CS4043 Advanced Programming

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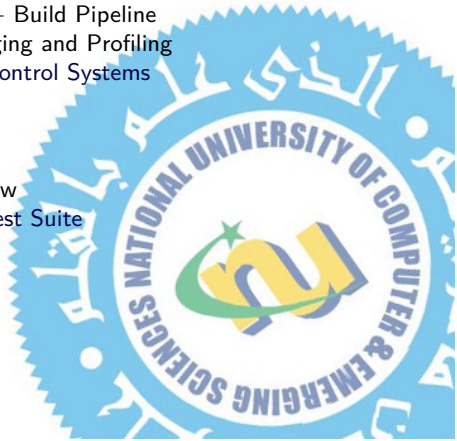
National University of Computer & Emerging Sciences, Peshawar

August 12, 2024

Syllabus



Course Overview

Marks Breakdown

- Mid-Term: 30 %
- Final Examination: 40%
- Assignments: 30%

Assignment Notes

- Use Linux based tools
- If C/C++ (Use GCC)
- Marking Scheme (Typical):
- No assignment submission through email
- I May run through similarity index.

Complex Software

Production Process

1. Customers & Line of Business
2. Software Development Lifecycles (Design → Develop → Testing → Deploy)

Deployment Platforms

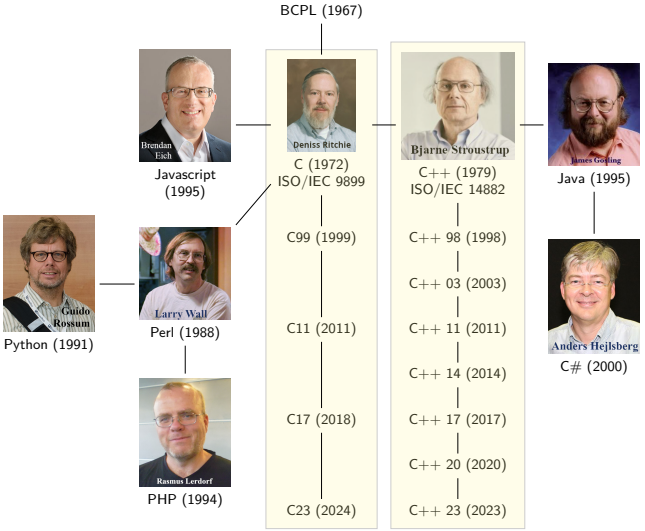
- Standalone Sytems
- Mobile Apps
- Distributed Software
- Big Data & Cloud
- Internet of Things
- ... Metaverse

- Software Complex than ever (Programming Languages, Data Sources, Integrated Data Types, Software Design, Algorithms, Performance, Group based Development, Security, ...)
- Solution: Embrace innovation in Programming Languages, Data Handling Methods, Undertake high level design choices, Software Development Frameworks, Development Methodologies, Execution Environments, ... All qualities of a **Software Architect** (job role appears with slight variations in names)

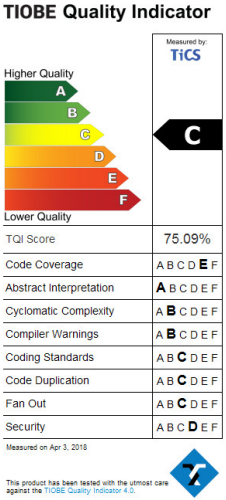
Complex Software (cont.)

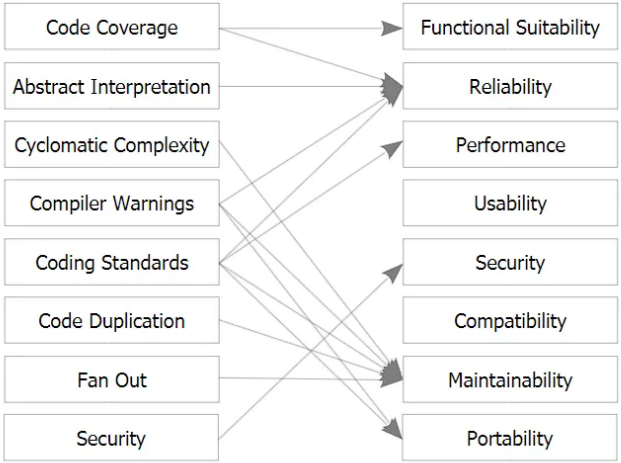
Programming Languages

Programming Languages (cont.)



TIOBE Index (ISO 25010)





TIOBE Index (ISO 25010) (cont.)

Feb 2022	Feb 2021	Change	Programming Language	Ratings	Change
1	3	↑	Python	15.33%	+4.47%
2	1	↓	C	14.08%	-2.26%
3	2	↓	Java	12.13%	+0.84%
4	4		C++	8.01%	+1.13%
5	5		C#	5.37%	+0.93%
6	6		Visual Basic	5.23%	+0.90%
7	7		JavaScript	1.83%	-0.45%
8	8		PHP	1.79%	+0.04%
9	10	↑	Assembly language	1.60%	-0.06%
10	9	↓	SQL	1.55%	-0.18%
11	13	↑	Go	1.23%	-0.05%
12	15	↑	Swift	1.18%	+0.04%
13	11	↓	R	1.11%	-0.45%
14	16	↑	MATLAB	1.03%	-0.03%
15	17	↑	Delphi/Object Pascal	0.90%	-0.12%
16	14	↓	Ruby	0.89%	-0.35%
17	18	↑	Classic Visual Basic	0.83%	-0.18%
18	20	↑	Objective-C	0.81%	-0.08%
19	19		Perl	0.79%	-0.13%
20	12	↓↓	Groovy	0.74%	-0.76%

Jun 2024	Jun 2023	Change	Programming Language	Ratings	Change
1	1		Python	15.39%	+2.93%
2	3	↑	C++	10.03%	-1.33%
3	2	↓	C	9.23%	-3.14%
4	4		Java	8.40%	-2.88%
5	5		C#	6.65%	-0.06%
6	7	↑	JavaScript	3.32%	+0.51%
7	14	↑↑	Go	1.93%	+0.93%
8	9	↑	SQL	1.75%	+0.28%
9	6	↓	Visual Basic	1.66%	-1.67%
10	15	↑↑	Fortran	1.53%	+0.53%
11	11		Delphi/Object Pascal	1.52%	+0.27%
12	19	↑↑	Swift	1.27%	+0.33%
13	10	↓	Assembly language	1.26%	-0.03%
14	12	↓	MATLAB	1.26%	+0.14%
15	8	↓↓	PHP	1.22%	-0.52%
16	13	↓	Scratch	1.17%	+0.15%
17	20	↑	Rust	1.17%	+0.26%
18	18		Ruby	1.11%	+0.17%
19	29	↑↑	Kotlin	1.01%	+0.50%
20	22	↑	COBOL	0.96%	+0.22%

By the Way . . .


CODING SPEED
PYTHON
C++
JAVA
EXECUTION SPEED
C++
JAVA
PYTHON
PeopleOfCodes

Frameworks vs Libraries

- Both provide reusable abstractions of code, wrapped in well defined API
- Libraries: Flow of control dictated by caller (software calls library)
- Frameworks: Flow of control dictated by Framework (Framework drives software)

Framework Examples

- General Software: .NET, Android SDK, ...
- GUI Based: Gnome, QT, ...
- Web Based: ASP.Net, ...
- Concurrency: Hadoop Map/Reduce, ...
- ...

Jobs (Pakistan) 2022-2023 Source: P@sha

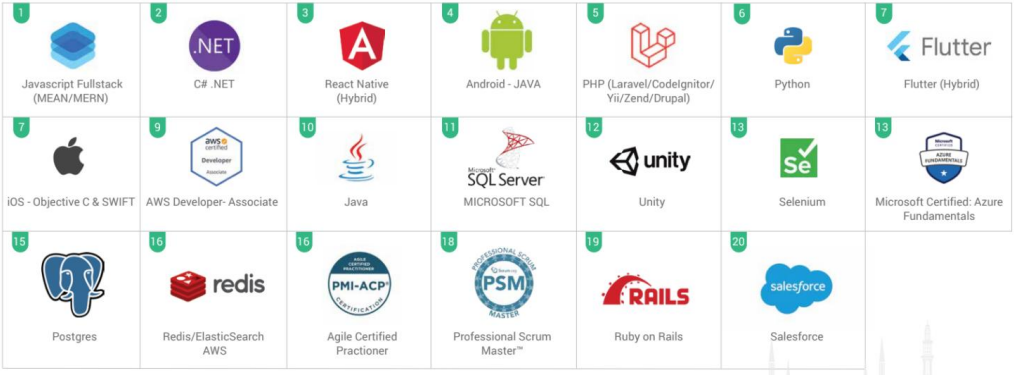


Figure 1: P@sha Top In-Demand Technologies & Tools

Jobs (Pakistan) 2022-2023 Source: P@sha (cont.)

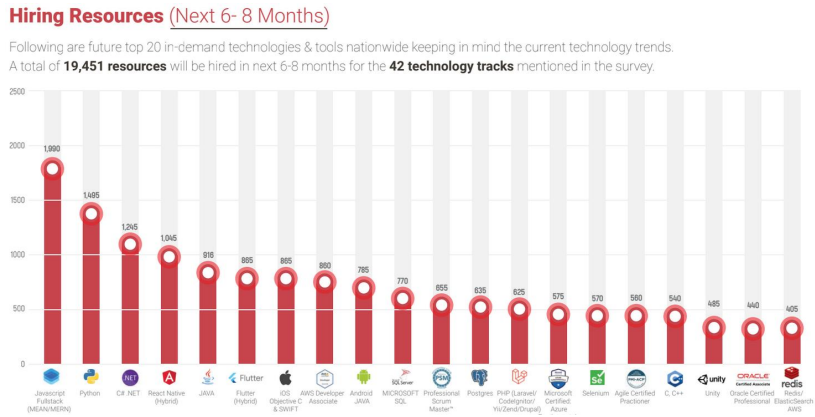


Figure 2: Next 6-8 Months Job Market

Jobs (Pakistan) 2022-2023 Source: P@sha (cont.)

Figure 3: Participating Companies List A

Jobs (Pakistan) 2022-2023 Source: P@sha (cont.)

