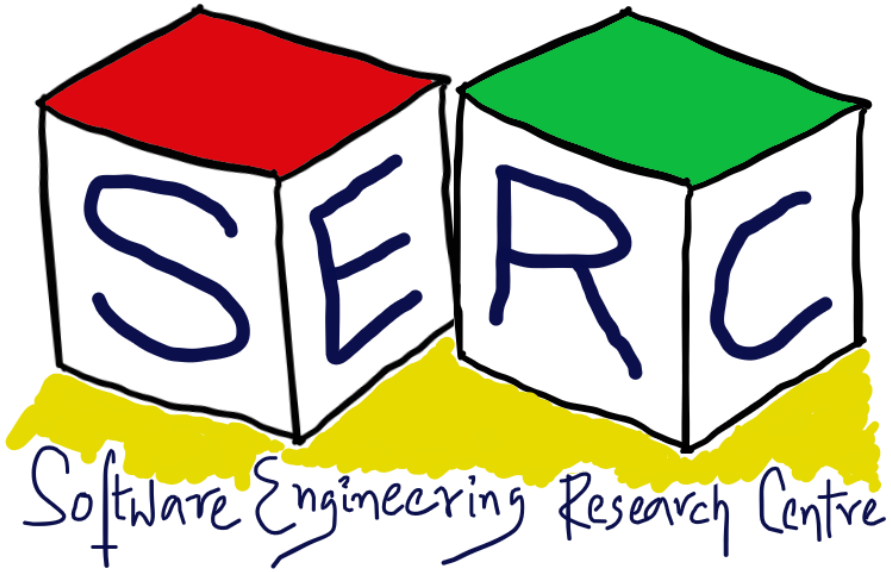
Introduction and Course Overview

CS6.401 Software Engineering



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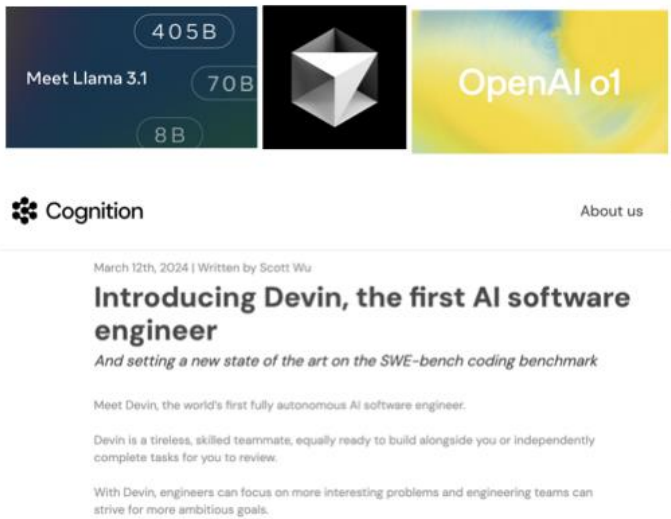
INTERNATIONAL INSTITUTE OF INFORMATION TECHNOLOGY
HYDERABAD

The Evolving Technology Landscape



GenAI Everywhere!!

Digital Twins with 5G, AR/VR/XR

AI Coming to the Edge!

Increasing concern over Sustainability

https://www.roadtovr.com
https://www.apple.com/in

Software-driven World

Everything is increasingly powered by Software!

