# Introduction

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Adapted from: Software Engineering Theory and Practice by Pfleeger & Atlee, Software Engineering Modern Approaches by Braude & Bernstein.

# Why Software Engineering?

# Motivation

- Software is everywhere.
- Goal of software engineering is the creation of software systems that meet the needs of customers and are reliable, efficient and maintainable.
- Good software engineering practices ensure that software makes a positive contribution to how we lead our lives.

# Needs of Customer


**Quality**



https://biswajit-svmchaser.blogspot.com, https://x.com/VenuDhingra, https://www.team-bhp.com

# Why Software Engineering?

- High failure rates: A large number of modern software projects are unsuccessful.


Failure isn't just a crash; it's the gap between expectation and reality

Ref: https://www.callibrity.com

# Why Software Engineering?

- High failure rates: A large number of modern software projects are unsuccessful.
  - Exceeds schedule
  - Over budget
  - Lower quality than expected
  - Too difficult to use
  - Performance issues


Failure isn't just a crash; it's the gap between expectation and reality

Ref: https://www.callibrity.com

# Why Software Engineering?

- Catastrophic consequences:
  - Ariane project
  - Radiation overdose


- Root Cause: Not enough robust methods.

# Software Engineering is Balance of Art & Science

- Writing software is both an art and a science.
  - it requires “artistic” craft.
  - and “engineering” rigor.
- Examples of artistic aspects:
  - Using an optimizing compiler as a tool.
  - Adopting a specific sorting algorithm.
- Engineering aspects: Parallels with building a house.

# House Building Analogy

- Stakeholders.
- Phases:
  - Conference/Discussions – Requirements.
  - Blueprints – Design
  - Construction
  - Inspection – Testing
  - Maintenance.
- Handling Change:
  - Materials (libraries) become unavailable.
  - Customers realizing new possibilities as the system takes shape.
  - Budget or schedule shifts forcing requirement changes.
- Context: Built within a larger social and governmental structure.

# Organization of Effort

## People

Project stakeholder

## Product

The software product plus associated documents

## Project

The activities carried out to produce the product

## Process

Framework within which the team carries out the activities necessary to build

# People (1/2)

- Business Management (Senior executives, Product managers) – Focus is on business issues including profit, cost effectiveness, market competitiveness, and customer satisfaction.
- Project Management (Project managers) – Responsible for planning and tracking a project.
- Development Team (Software engineers) – Responsible for developing and maintaining the software. It includes many tasks such as requirements gathering, software architecture and design, implementation, testing, configuration management, and documentation.

# People (2/2)

- Customers (Purchasers of the software) – They may not actually use the product and may be purchasing it for use by others in their organization. Interested in software that is cost-effective, meets speCific business needs, and is of high quality.
- End users (People interacting with the finished product) – Motivated by software that's easy to use and helps them perform their jobs as efficiently as possible.

# Product

- Project documentation – Documents produced during software definition and development.
- Source code.
- Test documents – Plans, cases and results.
- Customer documentation – Documents explaining how to use and operate product.
- Productivity measurements – Analyze project productivity.