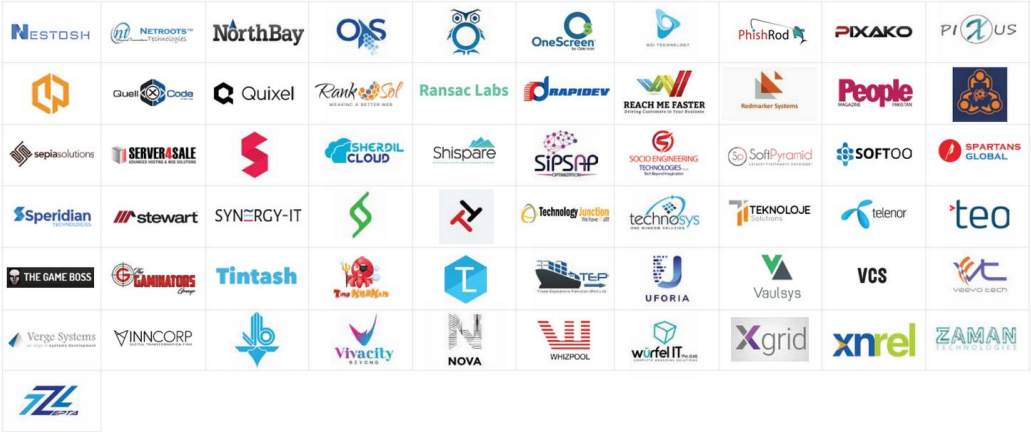
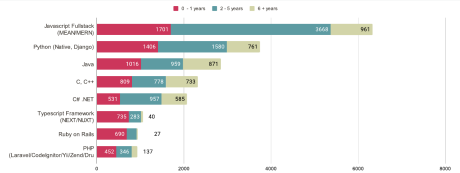


Figure 4: Participating Companies List B

Jobs (Pakistan) 2023-2024 Source: P@sha

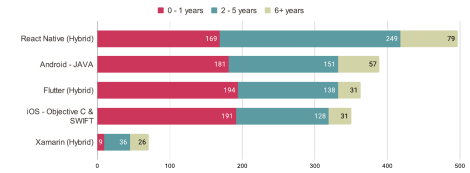
Resources Required Web Engineering Job Roles

A Total of **20,250 resources** are required in the 'Web Engineering' roles with the highest demand for **Javascript Fullstack (MEAN/MERN).**



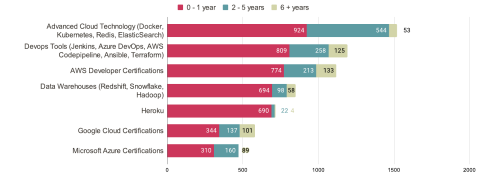
Resources Required Mobile Development Job Roles

A total of **1,670 resources** are required in the 'Mobile Development' roles with the highest demand for **React Native (Hybrid).**



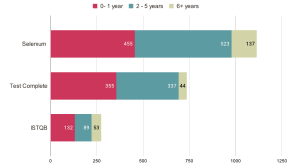
Resources Required Cloud Infrastructure - Tool / Certification

A total of **6,540 resources** are required in the 'Cloud Infrastructure - Tool / Certification' roles with the highest demand for **Advanced Cloud Technology (Docker, Kubernetes, Redis, ElasticSearch).**



Resources Required Automation & Software Testing - Tool / Certification

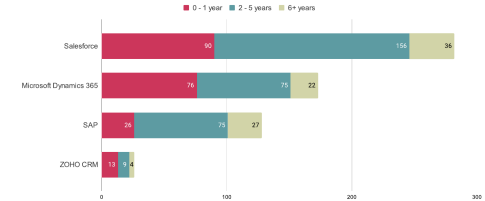
A total of **2125 resources** are required in the 'Automation & Software Testing - Tool/Certification' roles with the highest demand for **Selenium.**



Jobs (Pakistan) 2023-2024 Source: P@sha (cont.)

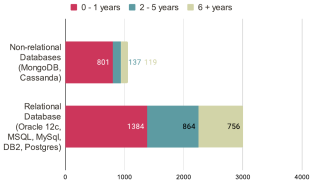
Resources Required CRM Tool

A total of **609 resources** are required in the 'CRM Tool' roles with the highest demand for **Salesforce.**



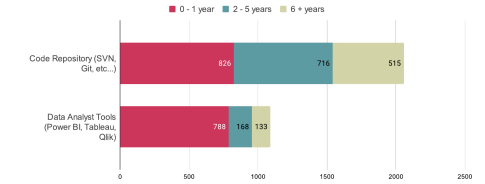
Resources Required Database Job Roles

A total of **4061 resources** are required in the 'Database' roles with the highest demand for **Relational Database.**



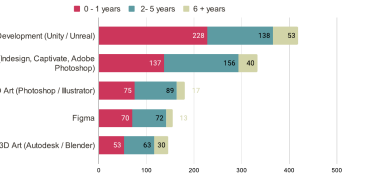
Resources Required Programming and Data Analyst

A total of **3146 resources** are required in the programming and data analyst domain with the highest demand for **Code Repository (SVN, Git, etc...)**



Resources Required Animation, Graphic, Games - 3D Engine/Tool

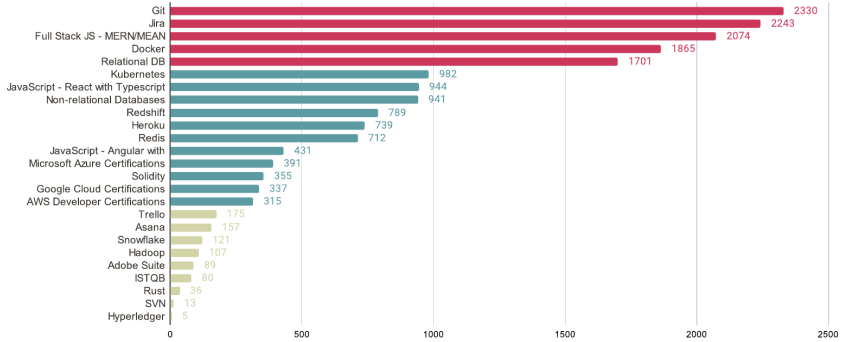
A total of **1234 resources** are required in the 'Animation, Graphic, Games - 3D Engine/Tool' with the highest demand for **Game Development (Unity/Unreal).**



Jobs (Pakistan) 2023-2024 Source: P@sha (cont.)

Resources Required Major tools & technologies for the Upskilling of Employees

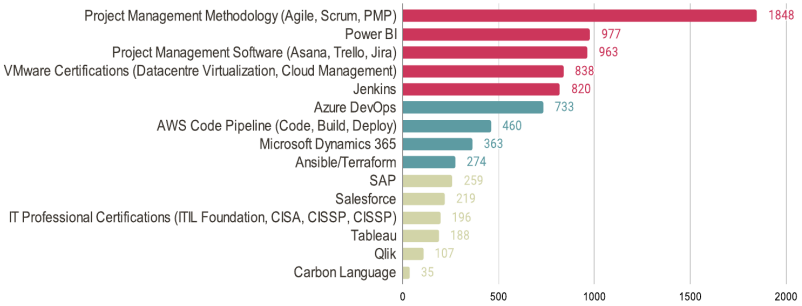
A total of **17,932 resources** are required in following tools & technologies for upskilling of employees with highest demand for **Git.**



Jobs (Pakistan) 2023-2024 Source: P@sha (cont.)

Resources Required – Major tools & technologies for the Reskilling of Employees

A total of **8,280** resources are required in following tools & technologies for reskilling of employees with highest demand for '**Project Management Methodology (Agile, Scrum, PMP)**'



Homework Task 1

Task Juggler

Use Task Juggler to create a Financial Proposal, and Project Gantt Chart for your Final Year Project

UI/UX Overview

UI

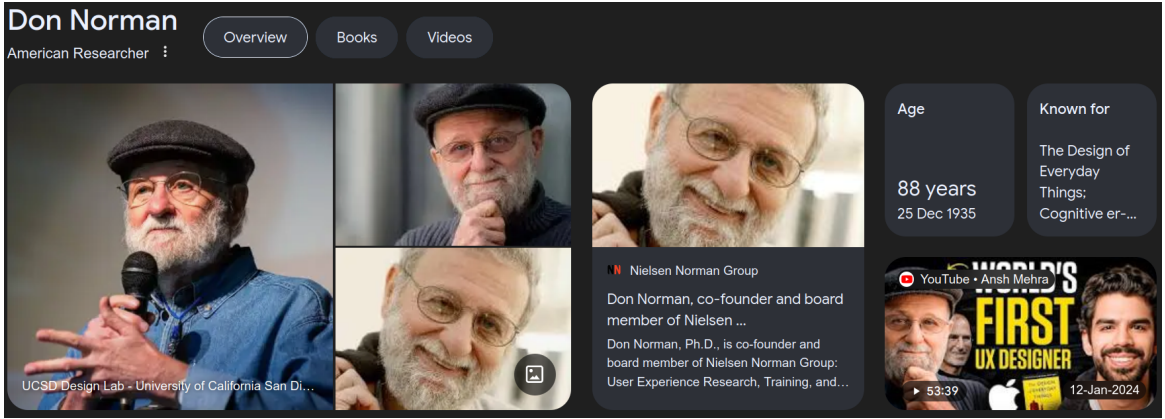
- UID: Design of **UI's** for machines and softwares, with focus on maximizing **usability** and **user experience**
- UI: Visual elements of a product, adaptable to different views (mobile, tablet, computer, ...)
- *Makes the interface beautiful*
- UI Designer: Typography, Colors, Styles, Branding, Spacing/Layouts, Number of items, Icons, Images, ...

UX

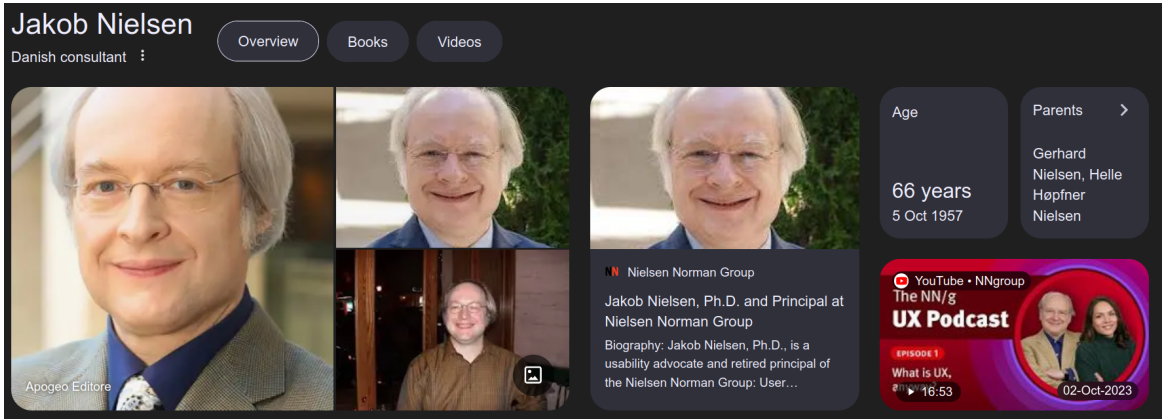
- UXD: Study user behaviour (usability, usefulness) and understanding user motivations (desirability) in the interaction with a product, with goal of maximizing digital experiences.
- *Makes the UI useful*
- UX Designer: Interaction design, Wireframes/Prototypes, Information architect, user research, personas, scenarios, ...