Smart bottles, watches

Hugging Face

AI/GenAI platforms

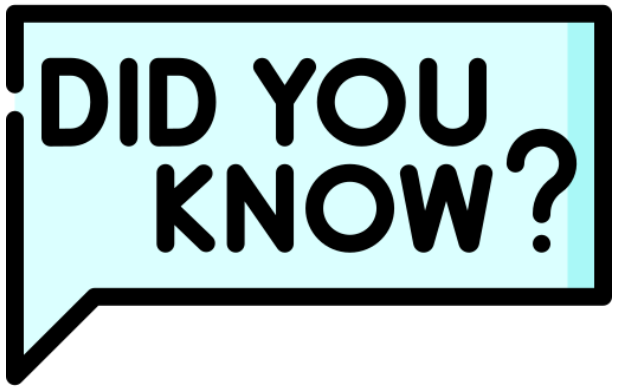
Boston Dynamics

Tesla Car in Autopilot mode

Source: Google images, tesla, openai

Some Interesting yet Serious Facts

1. About **70%** of the cost goes for software maintainence
2. Modern car runs **100 million** lines of code - Smartphone on wheels!
3. Single autonomous car can generate up to **4TB of data** per day!
4. By end of 2025, we will have **30 billion** connected IoT devices
5. **> 50%** of the ML systems considered failures in production
6. Software emissions are equivalent to air, rail and shipping combined!!
7. ……



Sources: Gartner, Cisco

What is the big deal?

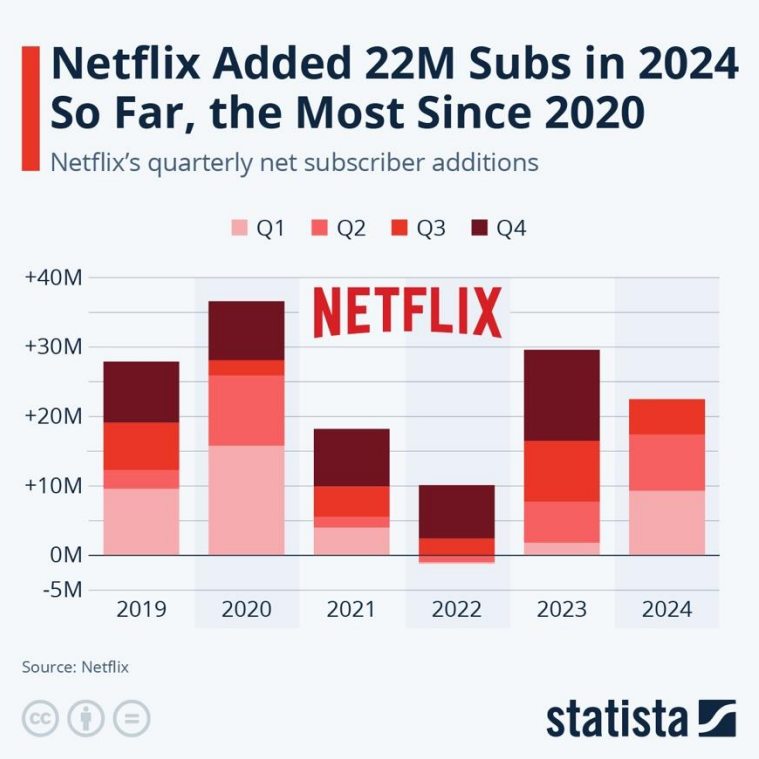
Let’s draw some parallels

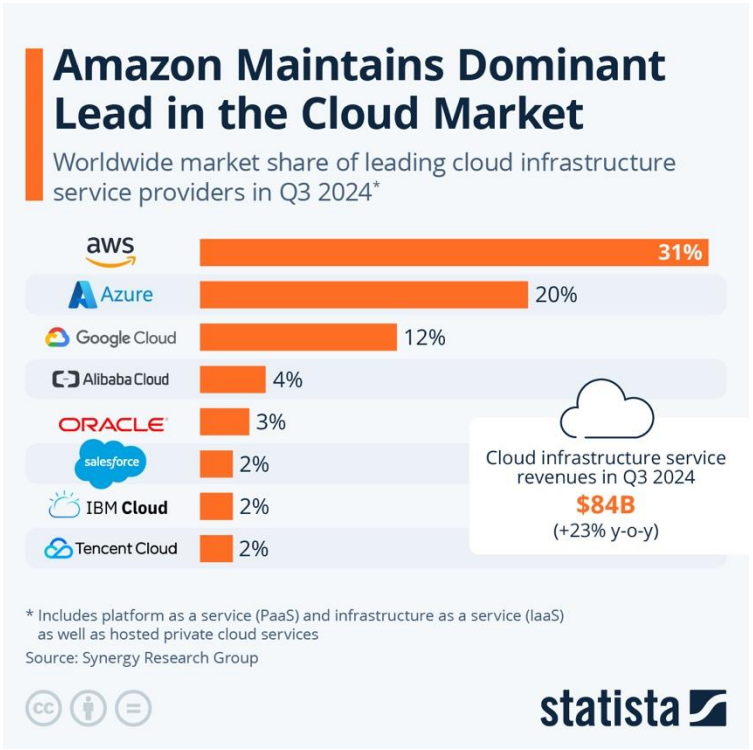
When do you say something is well engineered?

