specified steps in order and then exit
- that style is still used, just not as frequently
    - example: computing Page Rank or other Big Data work

UI Thread

- Where is the event loop in these Swing programs?

- The library creates a separate thread that runs that event loop
  - the “UI thread”
  - created when the **`JFrame`** is made visible
  - application does not exit until this thread also finishes
    - that happens automatically when the window is closed

Problems with SimpleFieldDemo

- Code is too **verbose**
  - can be improved using Lambda syntax

- Code is *not at all* **modular**
  - one file that mixes data, presentation, interaction

- **Too much work** involved with laying out elements

Easier Layout Idea #1: Just Say No

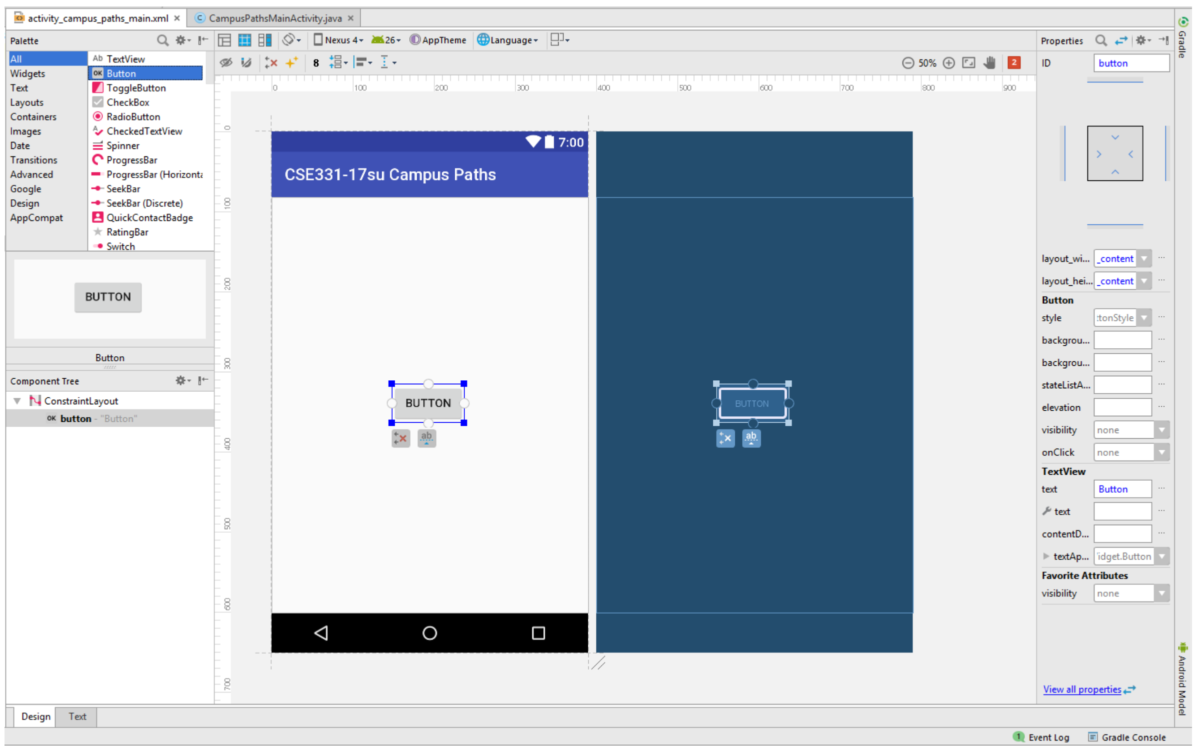
- Much of the difficulty here has to do with resizing…

- Do we really need to support resizing?

- Two platforms restrict resizing in some ways:
  - Android / iPhone
  - Bootstrap (HTML)

iPhone / Android Layout

- iPhone and iPad come in fixed sizes
- Just give a fixed layout for each possible size



Bootstrap (HTML)

- Width is restricted to one of 5 values (phone up to huge screen)
  - library automatically switches to best match for screen width
  - can use the same design for multiple sizes if you wish

- Still allows arbitrary height for the content

Bootstrap Example

BootstrapDemo.html

Easier Layout Idea #2: Declarative UI

- How much of layout needs to be code?
  – does this really require forward / backward reasoning?