UI/UX Overview (cont.)

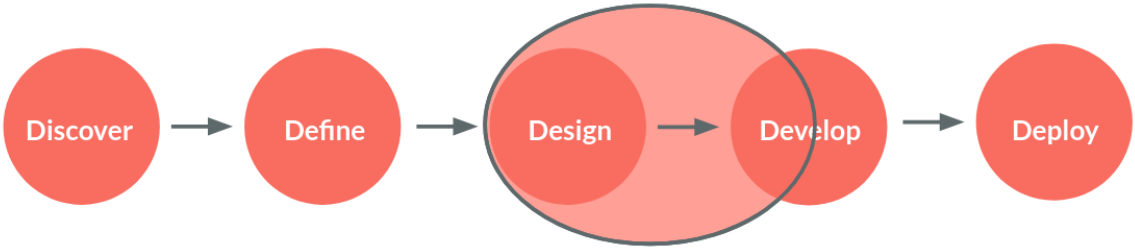
UI/UX Overview (cont.)



UI/UX Overview (cont.)



UI/UX Design Process



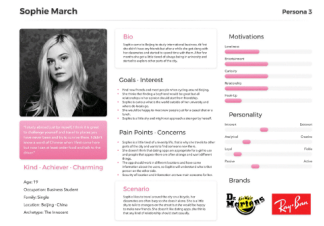
Design

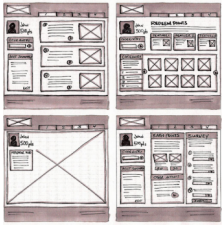
- Iterate (Information Architecture: Personas & User Research, Storyboards, Wireframes)
- Prototype (Visual Design & Layout, Interaction Design, Accessibility)
- Test (Usability Testing, A/B Testing)

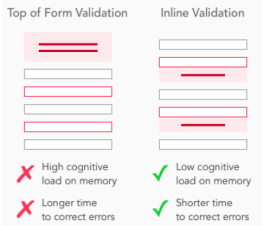
UI/UX Design Process (cont.)

Develop (Front-end)

- Responsive Layouts
- Behavior (React/Angular)
- ...







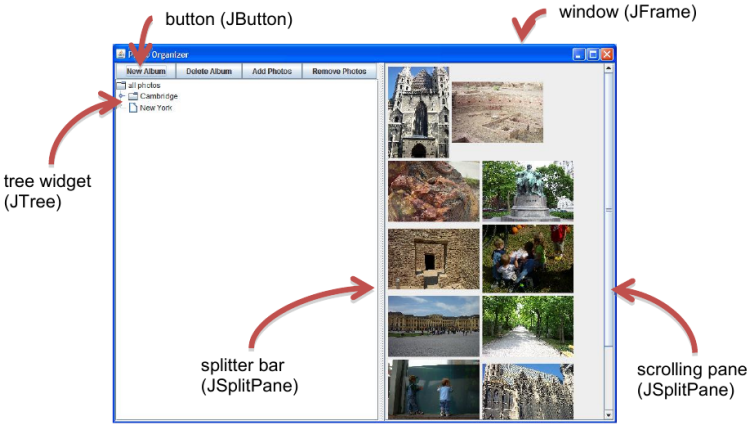
UI/UX Design Process (cont.)

UI Frameworks

- Python: Tkinter, PyQT, PyGTK, wxPython, ...
- C/C++: TCL/TK, GTK (Gnome), QT, WxWidgets, NCurses, Flutter (Google), ...
- Java: Swing, JavaFX, ...

Visual Elements in a Tree (View Tree)

- GUI's composed of View Objects; Each occuping certain portion of screen (covering a rectangular area = bounding box)
- View Objects arranged into a hierarchy of Containment (views inside other views)
  - Examples of Containers: Window, Panel, Toolbar, etc.
  - Child views are nested inside parent's bounding box
- Primitive Views (Do not contain other Views)
  - Buttons, Trees, Textbox, Thumnail, etc.
- View Objectives can be composited / grouped / joined together



Visual Elements in a Tree (View Tree) (cont.)

```
1   <?xml version="1.0" encoding="UTF-8"?>LF
2   <ui version="4.0">LF
3    <class>Dialog</class>LF
4    <widget class="QDialog" name="Dialog">LF
69   <resources/>LF
70   <connections>LF
71    <connection>LF
72     <sender>buttonBox</sender>LF
73     <signal>accepted()</signal>LF
74     <receiver>Dialog</receiver>LF
75     <slot>accept()</slot>LF
76     <hints>LF
86    </connection>LF
87    <connection>LF
88     <sender>buttonBox</sender>LF
89     <signal>rejected()</signal>LF
90     <receiver>Dialog</receiver>LF
91     <slot>reject()</slot>LF
92     <hints>LF
93      <hint type="sourcelabel">LF
97      <hint type="destinationlabel">LF
98       <x>286</x>LF
99       <y>274</y>LF
100     </hint>LF
101    </hints>LF
102   </connection>LF
103  </connections>LF
```

Figure 5: QT GUI as XML Tree

Visual Elements in a Tree (View Tree) (cont.)

View Object Properties (Layout)

- Arrangement of bounding boxes of each view object arranged on the basis of a layout.
- May involves information about position and size of view objects

View Object Properties (Output)

- Each View Object responsible for displaying itself
- Associated with a thread
- If Tree changes, so will its child nodes

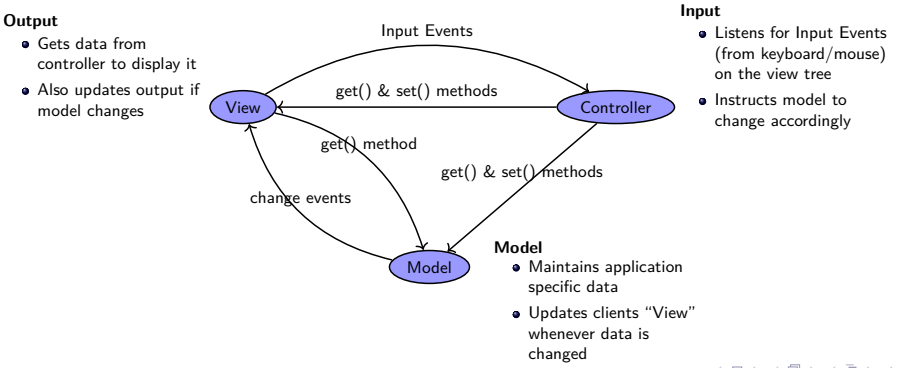
Visual Elements in a Tree (View Tree) (cont.)

View Object Properties (Input)

- Enabled View Objects can listen for input from Keyboard and Mouse using additional threads
  - **Event Object** Contains information about an event
  - **Event Source** The component where an event is generated
  - **Event Listener** A listener is created which records an interest to the particular stream of events. It then listens for the event.
  - **Event Handler** What to do when an event occurs (User Defined) A function is called whenever a new event occurs.

Model View Controller (MVC)

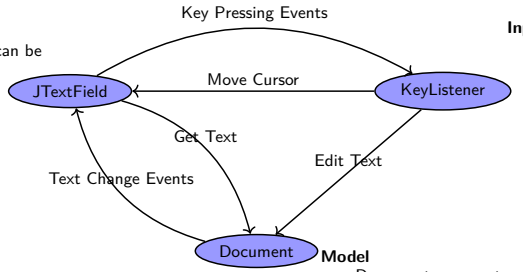
- A software architecture pattern for GUI's (initially) and Web Services
- Introduced in 1970's
- Separates GUI front-end from application back-end
  - Back-end code = Model
  - Front-end code = View, Controller



Model View Controller (MVC) (cont.)

Output

- JTextField is a Jcomponent that can be added to the view hierarchy



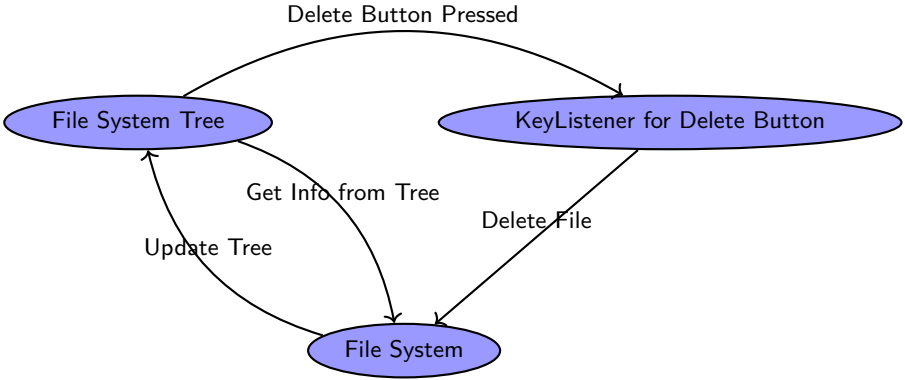
Input

- KeyListener is a listener for Keyboard Events

Model

- Document represents multiple strings of characters

Model View Controller (MVC) (cont.)



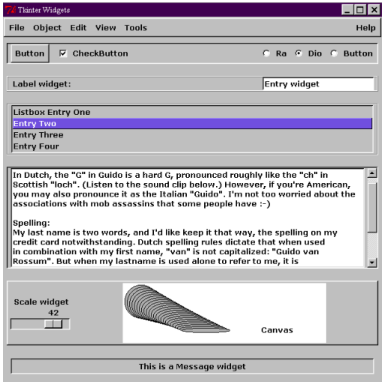
Model View Controller (MVC) (cont.)