Functionality + Performance, Scale, Maintainability,.....

How Disney+ Hotstar managed its historic 5.9 crore concurrent viewership during WC finals

Mukund Acharya, Head of Technology, Disney+Hotstar, in an exclusive interview, revealed the tech behind Disney+ Hotstar's benchmark achievement during the ICC World Cup 2023.





Source: Googe images, Indianexpress, statista

Is Software that Critical?

Your PC ran into a problem and needs to restart. We're just collecting some error info, and then we'll restart for you.

20% complete

For more information about this issue and possible fixes, visit https://www.windows.com/stopcode

If you call a support person, give them this info:

Stop code: CRITICAL_PROCESS_DIED

CrowdStrike issue – The consequences

- 8.5 million devices affected! - 1% of the entire windows users
- Airlines - Delta, KLM, Ryanair, Lufthansa,. Many passengers were stranded in airports
- Financial organisations - London stock exchange, Visa, …
- Healthcare - independent pharmacies and GP surgeries
- Media, retail, train operating companies…….

Economic and social impact!!!

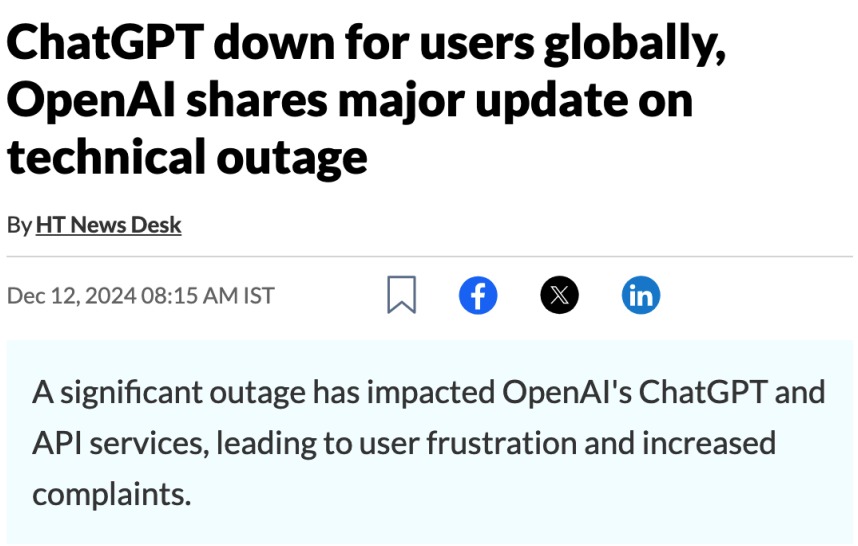
Few of the many software issues

TECH \ AMAZON \

Amazon Web Services says overwhelmed network devices triggered outage