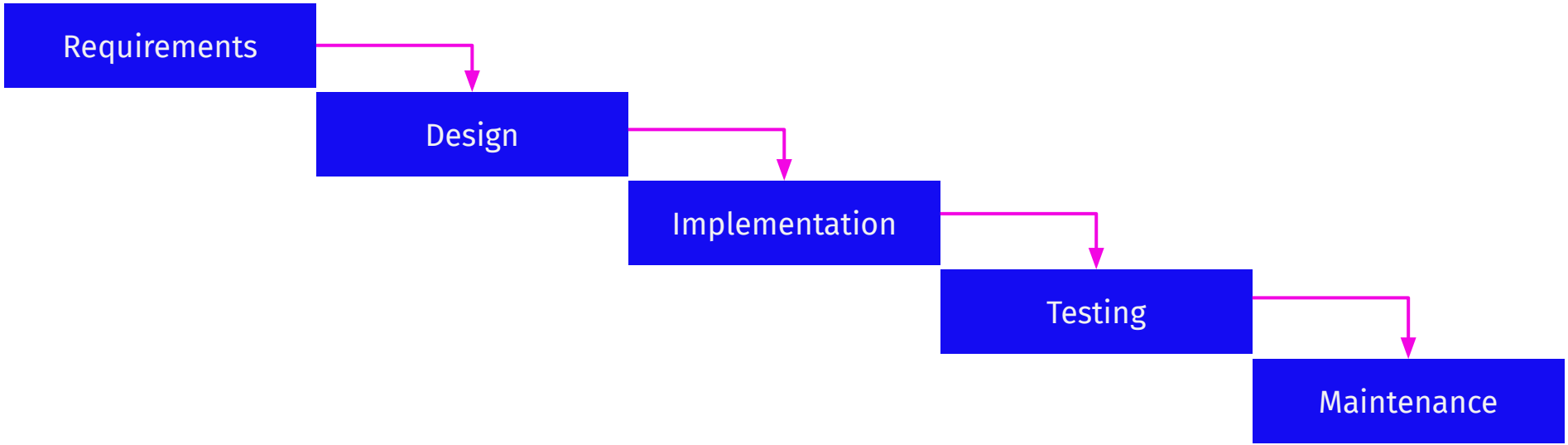
# Project

- Planning – Plan, monitor, & control the software project.
- Requirement analysis – Define what to build.
- Design – Describe how to build.
- Implementation – Write code.
- Testing – Validate the software meets the requirement.
- Maintenance – Resolve errors, add new features to meet new requirements.

# Process (1/2)

- Framework for discipline.
- Guiding structure.
- Time-bound phases.
- Process definitions.

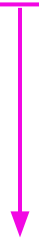
# Process (2/2)




Example: Waterfall software development process

# View as a Software Engineer

We can concentrate on the computers and programming languages, OR we can view them as tools to be used in designing and implementing a solution to a problem.

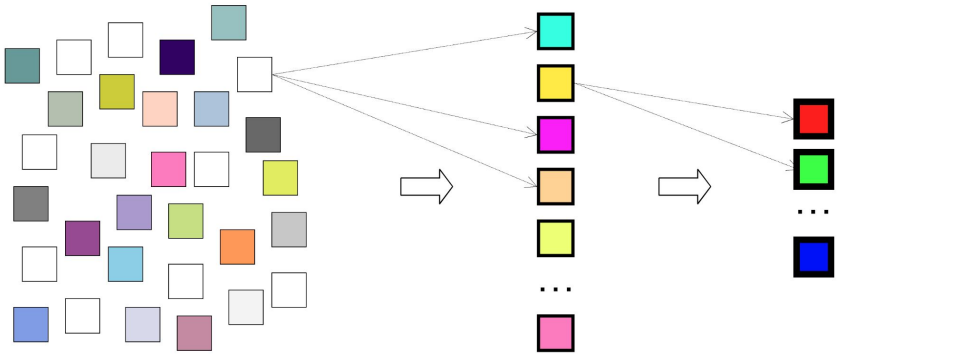


Software Engineer

# Introduction to OCaml

# Programming Paradigm

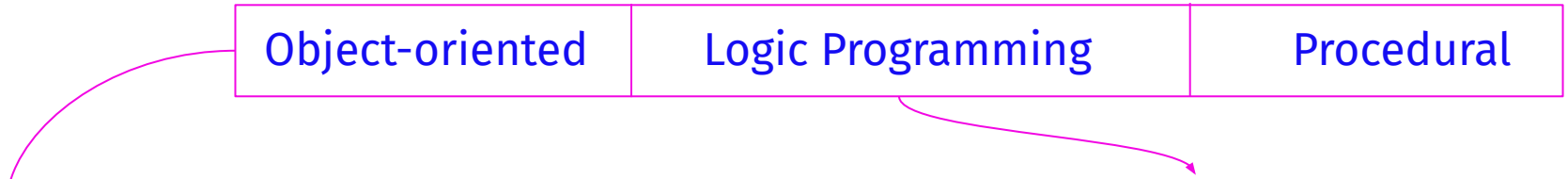
A programming paradigm is an approach to programming a computer based on a mathematical theory or a coherent set of principles.




Ref: Programming Paradigms by Peter Van Roy

# Programming Paradigm

Each paradigm supports a set of concepts that makes it the best for a certain kind of problem.




Best for problems with a large number of related data abstractions organized in a hierarchy.

Best for transforming or navigating complex symbolic structures according to logical rules.

# Functional Programming

- Functional Programming (FP) is a programming paradigm where computation is expressed as the evaluation of mathematical functions, emphasizing immutability and minimizing side effects and changing state.
- I have two functions $f(x)$ and $g(x)$ where the $f(x)$ uses the results computed by $g(x)$. How do I compose?
  Mathematically:
  $result = f(g(x))$
- Functional programming is about building such pipelines.