Benefits of Separating Model from View

- Many views of same application data possible
- Allows for creating user interface toolkits (view toolkits, completely separate from the application data)

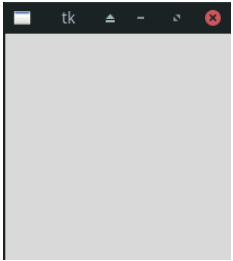
Tkinter

- Python interface to TK (GUI tool for TCL/TK)
- Standard GUI Library in Python (bundled)
- Object Oriented Approach
- Elements represent MOTIF components (non-native components)



Hello World

```
import tkinter

root = tkinter.Tk()

# Widget Codes

root.mainloop()
```



Bypassing WM

```
screen_width  = str(root.winfo_screenwidth())
screen_height = str(root.winfo_screenheight())

root.geometry(screen_width+"x"+screen_height+"+0+0")
print(root.winfo_geometry())
print(root.winfo_width(), root.winfo_height())

root.overrideredirect(True)
```

Top Level

```
t1 = Toplevel(root)

t2 = Toplevel(root)
t2.transient(root)
```

Frames

```
for relief in [RAISED, SUNKEN, FLAT, RIDGE, GROOVE, SOLID]:
  f = Frame(root, borderwidth=2, relief=relief)
  Label(f, text=relief, width=10).pack(side=LEFT)
  f.pack(side=LEFT, padx=5, pady=5)
```

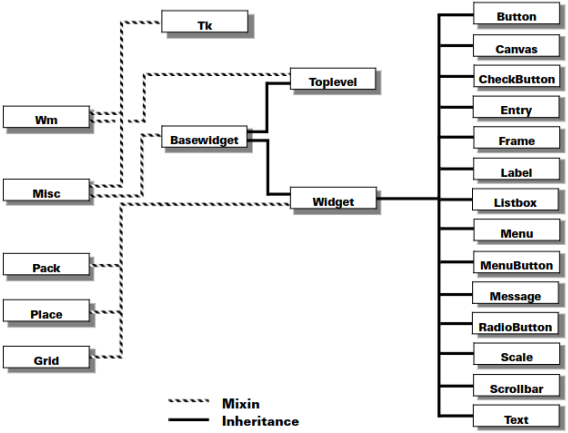
Common Widgets

```
Label(root, text="Label Text", wraplength=300,
                               justify=LEFT).pack()

Button(root, text="Go1", command=go1func).pack()
Button(root, text="Go2", command=lambda: go2func()).pack()

e = StringVar()
Entry(root, width=40, textvariable=e).pack()
```

Hello World (cont.)

```
print(dir(root))
'''['_Misc__winfo_getint', '_Misc__winfo_parseitem', '__class__', '__delattr__', '__dict__', '__dir__', '__doc__', '__eq__', '__format__', '__ge__', '__getattr__',
'__getattribute__', '__getitem__', '__getstate__', '__gt__', '__hash__', '__init__', '__init_subclass__', '__le__', '__lt__', '__module__', '__ne__', '__new__',
'__reduce__', '__reduce_ex__', '__repr__', '__setattr__', '__setitem__', '__sizeof__', '__str__', '__subclasshook__', '__weakref__', '_bind', '_configure',
'_displayof', '_getboolean', '_getconfigure', '_getconfigure1', '_getdoubles', '_getints', '_grid_configure', '_gridconvvalue', '_last_child_ids', '_loadtk',
'_nametowidget', '_noarg_', '_options', '_register', '_report_exception', '_root', '_subst_format', '_subst_format_str', '_substitute', '_tclCommands', '_tkloaded',
'_unbind', '_w', '_windowingsystem', 'after', 'after_cancel', 'after_idle', 'anchor', 'aspect', 'attributes', 'bbox', 'bell', 'bind', 'bind_all', 'bind_class',
'bindtags', 'cget', 'children', 'client', 'clipboard_append', 'clipboard_clear', 'clipboard_get', 'colormapwindows', 'columnconfigure', 'command', 'config',
'configure', 'deiconify', 'deletecommand', 'destroy', 'event_add', 'event_delete', 'event_generate', 'event_info', 'focus', 'focus_displayof', 'focus_force',
'focus_get', 'focus_lastfor', 'focus_set', 'focusmodel', 'forget', 'frame', 'geometry', 'getboolean', 'getdouble', 'getint', 'getvar', 'grab_current', 'grab_release',
'grab_set', 'grab_set_global', 'grab_status', 'grid', 'grid_anchor', 'grid_bbox', 'grid_columnconfigure', 'grid_location', 'grid_propagate', 'grid_rowconfigure',
'grid_size', 'grid_slaves', 'group', 'iconbitmap', 'iconify', 'iconmask', 'iconname', 'iconphoto', 'iconposition', 'iconwindow', 'image_names', 'image_types',
'info_patchlevel', 'keys', 'lift', 'loadtk', 'lower', 'mainloop', 'manage', 'master', 'maxsize', 'minsize', 'nametowidget', 'option_add', 'option_clear', 'option_get',
'option_readfile', 'overrideredirect', 'pack_propagate', 'pack_slaves', 'place_slaves', 'positionfrom', 'propagate', 'protocol', 'quit', 'readprofile', 'register',
'report_callback_exception', 'resizable', 'rowconfigure', 'selection_clear', 'selection_get', 'selection_handle', 'selection_own', 'selection_own_get',
'send', 'setvar', 'size', 'sizefrom', 'slaves', 'state', 'title', 'tk', 'tk_bisque', 'tk_focusFollowsMouse', 'tk_focusNext', 'tk_focusPrev', 'tk_setPalette',
'tk_strictMotif', 'tkraise', 'transient', 'unbind', 'unbind_all', 'unbind_class', 'update', 'update_idletasks', 'wait_variable', 'wait_visibility', 'wait_window',
'waitvar', 'winfo_atom', 'winfo_atomname', 'winfo_cells', 'winfo_children', 'winfo_class', 'winfo_colormapfull', 'winfo_containing', 'winfo_depth', 'winfo_exists',
'winfo_fpixels', 'winfo_geometry', 'winfo_height', 'winfo_id', 'winfo_interps', 'winfo_ismapped', 'winfo_manager', 'winfo_name', 'winfo_parent', 'winfo_pathname',
'winfo_pixels', 'winfo_pointerx', 'winfo_pointerxy', 'winfo_pointery', 'winfo_reqheight', 'winfo_reqwidth', 'winfo_rgb', 'winfo_rootx', 'winfo_rooty', 'winfo_screen',
'winfo_screencells', 'winfo_screendepth', 'winfo_screenheight', 'winfo_screenmmheight', 'winfo_screenmmwidth', 'winfo_screenvisual', 'winfo_screenwidth',
'winfo_server', 'winfo_toplevel', 'winfo_viewable', 'winfo_visual', 'winfo_visualid', 'winfo_visualsavailable', 'winfo_vrootheight', 'winfo_vrootwidth', 'winfo_vrootx',
'winfo_vrooty', 'winfo_width', 'winfo_x', 'winfo_y', 'withdraw', 'wm_aspect', 'wm_attributes', 'wm_client', 'wm_colormapwindows', 'wm_command', 'wm_deiconify',
'wm_focusmodel', 'wm_forget', 'wm_frame', 'wm_geometry', 'wm_grid', 'wm_group', 'wm_iconbitmap', 'wm_iconify', 'wm_iconmask', 'wm_iconname', 'wm_iconphoto',
'wm_iconposition', 'wm_iconwindow', 'wm_manage', 'wm_maxsize', 'wm_minsize', 'wm_overrideredirect', 'wm_positionfrom', 'wm_protocol', 'wm_resizable', 'wm_sizefrom',
'wm_state', 'wm_title', 'wm_transient', 'wm_withdraw']'''

print(root.winfo_children())                    # [<tkinter.Label object .!label>, <tkinter.Button object .!button>]
```

Library Structure



Class Based GUI

```
class GUI:
  def __init__(self, master):
    self.root = master
    self.root.title("Class based version")

root = tkinter.Tk()
my_gui = GUI(root)
root.mainloop()
```

Radio Buttons

```
var = IntVar()
for text, value in [('Passion fruit', 0), ('Loganberries', 1), ('Mangoes in syrup', 2)]:
  Radiobutton(root, text=text, value=value, variable=var, command=radiogo).pack()

def radiogo():
  r = var.get()
```

Check Buttons

```
var = [IntVar() for i in range(3)]
for text, value in [('Passion fruit', 0), ('Loganberries', 1), ('Mangoes in syrup', 2)]:
  Checkbutton(root, text=text, variable=var[value], command=checkgo).pack()

def checkgo():
  r1 = var[0].get()
  r2 = var[1].get()
  r3 = var[2].get()
```

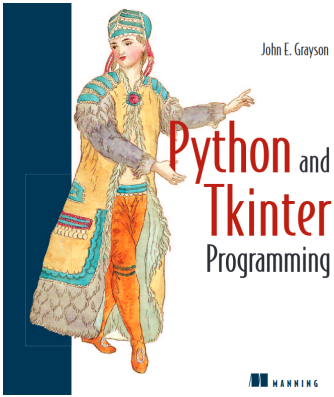
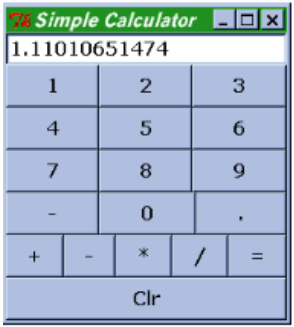


Figure 6: Reading List: Refer to Section 4.1


Simple Calculator
1.11010651474
1
2
3
4
5
6
7
8
9
-
0
.
+
-
*
/
=
Clr

Homework Task 2

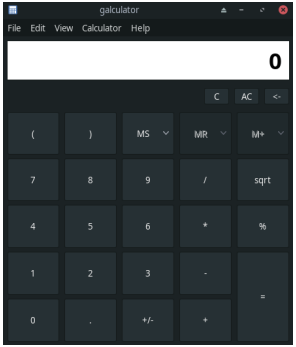


Figure 7: Modify the provided calc.py code to create this layout

Overview

- Collaborative (Cloud + Local Cache)
- Flavours: Web (figma.com) or Desktop
- Web: Uses google fonts
- Desktop: Uses system fonts

- Most tools at no cost (Free, 12$/month, 45$/month)
- Able to generate CSS, iOS, Android code

Overview (cont.)

Alternates

- Sketch
- Adobe XD
- Canva
- GPT (?)
- ...