Amazon says it plans to improve its response to outages

By Emma Roth | Dec 11, 2021, 3:34pm EST

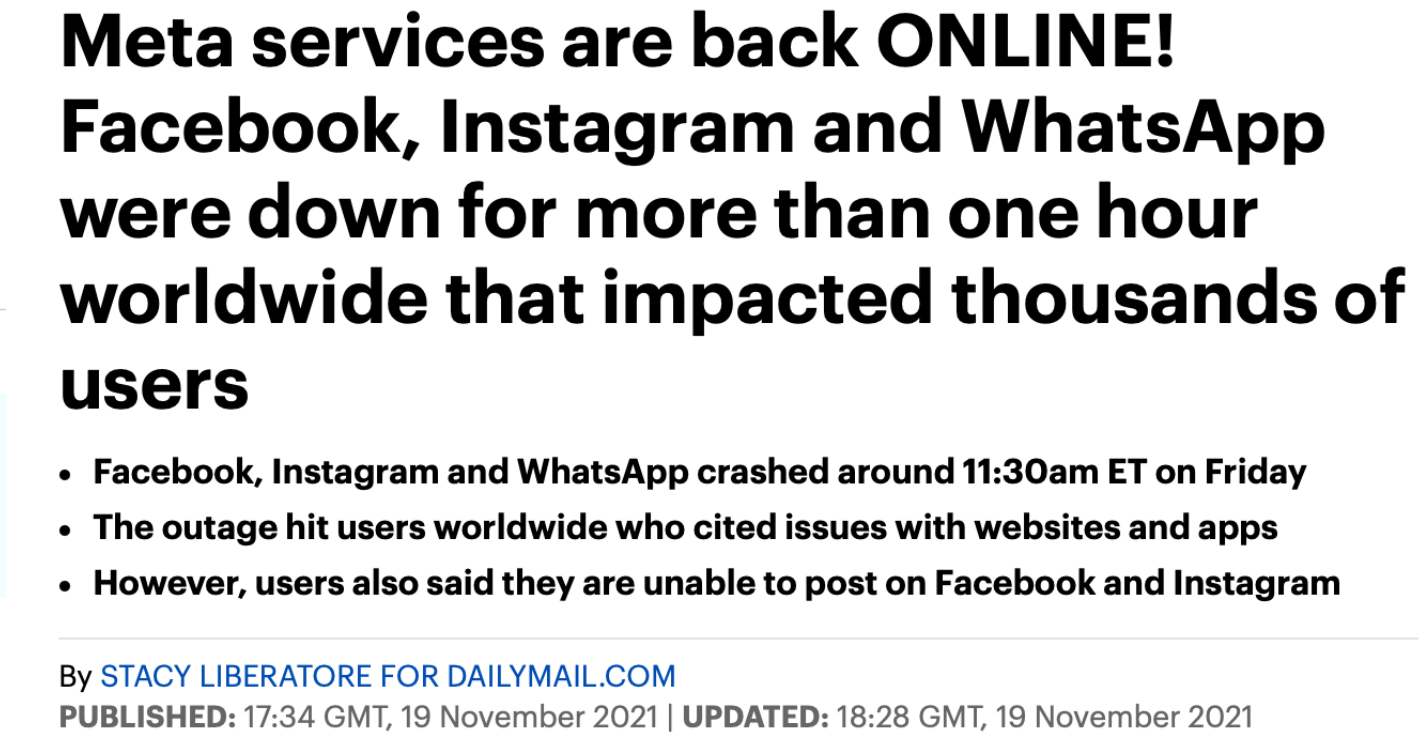


ChatGPT down for users globally, OpenAI shares major update on technical outage

By HT News Desk

Dec 12, 2024 08:15 AM IST

A significant outage has impacted OpenAI's ChatGPT and API services, leading to user frustration and increased complaints.



Meta services are back ONLINE! Facebook, Instagram and WhatsApp were down for more than one hour worldwide that impacted thousands of users

- **Facebook, Instagram and WhatsApp crashed around 11:30am ET on Friday**
- **The outage hit users worldwide who cited issues with websites and apps**
- **However, users also said they are unable to post on Facebook and Instagram**

By STACY LIBERATORE FOR DAILYMAIL.COM

PUBLISHED: 17:34 GMT, 19 November 2021 | **UPDATED:** 18:28 GMT, 19 November 2021

Huge economical impact!!

Source: dailymail, google news

Few of the many software issues

IT failures causing patient deaths, says NHS safety body

19 December 2023

Share Save

Sharon Barbour, Nat Wright and Philippa Roxby
BBC News

Catastrophic software errors doomed Boeing's airplanes and nearly destroyed its NASA spaceship. Experts blame the leadership's 'lack of engineering culture.'