- iPhone / Android show that this can be done
  – only for fixed sized screens

- HTML can be used as a more declarative language for UI
  – (.NET and other frameworks have comparable toolkits)

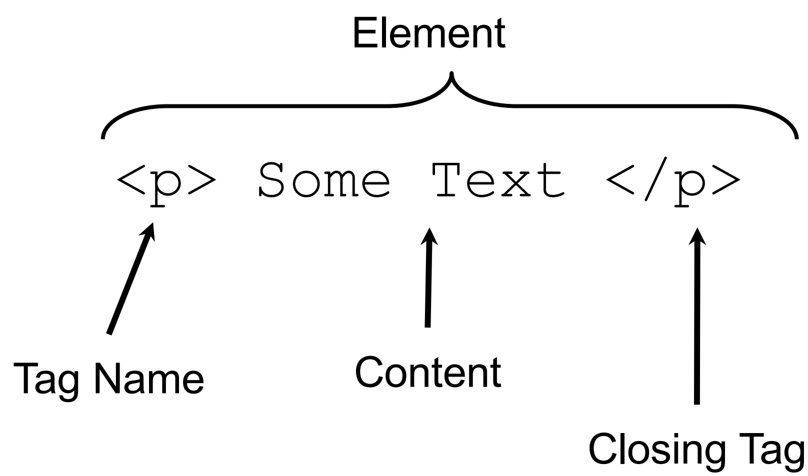
HTML

- Hyper-Text Markup Language

- Language for writing documents shown in a web browser
  - co-opted to display the UI for Web apps

- Document is a sequence of tags and text

Anatomy of a Tag



Anatomy of a Tag

Element

```
<p id=”firstParagraph”> Some Text </p>
```

Tag Name

Attribute Name

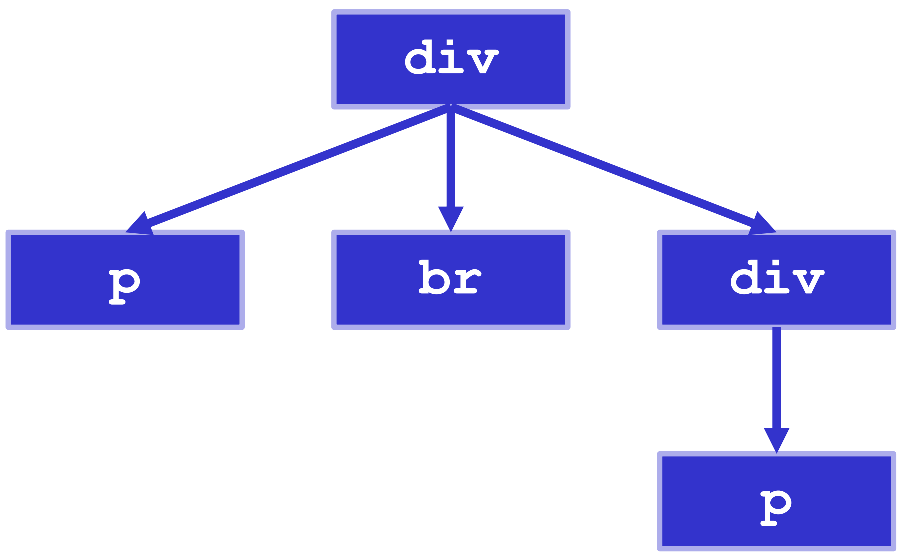
Attribute Value

Content

Closing Tag

Tags form a Tree

```
<div>
   <p id="firstParagraph"> Some Text </p>
   <br>
   <div>
      <p>Hello</p>
   </div>
</div>
```



This tree, as it lives in the browser, is often called the "DOM" – *Document Object Model*

A Few Useful Tags

- See the W3Schools HTML reference for a complete list, along with all their supported attributes.

- Some worth knowing:
  - `<p>` - Paragraph tag, surrounds text with whitespace/line breaks.
  - `<div>` - “The curly braces of HTML” - used for grouping other tags. Surrounds its content with whitespace/line breaks.
  - `<span>` - Like `<div>`, but no whitespace/line breaks.
  - `<br />` - Forces a new line (like “\n”). Has no content.
  - `<html>` and `<head>` and `<body>` - Used to organize a basic HTML document.

HTML for UI

- Consists tags and their content
  - components become tags
    - input fields, buttons, etc.
    - e.g., `<button>`
  - containers have start and end tags
    - tags placed in between are children
    - e.g., `<div>` and `<p>`
  - additional information provided to the tag with “attributes”

- HTML removes the need for **`panel.add`** calls
  - parent / child relationship *implied* by tree structure

HTML + JS

- To make an app we also need **code**
- Code is provided inside a `<script>` tag
  - all browsers support the JavaScript language
  - more in a moment…

HTML + JS UI Example

HtmlFieldDemo.html

HTML + JS + CSS

- Cascading Style Sheets allow separation of styling from rest
  - **styling** is colors, margins, etc.
  - allows non-programmers to take some of this work
    - code produces document structure (tree of tags)
    - changes to tags require agreement by both parties

Dynamic Web Content

- Earlier example had a fixed set of components.
  – same for iPhone / Android apps

- More realistic apps need to change the set of components displayed on the screen dynamically
  – consider Gmail as an example
  – need the components to come from code

JS Example

register/index.js

Remaining Problems

- ~~Code is extremely **verbose**~~
  - ~~can be improved using Lambdas~~

- Code is *not sufficiently* **modular**
  - one JS mixes data, display, interaction

- ~~**Too much work** involved with laying out elements~~

- Poor **tool support**
  - HTML is created in strings!
  - (and other issues not mentioned so far…)