Welcome Screen

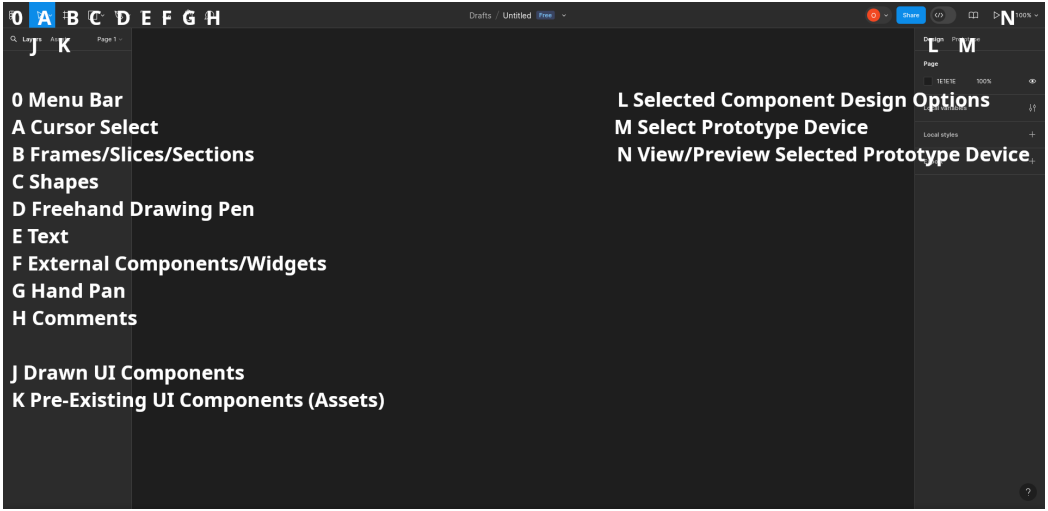
- Design File (Graphic / UI Designs)
- Figjam Board (Collaborative Whiteboard)
- Slidedeck (Presentations)

Figjam

- Navigation
- Freehand Drawing Marker
- Shapes & Connectors
- Sticky Notes (for comments)
- Text Components
- Sections
- Tables
- Stamps
- Libraries / Templates

Research (Mission Statement) → Competitor Analysis → Moodboard → User Personas → Golden Path

Design File



0 Menu Bar
A Cursor Select
B Frames/Slices/Sections
C Shapes
D Freehand Drawing Pen
E Text
F External Components/Widgets
G Hand Pan
H Comments

J Drawn UI Components
K Pre-Existing UI Components (Assets)

L Selected Component Design Options
M Select Prototype Device
N View/Preview Selected Prototype Device

Design File (cont.)

Frames

- Used as Artboard + Container (different from Groups)

Options

- Create Own UI components
- Download Resources (free) from web

Figma - TKInter Interfacing

TkInter Export

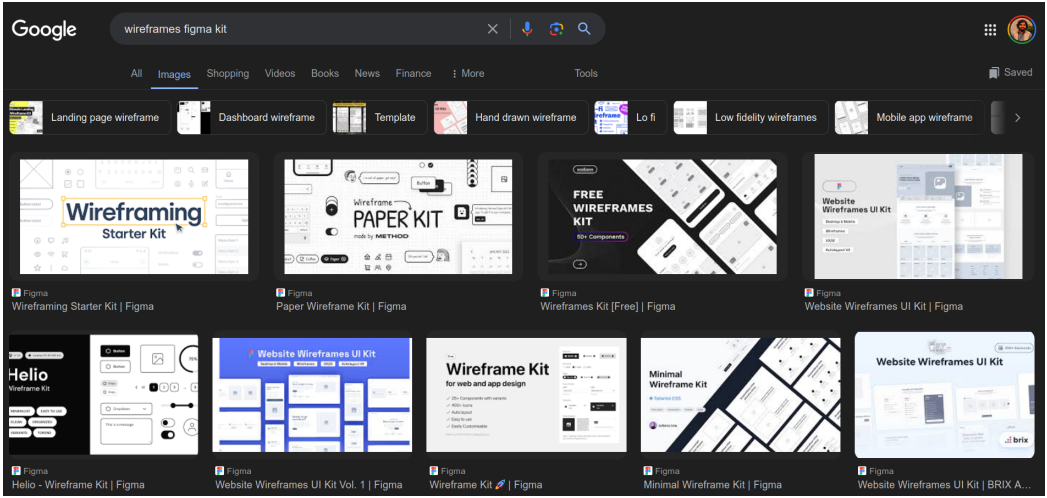
- https://github.com/ParthJadhav/Tkinter-Designer
- Specify API Token (Accessible from User Settings)
- Specify Figma Project Folder (Accessible from Share Option)
- Specify Local Directory for Export
- Launch using Python

Wireframes

- Draft of a raw UI without any stle, detail, or even color
- Helps teams align requirements, keeping UX design conversations focused and constructive.
- Covers:
  - Screen Layouts
  - Navigation Bars
  - Components of UI/UX
  - Interactive Elements

- Blueprint / Skeleton
- Use pen and paper if you want
- Plenty of Figma Wireframe Kits

Wireframes (cont.)



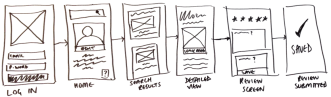
Wireframes (cont.)

Is It Needed?

- Working in an established/embedded design system
- Explored design needs to copy best practices (competitor lookalike)

Low Fidelity

Basic wireframes focused on layout, basic navigation, and information architecture. Show what the interface will look like. Illustrate user flows with key UI design elements.



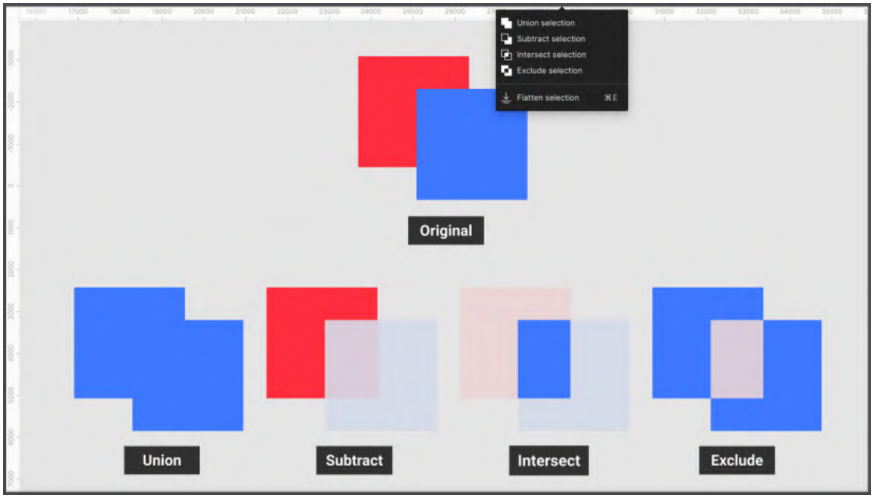
Mid Fidelity

Helps iterate and shape the final design. Maps out core functionality and key interactions to designed pathways

High Fidelity

Looks like early product mockups, without the functionality of low-fidelity prototypes. Layouts, Navigation, Architectures much refined. Includes brand elements like fonts, logos.

Preparing Complex Designs



Preparing Complex Designs (cont.)

Components

- Helps prepare Reusable UI Objects (Parent Child Relationship, Parent Change Can Change All Children, Child Change effects Concerned Child Only)
- Parent Component can be stored in non-visible Area
- Helpful for creating Variants

Design Principles (Usability)

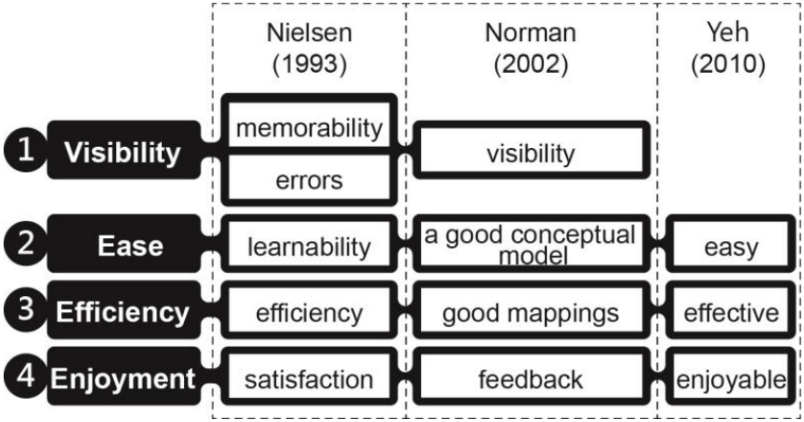


Figure 8: Wang, C.M., Huang, C.H., A Study of Usability Principles and Interface Design for Mobile e-Books, Ergonomics, 2015

A/B Testing

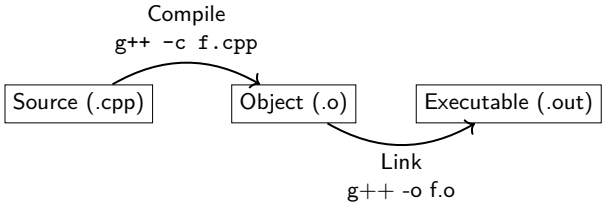
A/B Testing

Broader objective to compare two (or more) versions of a UI to find which is better? Quite flexible in choice of comparison technique.

Preparation

1. Prepare UI Pathways
2. Prepare UI(s) for each node in Pathway
3. Collect Data for UI(s) that is linked to Usability Design Principles (e.g. Response Time, Pathway Goals, number of components, memory usage, etc.)
4. Normalize Data (scale or 0-1)
5. Find better score (simple comparison vs statistical testing)

Build Pipelines




```
g++ [options] source.cpp
```

```
gcc [options] source.c
```

```
clang++ [options] source.cpp
```

```
clang [options] source.c
```

```
icpc [options] source.cpp
```

```
icc [options] source.c
```

Sources

Integrated Development Environment

- CodeBlocks, Vim, Sublime Text, IntelliJ, Eclipse, Xcode, Android Studio, Geany, pyCharm, ... [a]
- Whichever you are comfortable with.
- Desirable Features:
  - Auto Complete features.
  - Auto Compilation features.
  - Debugger integration.
  - Code folding.
  - One IDE for all (development, office work)
  - Cross-Sectional Editing.
  - Remote development.
  - Integration with versioning systems
  - ...

[a] pypl.github.io for ranking

Sources (cont.)

Naming and Style Conventions

- cpp, hpp in C++, and c, h in C.
- followCamelCaseNamingConvention
- Folder conventions: *src* for source code, *build* or *bin* for binaries, *lib* for libraries, *doc* for documentation, *test* for unit testing.
- Suffixes: *g_* for global, *s_* for static, *c_* for constant variables.
- ... Much more on **google.github.io/styleguide** (Note: Company specific Guides)
- Can be enforced at commit time, or using static code checkers (e.g. **cpplint**)
- Indentation can be forced using **indent** with args gnu (for Stallman), kr (for Kernighan & Ritchie), linux (for Torvalds), orig (for Berkeley). Check man pages for details.

Sources (cont.)