# Functional Style in C

```c
#include <stdio.h>

int g(int x)
{
   return x * 2;
}

int f(int x)
{
   return x + 5;
}
```

```c
typedef int (*int_func)(int);

int pipeline(int_func outer_function, int_func inner_function, int x)
{
   int inner_result = inner_function(x);
   int final_result = outer_function(inner_result);
   return final_result;
}
```

# Functional Style in C

```c
int main()
{
    int input = 10;
    printf("Input: %d\n", input);

    int result_f_g = pipeline(f, g, input);
    printf("Result: %d\n", result_f_g);

    int result_g_f = pipeline(g, f, input);
    printf("Result: %d\n", result_g_f);

    return 0;
}
```

Benefit: Can compose the function sequence at will

# Side-Effects

```c
#include <stdio.h>

int count = 0;

void add_to_acc(int value) {
    count += value;
}
```

Modifies external state

# Why learn OCaml?

- OCaml is an industrial-strength, statically-typed functional language.
- New programming paradigm.
- Used by industry
  - Jane Street
  - Meta
  - Bloomberg
  - ...
  - Many more

# Hello World!

hello_world.ml🐫

```
let () = print_endline "Hello, World!";;
```

```
(* single line comment *)
(* multiple line comment,
commenting out part
of a program *)
```

A built-in function

Bind values

```
> ocaml
OCaml version 5.3.0
> ocamlc -o hello_world hello_world.ml
> ./hello_world
Hello, World!
```

# Expressions

- Everything has a value & every value has a type.
- OCaml has type inference. For most parts, it can automatically determine type of an expression.

```
10 * 5;;

let student = "Ashoka";;
```

```
- : int = 50
val student : string = "Ashoka"
```

value declaration

# if then else

- This is an expression unlike if-else in C/C++ where it is a statement.
- It always produces a value.
- Both branches must return the same type.
- It can be used anywhere an expression is allowed.

```
2 * if "one" = "two" then 3 else 4;;
```

```
- : int = 8
```

🤔Any similar expression in C/C++?

- Specifies where to go next or what action to perform?
- It does not evaluate to a value and an if block can't be assigned to a variable.

# Data Types

```
let house_number = 71;;
let lakh = 1_00_000;;

let pi = 4.0 *. atan 1.0;;

(1 < 2) = false;;

'a';;

"Hello" ^ " " ^ "world";;
```

int → 64-bit platforms range is $-2^{62}$ to $2^{62}$ -1. Why 63 bits? One bit is used by OCaml runtime implementation.

float → approximate representation. What does adding 0.1 and 0.2 produce?

bool → IEEE 754 standard. 53 bits of mantissa & exponent ranges -1022 to 1023

char → represented as 8-bit integers between 0 and 255

string → ^ is string concat operator

# Try Out

- Evaluate `max_int`
- Evaluate `min_int`
- Evaluate `max_int + 1`

# Local Definitions

```
let y = 50 in y * y;;
y;;
```


- This creates a binding for `y` only in the expression following the `in` keyword. It throws an error in the global scope as can be seen from the last line of the above code block.
- `let __ = __ in __` is an expression, and it can be used within another expression in order to have several values with their own names.

```
let a = 1 in
let b = 2 in
   a + b;;
```

# Type Conversions

```
int_of_char '\n';;

float_of_int 2;;

"Hello".[1];;
```

```
- : int = 10
- : float = 2.
- : char = 'e'
```

- float_of_int
- int_of_float
- int_of_char
- char_of_int
- string_of_int
- string_of_float
- string_of_bool
- bool_of_string
- int_of_string
- float_of_string

# Data Types

- Predefined data structures include `tuples`, `arrays`, `lists`
- `list`
  - empty list are called *nil* and represented by `[]`
  - the `::` operator is used to add elements in front of the list
  - all elements must be of same type
  - lists are immutable

```
let lst = ["one"; "two"; "three"];;
"zero" :: lst;;
let e = [];;
```

type variable, meaning it can be a list of any type

```
val lst : string list = ["one"; "two"; "three"]
- : string list = ["zero"; "one"; "two"; "three"]
val e : 'a list = []
```

# Data Types

- `tuple`
  - Tuples are fixed-length collections of elements of any type. Written as `(1, 2, 3)` or `(1, "two", 'T')`
- `array`
  - Arrays are mutable, fixed-size block of memory.
  - all elements must be of same type.

```
let nums = [| 1; 2; 3 |];;
nums.(1) <- 200;;
nums;;
```

```
val nums : int array = [|1; 2; 3|]
- : unit = ()
- : int array = [|1; 200; 3|]
```

# This is the end