MORGAN MCFALL-JOHNSEN | FEB 29, 2020, 18:41 IST

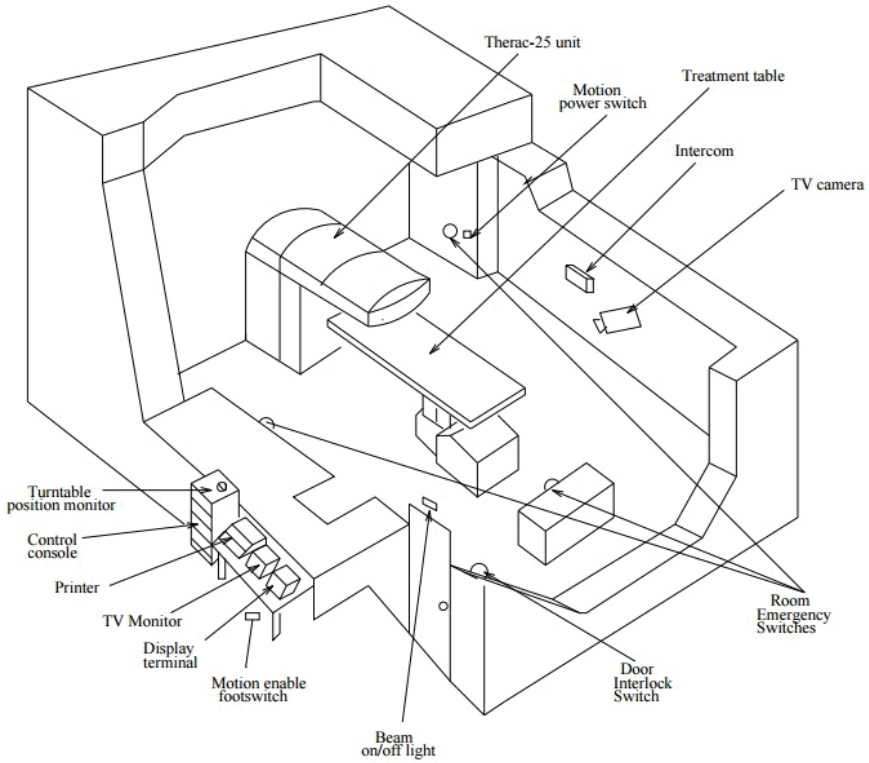


Figure 5: A typical Therac-25 facility after the final CAP.

Can be fatal!!

Source: Googe images, semantic scholar

Why Software Engineering?

Why Study Software Engineering?

- Acquire skills to understand and build high quality software systems
  - Systems could be large and complex - millions of lines of code
  - How to comprehend an existing system?
  - How to break a program into smaller and manageable parts?
  - Development of large and complex software requires teamwork
  - Achieve sufficient quality (eg: maintainability, performance, reliability etc.)
- Learn techniques: specification, designing, development, testing, project management, etc.

Its still a **young discipline –** The term “software engineering” was just coined in 1968

Source: Googe images

Software Engineer is not just another title

- Software engineer is considered as just another role sometimes
- Many countries require software engineers to go through a certification or licensing process
- Going forward software engineers will be dealing with more and more critical systems
- Software for critical systems need to go through certification process

Licensing is already in place in some countries for some specific SE roles!!

Licensing Professional Software Engineers: Seize the Opportunity

By Phillip A. Laplante
Communications of the ACM, July 2014, Vol. 57 No. 7, Pages 38-40
10.1145/2618111
Comments (1)

VIEW AS: SHARE:

In his July 2013 *Communications* column, ACM President Vint Cerf revisited the controversy of licensing professional software engineers in the U.S. This issue has been one that divides the profession since reasonable cases can be made both pro and con. Officially, ACM has opposed and IEEE has supported such licensure. Even within both organizations, though, there is substantial support and opposition.[1,2,3,5] I think President Cerf was right in suggesting that, because of the dramatic growth in interacting software in both devices and in applications that significantly impact peoples' lives, and more importantly, because licensing is happening, we have reached a tipping point.

Source: Googe images, c-ACM

Don’t worry we have SE course!!

What probably you have done so far?