Comments

- Governed by style guidelines.
- Documentation generators (Latex, HTML, XML, PDF, Man): Doxygen, Sphinx
- Doxygen Step 1: Fix settings
- Doxygen Step 2: Write comments (E.g. below)

```
/**
 * Search whether a given directed edge exists in a graph. Edges are specified as
 * head-tail pairs and must be specified in order.
 * @param G Graph object
 * @param head First incident vertex on edge
 * @param tail Second incident vertex on edge
 * @return Not Found = 0, Found = 1
 */
int directedEdgeExists(struct nGraph *G, int head, int tail) { }
```

- Doxygen Step 3: Generate documentations

Pre-Processing

- Source code transformation by Pre-Processor
- Pre-processor behavior controlled by directives
- File Inclusions:

```
#include <iostream>
#include <boost/tokenizer.hpp>
#include "my_header_file.hpp"
#include "some_directory/my_header_file.hpp"
```

- Macro definitions

```
#define DEBUG_LEVEL 10
#define myMacro(param1, param2) param1+param2
```

- Conditional Compilation Directives

```
#if, #ifdef, or #ifndef directive
#elif
#else
#endif
```

Compilations

Common Arguments

- -c Compile only
- -g Debugging symbols
- -p Performance symbols
- -O*n* Optimization level to *n* (0; none, 3: full)
- -stc Version (e.g. -std=c++20)
- -I Include directory
- -L Library path
- -l*txt* Linking with library (lib*txt*) file
- -Wall enable most warnings
- -Wextra enable extra warnings
- -Werror treat warnings as errors

Compilations (cont.)

ELF64

- Executable and Linkable Format (for all executables, object code, libraries)
- Described in elf.h of Linux kernel
- Learning Benefits: Digital forensics, OS internals, Malware research
- Viewable using `readelf`

ELF File Structure

- ELF Header (64 bytes, -h switch)
- Program Header (-l switch)
- Section Header (-S switch)

ELF File Types

- Relocatable
- Executable
- Shared Object Files

Compilations (cont.)

```
ELF Header:
  Magic:   7f 45 4c 46 02 01 01 00 00 00 00 00 00 00 00 00
  Class:                             ELF64
  Data:                              2s complement, little endian
  Version:                           1 (current)
  OS/ABI:                            UNIX - System V
  ABI Version:                       0
  Type:                              REL (Relocatable file)
  Machine:                           Advanced Micro Devices X86-64
  Version:                           0x1
  Entry point address:               0x0
  Start of program headers:          0 (bytes into file)
  Start of section headers:          384 (bytes into file)
  Flags:                             0x0
  Size of this header:               64 (bytes)
  Size of program headers:           0 (bytes)
  Number of program headers:         0
  Size of section headers:           64 (bytes)
  Number of section headers:         9
  Section header string table index: 1
```

Figure 9: ELF File Header `readelf -h obj.o`

Linking Process

Static Linking

- Code and variables resolved at compile time by interpreter ld, and copied into target application as a stand-alone executable
- .a filename convention
- Benefits: No dependency problems (single executable file)
- Cost: Large file size, Library code possibly loaded multiple times in memory

```
// file get15.c
// gcc -c get15.c


int get15() {
  return 15;
}

// ar -cvr libget15.a get15.o
```

```
// file main.c
// gcc main.c get15.o
// gcc main.c libget15.a
// gcc main.c -lget15

int main() {
  return get15();
}
```

Linking Process (cont.)

Dynamic Linking

- Code and variables resolved at load time by runtime interpreter ld-linux.so.2, and copied into target executable as symbols
- .so file convention
- Benefit: Small file size, library code loaded once in shared memory
- Cost: Dependency management

```
// file get15.c
// gcc -shared get15.c -o libget15.so
```

```
// file main.c
// gcc main.c -lget15
```

Linking Process (cont.)

```
# Output: readelf -S a.out
[21] .dynamic          DYNAMIC          0000000000003de8  00002de8
     00000000000001f0  0000000000000010  WA       7     0     8

#Output: readelf -d a.out
Dynamic section at offset 0x2de8 contains 27 entries:
  Tag        Type                         Name/Value
 0x0000000000000001 (NEEDED)             Shared library: [libget15.so]
 0x0000000000000001 (NEEDED)             Shared library: [libc.so.6]
 0x000000000000000c (INIT)               0x1000
# .. . continues
```

- Use symbolic links when dealing with multiple versions

```
gcc -shared -Wl,-soname,libget15.so.1 -o libget15.so.1.0 get15.c
ln -sf libget15.so.1.0 libget15.so.1
ln -sf libget15.so.1.0 libget15.so
```

Automated Builds

- Single-file programs do not work well when code gets large
- Larger programs are split into multiple files
- Retyping commands is wasteful (In Bash, Use ↑ or `CTRL+R` as shortcut)

Automated Builds (cont.)

GNU Autotools

- Natively Supported Languages: C, C++, Objective C, Objective C++, Fortran, Fortran 77, Erlang, Go, ...
  Often used for C programs, but not language-specific.

Autoconf

Generates Configuration Scripts

Automake

Automatic compiling/building executables and libraries

Libtool

Portable creation of shared libraries

Makefile Format

```
myprogram : file1.c file2.c file3.c
	gcc -o myprogram file1.c file2.c file3.c
```

- Launch as `make` for first target, or `make myprogram` with direct target name
- Runs commands only if needed (based on timestamp)

Automated Builds (cont.)

```
all: aprogram

aprogram : foo.o bar.o
         gcc -o aprogram foo.o bar.o

foo.o: foo.c
         gcc -c foo.c

bar.o: bar.c
         gcc -c bar.c
```

- Standard Makefile targets: all, install, clean, distclean, ...
- Standard Variables: CC, CFLAGS, CXX, CXXFLAGS, LDFLAGS, ...

configure.ac : Autoconf Hello World

```
AC_INIT([ProjectName], [1.0])
AC_OUTPUT
```

- Create the File configure.ac
- Run autoconf in the same directory (or better, run autoreconf)

Debugging Using GDB / DDD

Code Debugging

- Step through a program line by line
- Inspect variables and objects as it steps through
- Inspect disassembled code as it steps through
- Inspect call stack as it steps through

Debugging Using GDB / DDD (cont.)

Code Debugging

GNU Debugger GDB

- Compile Time: `gcc -g myCode.c`
- Run Time: `gdb ./a.out`, followed by `run arg1 arg2`
- NCurses based frontend using `gdb ./a.out -tui`, or launching as normal, and issuing `layout src` after inserting any breakpoint.
- Commands:
  - Breakpoints `break file.c:10`, OR `break 10`, OR `break myFunc`
  - Delete breakpoints using `delete` or specifically by name
  - To view code: `list`
  - To view disassembled code: mintinlinebash|disassemble myFunc|
  - Iterate through code: `continue`, `step`, `next`
  - Inspect variables using: `print variableName`

Debugging Using GDB / DDD (cont.)

Code Debugging

GNU Project - Software

DDD v3.3 DataDisplayDebugger

- About DDD
- DDD News
- Getting DDD
- Building DDD
- Documentation
- Alpha Releases
- Reporting Bugs
- Where can I learn more about the debuggers DDD uses?
- Help and Assistance
- References

What is DDD?

GNU DDD is a graphical front-end for command-line debuggers such as GDB, DBX, WDB, Ladebug, JDB, XDB, the Perl debugger, the bash debugger bashdb, the GNU Make debugger remake, or the Python debugger pydb. Besides ``usual'' front-end features such as viewing source texts, DDD has become famous through its interactive graphical data display, where data structures are displayed as graphs.

Debugging for Memory Problems using Valgrind

Memory Profilers

Typical Memory Problems

- Uninitialized Variables
- Read/Write to un-allocated Memory (maybe segfaults generated)
- Deleting or Freeing dynamically created memory twice
- Memory Leaks

```
void f() {
  int *x = malloc(10 * sizeof(int));
  x[10] = 0;
}

int main(int argc, char *argv[]) {
  int n, i;
  f();
  for (i = 0; i < n; i++);
  return 0;
}
```

```
valgrind --leak-check=full ./a.out
```

Debugging for Memory Problems using Valgrind (cont.)

Memory Profilers

```
==23294== Invalid write of size 4
==23294==    at 0x108728: f (in /home/omar/work/codes/c/valgrind/a.out)
==23294==    by 0x108749: main (in /home/omar/work/codes/c/valgrind/a.out)
==23294==  Address 0x5204068 is 0 bytes after a block of size 40 allocated
==23294==    at 0x4C2EF1F: malloc (vg_replace_malloc.c:299)
==23294==    by 0x10871B: f (in /home/omar/work/codes/c/valgrind/a.out)
==23294==    by 0x108749: main (in /home/omar/work/codes/c/valgrind/a.out)
==23294==
==23294== Conditional jump or move depends on uninitialised value(s)
==23294==    at 0x10875D: main (in /home/omar/work/codes/c/valgrind/a.out)
==23294==
==23294== More than 10000000 total errors detected. I am not reporting any more.
==23294==
==23294== HEAP SUMMARY:
==23294==    in use at exit: 40 bytes in 1 blocks
==23294==    total heap usage: 1 allocs, 0 frees, 40 bytes allocated
==23294==
==23294== 40 bytes in 1 blocks are definitely lost in loss record 1 of 1
==23294==    at 0x4C2EF1F: malloc (vg_replace_malloc.c:299)
==23294==    by 0x10871B: f (in /home/omar/work/codes/c/valgrind/a.out)
==23294==    by 0x108749: main (in /home/omar/work/codes/c/valgrind/a.out)
==23294==
```

Debugging for Memory Problems using Valgrind (cont.)

Memory Profilers

```
==23294== LEAK SUMMARY:
==23294==    definitely lost: 40 bytes in 1 blocks
==23294==    indirectly lost: 0 bytes in 0 blocks
==23294==    possibly lost: 0 bytes in 0 blocks
==23294==    still reachable: 0 bytes in 0 blocks
==23294==    suppressed: 0 bytes in 0 blocks
```

Observing Memory Usage Behavior using Massif

Memory Profilers

- Memory usage as a function of allocation/deallocation event on heap (including stack)
- Usage: `valgrind --tool=massif --time-unit=B ./a.out`
- Visualization usage: `massif-visualizer massif.out.pid`

Observing Memory Usage Behavior using Massif (cont.)

Memory Profilers

Performance Measurement

Code Profilers

Profiler

An analysis that may measure usage of instructions in terms of their frequency or duration of execution. The goal of profiling is to aid program optimization.

- Common and Powerful Tools for Profiling Code: time, Fine-grained profiling, callgrind, gprof, oprofile, ...

`time ./a.out`

```
time ./a.out
# output of my program, if any.
real 0m0.003s # Wall clock time
user 0m0.001s # Userspace (accumulated CPU for both library + user space)
sys  0m0.001s # Kernelspace (I/O and/or syscalls)
```

- General Tip: Run for sufficiently long period + allow for relaxation period.

Performance Measurement (cont.)

Code Profilers

Fine Grained profiling

- Multiple Solutions !!!

```
struct timespec start, finish;                    // Defined in time.h
// struct timespec contains tv_sec, and tv_nsec
// struct timeval contains  tv_sec, and tv_usec

/* vs CLOCK_REALTIME (NTP dependent) */
clock_gettime(CLOCK_MONOTONIC, &start);
  /* Code Here */
clock_gettime(CLOCK_MONOTONIC, &finish);

double elapsed = (finish.tv_sec - start.tv_sec);
elapsed += (finish.tv_nsec - start.tv_nsec) / 1e9;
```

Performance Measurement (cont.)

Code Profilers

callgrind

- Part of valgrind,
- Compiler Flags: `gcc -g myCode.c`
- Call using valgrind: `valgrind --tool=callgrind ./a.out`
- View output on Terminal: `callgrind_annotate --auto=yes callgrind.out.NNNN`
- View output in GUI: `kcachegrind callgrind.out.NNNN`

Performance Measurement (cont.)

Code Profilers

gprof

- Compile as: `gcc myCode.c -pg`
- Run as: `./a.out` (will be slower than without profiling), output in `gmon.out`
- View gprof using: `gprof ./a.out`

% time	cumulative seconds	self seconds	calls	self s/call	total s/call	name
39.47	12.01	12.01	1	12.01	21.38	func1
30.79	21.38	9.37	1	9.37	9.37	func2
30.79	30.75	9.37	1	9.37	9.37	new_func1
0.13	30.79	0.04				main

Performance Measurement (cont.)

Code Profilers

```c
#include<stdio.h>

void func1(void)
{   printf("\n Inside func1 \n");
    for(int i = 0; i<0xffffffff; i++);
    new_func1();
    return;
}

int main(void)
{
    printf("\n Inside main()\n");
    for(int i = 0; i<0xffffff; i++);
    func1();
    func2();

    return 0;
}
```

```c
void func2(void)
{   printf("\n Inside func2 \n");
    for(int i = 0; i<0xffffffaa; i++);
    return;
}
```

```c
void new_func1(void)
{   printf("\n Inside new_func1()\n");
    for(int i = 0;i <0xfffffee; i++);
    return;
}
```

Performance Measurement (cont.)

Code Profilers

Call Graph Output

```
index % time    self  children    called     name
[1]    100.0    0.04   30.75                 main [1]
               12.01    9.37       1/1           func1 [2]
                9.37    0.00       1/1           func2 [3]
-----------------------------------------------
               12.01    9.37       1/1           main [1]
[2]     69.4   12.01    9.37       1         func1 [2]
                9.37    0.00       1/1           new_func1 [4]
-----------------------------------------------
                9.37    0.00       1/1           main [1]
[3]     30.4    9.37    0.00       1         func2 [3]
-----------------------------------------------
                9.37    0.00       1/1           func1 [2]
[4]     30.4    9.37    0.00       1         new_func1 [4]
-----------------------------------------------
```

Performance Measurement (cont.)

Code Profilers

OProfile

- Install it
- Run any code as: `sudo operf ls` (previously it was a kernel module as CONFIG_OPROFILE)
- output written to: oprofile_data in current directory
- View output as: `opreport`
- Cleanup by removing directory

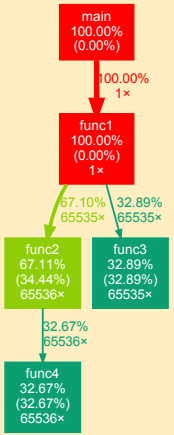
Performance Measurement (cont.)

Code Profilers

gprof2dot

- Can be called with any profiler tools
- Generates interesting graphics for documentation / publications
- Usage:

```
gprof ./a.out | gprof2dot | dot -Teps -o output.eps
```



Code Coverage using Gcov

- Find out different un-used portions of code during various tests.
- Compile using:

  `gcc -Wall -fprofile-arcs -ftest-coverage myCode.c`

  or

  `gcc myCode.c --coverage`
- Run your program
- Call `gcov myCode.c`

```
for (i = 1; i < 10; i++)
  {
    if (i % 3 == 0)
      printf ("%d is divisible by 3\n", i);
    if (i % 11 == 0)
      printf ("%d is divisible by 11\n", i);
  }
```

Code Coverage using Gcov (cont.)

Coverage output

```
      10:    8:  for (i = 1; i < 10; i++)
       -:    9:    {
       9:   10:      if (i % 3 == 0)
       3:   11:        printf ("%d is divisible by 3\n", i);
       9:   12:      if (i % 11 == 0)
   #####:   13:        printf ("%d is divisible by 11\n", i);
       -:   14:    }
```

Cross Compilation

- Compiler support required to merge object files of different languages
- Why? Performance and Native Calls

Wrapper Libraries

- C extension modules (for Python, Cython)
- Java extension modules (for Python, Jython)
- Mex files (for Matlab)
- Swift - Objective C extensions
- ...

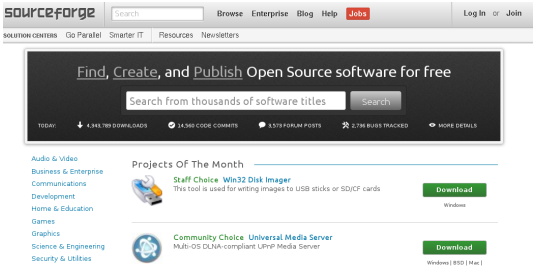
Cross Compilation (cont.)

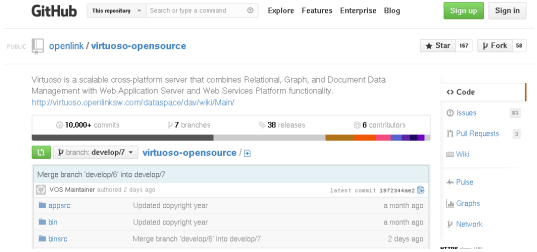
Example 1 (C Code)

```python
from ctypes import *

so_file="./fputs.so"
myCFunctions=CDLL(so_file)

myCFunctions.myfputs(b"Hello", b"write.txt")
```

```c
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>

int myfputs(char *s, char *f) {
  FILE *fp = fopen(f, "w");
  int ret = fputs(s, fp);
  fclose(fp);
  return ret;
}
```

Version Control Systems





- Source Forge, Google Code (shelved), Github

Version Control Systems (cont.)

Version Control Systems

- A software tool that can store source code @ a central location
- Keeps a record of changes that have been made from time to time
- Keeps a record of who did what changes from time to time
- Can be used as a backup if something goes wrong in your code.

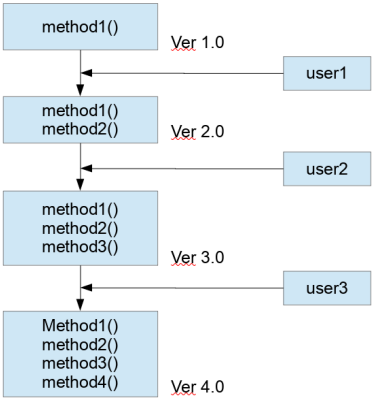
Individual Code Developer

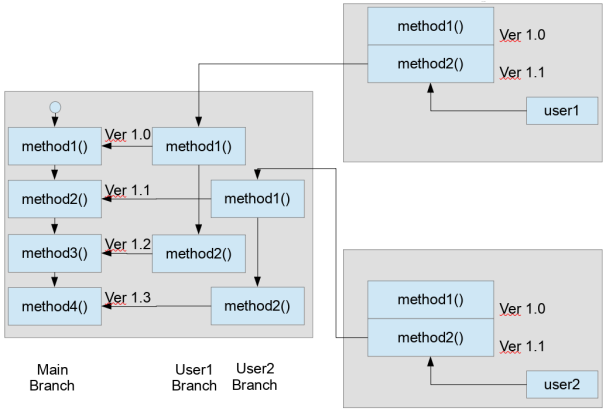
- Can use version control as a backup tool
- Knows that the recent version is the live code
- Can maintain branches, e.g. developer branch, like branch, test branch, etc. etc. (Branches also known as Trunks)

Team Developers

- Each developer on a separate branch
- Developers can be in different parts of the world
- *upstream* can merge branches of two developers to do a version increment.

Centralized vs Distributed Version Control Systems





Centralized vs Distributed Version Control Systems (cont.)

Popular Version Control Systems

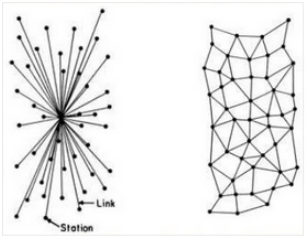
- SVN; Sub-version (Centralized)
- GIT (Distributed)
- Bazaar
- Mercurial
- ...

SVN (Centralized)

- Corruption risk. Will effect everybody
- Won't work on low network speeds
- Not scalable if users are too much
- Stores Complete Files

Git (Distributed)

- Corruption will only affect a local server
- Support for Load Balancing.
- Stores Partial Files.



Partial Storage

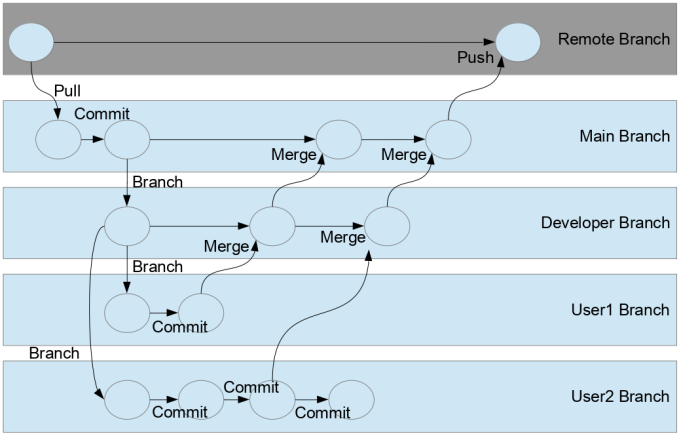
- Version 1.0
  - public class test {
    public static void main(String[] args) {
    }
    }
- Version 2.0
  - public class test {
    public test() {
    }
    public static void main(String[] args) {
    new test();
    }
    }

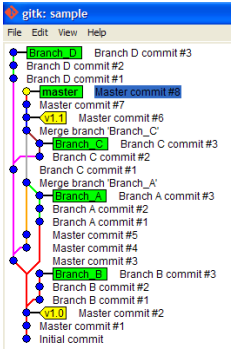
Stores This

Stores This

and This

Git Workflow





Git Workflow (cont.)

How to Work with these Workflows?

- Built-into Eclipse (no need to install anything else)
- Built-into Netbeans (no need to install anything else)
- Via Commands on the Command Line
- Via Clients: GitHub (browser), Gitlab (Browser), SourceTree, Git-Cola, Git-Eye, SmartGit, GitG (Linux), Giggle, ...
- Hosting your own Git: gitolite

Jenkins
Overview

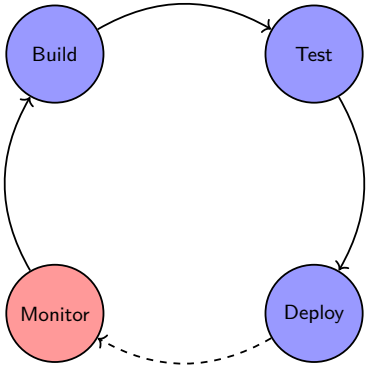
- An Open Source and self-contained Server tool made in java for Continuous Integration (CI) and Continuous Deployment (CD)
- Actual implementation toolkit for *Automation Patterns*
- Used internally by likes of Dell, Ebay, Github Social, Facebook, Etsy, NASA, Netflix, LinkedIn, ...
- CI/CD: Extreme Programming Concept centered around Building, Testing, Deploying with least human intervention (introduced in 1990s)
  - `watch ls -lh`, `watch cat file.txt`, ...
  - `inotifywatch /home/omar`

```
Establishing watches...
Finished establishing watches, now collecting statistics.
total  access  modify  close_write  close_nowrite  open  create  delete  filename
35     4       26      0            2              2     0       1       /home/omar/
```

  - `while inotifywait -e close_write myfile.py; do ./myfile.py; done`
- Traditional vs Jenkins Architecture

Jenkins (cont.)

Overview



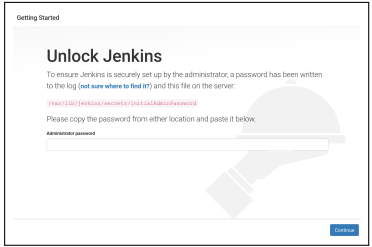
Jenkins (cont.)

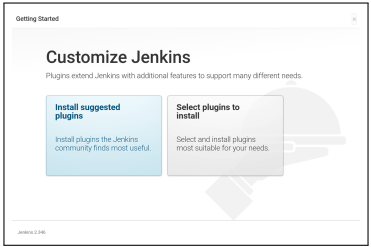
Overview

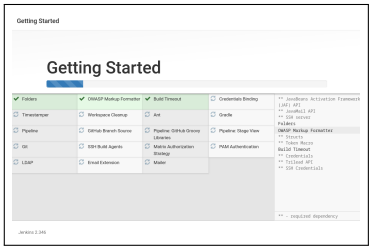
Installation

```
apt-get install jenkins
systemctl start jenkins
systemctl status jenkins
```

- Launch from localhost:8090

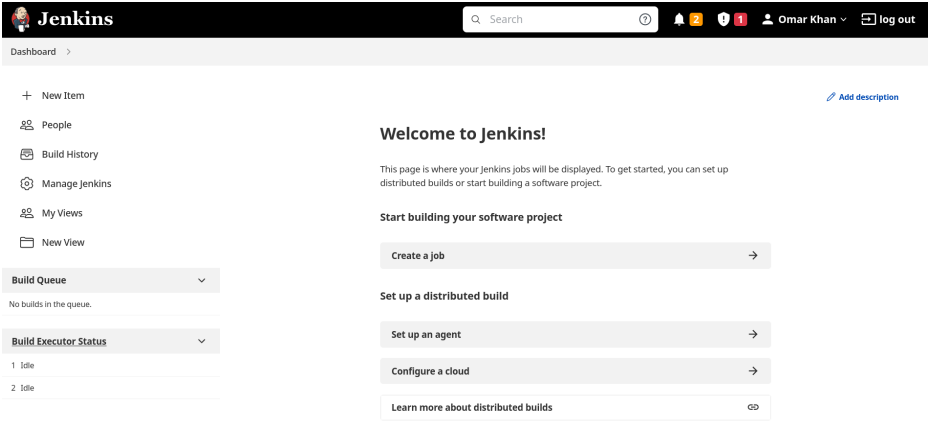






Jenkins (cont.)

Overview



Pipelines

- Suite of plugins which supports implementing and integrating CI/CD pipelines into Jenkins.
- Implemented through Pipeline Domain-Specific Language (DSL) Syntax
- Definitions written into a textfile called *Jenkinsfile*
- Pipelines coordinated through a *Jenkins Controller*

```
pipeline {
    agent any
    stages {
        stage('Build') {
            steps {
                //
            }
        }
        stage('Test') {
            steps {
                //
            }
        }
        stage('Deploy') {
            steps {
                //
            }
        }
    }
}
```

Docker

- Deployment Versioning issues
- Docker: Tool for runnning Containers in an isolated environment
- Container: An environment containing all libraries and resources required to run a process in isolation
- Images: A stored (readonly once created) blueprint for Containers (runtime environment, dependencies, Configurations, ...)
- Virtualenv: A Container for Python

Case: Python Virtual Environment (Venv)

```
pip install virtualenv          # Install (>= python3.3)
python -m venv myEnv            # bin, etc, lib, share, include, etc.
source myEnv/bin/activate       # Activate
deactivate                      # Deactivate
```

Virtual Machines	Containers
Large Footprint, Full Operating System, Slow	Shares Operating System (smaller size footprint), Faster

Installation and Usage

Docker Install

- Install on Linux (one liners usually)

```
pacman -S docker
systemctl start docker
```

- Windows 10: Requires Power Shell, Enable Windows Sub System, Enable Virtual Environment, Install and Set WSL
- $<$ Windows 10: Use Cygwin

Docker Hub

- Docker Hub: Online repository of Docker Images (Parent Images)

```
docker pull node                    # Name of Node.js image from docker hub
docker pull node:17-alpine          # Version of Node.js image
docker images                       # Show list of Images
```

Installation and Usage (cont.)

DockerFile

```
FROM node:17-alpine              # Fetch Parent Image
COPY . /app                      # Copy files
WORKDIR /app                     # Set Work Directory
RUN npm install                  # Run (Building Image)
CMD ["node", "app.js"]           # Run (when Run as a Container)
```

- Run as `docker build -t myapp .`

- For Versioning, use `docker build -t myapp:v1 .`

Container Usage

Running/Stopping Containers

```
docker images                          # View all images
docker run imageName                   # Create and Run image from Repository
docker run --name myApp imageName      # Same thing but with app name
docker ps                              # View all running  containers
docker ps -a                           # View all containers
docker stop containerID                # Stop by Container ID or app name
docker start containerID               # Start the Container
docker start -d containerID            # Run in detach mode (as in bg)
```

- Run: Create and Start, Multiple containers can be started from single image
- Start: Start only, start one container instance only

Running Commands

```
docker run myApp:latest \
  bash -c "echo hello > file.txt && cat file.txt"
```

Container Usage (cont.)

Deleting Images

```
docker image rm myApp              # Delete if not containerized (stop it first)
docker image rm myApp -f           # Force delete even if containerized
docker container rm myApp          # Remove containers
docker system prune -a             # Remove all containers and images
```

Docker File System

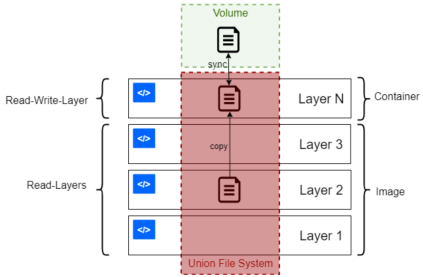


Figure 10: Docker File System

- Lost Read/Write Changes

Bind Mounts

```
docker run -v $(pwd):/my/folder myApp:v1 \
  bash -c "echo Hello > /my/folder/file.txt"
```

- Host Location : Container Location : mode
- Container Location created on demand if not already created
- Container Location must be the same as directory structure on host machine (so Linux only)
- Modes: ro for read only, z for shared amongst containers label, Z for private label

Docker File System (cont.)

Volume Mounts

- Native Container Mounts
- Lifetime of Volume Mount is larger than lifetime of Container
- Performance faster than bind mounts

```
docker volume create data_volume                    # Create data_volume
docker volume ls                                    # View available volumes
docker volume inspect data_volume                   # Details on the volume
docker volume rm data_volume                        # Delete volume

docker run -v data_volume:/my/folder/ myApp:v1 \
  bash -c "echo Hello > /my/folder/file.txt"
```

- Host Location : Container Location : mode
- Modes: ro for read only, z for shared amongst containers label, Z for private label

Google Test

- Test code piece by piece to see if gives expected output
- Works with C++ (For C, just use `assert.h`)

Sample Output

```
[----------] Global test environment set-up.
[----------] 1 test from myTest
[ RUN      ] myTest.test1
[       OK ] myTest.test1 (0 ms)
[----------] 1 test from myTest (0 ms total)
```

Google Test (cont.)

Hello World

```
/* g++ myCode.cpp -lgtest -lgtest-main -pthread */
#include <iostream>
#include <gtest/gtest.h>
using namespace std;

TEST( myTestName, testInstance1) {
  ASSERT_TRUE(1 == 1);
}

int main(int argc, char *argv[])
{
  testing::InitGoogleTest(&argc, argv);

  return RUN_ALL_TESTS();;
}
```

Google Test (cont.)

Possible Responses

- Success
- Fatal Failure
- Non-Fatal Failure

Fatal Failures

- `ASSERT_EQ(x,y)`
- `ASSERT_NE(x,y)`
- `ASSERT_LT(x,y)`
- `ASSERT_LE(x,y)`
- `ASSERT_GT(x,y)`
- `ASSERT_GE(x,y)`
- `ASSERT_TRUE(x == y)`
- `ASSERT_FALSE(x == y)`

Non-Fatal Failures

- `EXPECT_EQ(x,y)`
- `EXPECT_NE(x,y)`
- `EXPECT_LT(x,y)`
- `EXPECT_LE(x,y)`
- `EXPECT_GT(x,y)`
- `EXPECT_GE(x,y)`
- `EXPECT_TRUE(x == y)`
- `EXPECT_FALSE(x == y)`