- **IIIT Undergrad:** Introduction to software systems (ISS), low level OO principles and some high-level design in Design and Analysis of Software Systems (DASS)

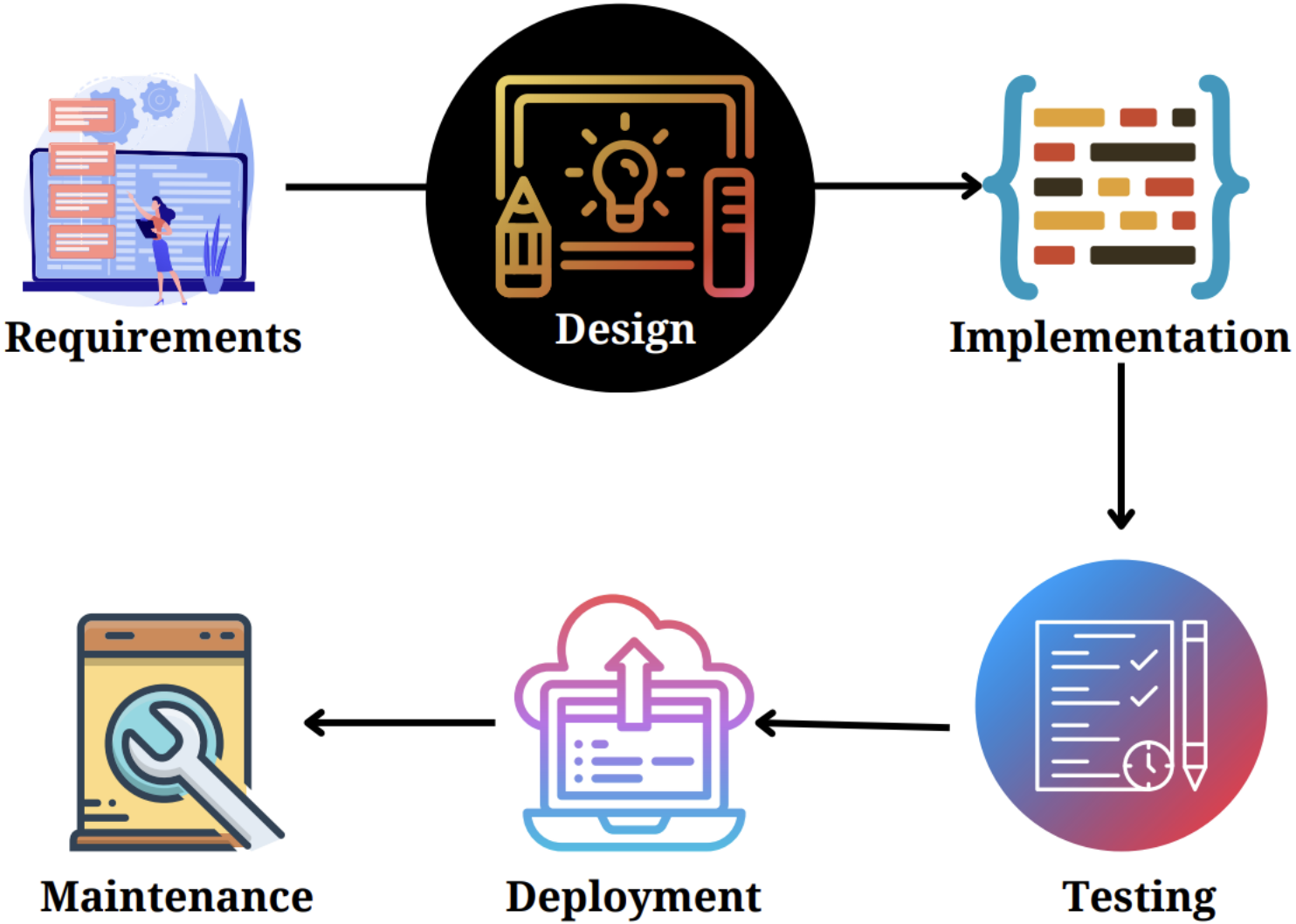
- **Grads at IIIT:** Problem solving course and Software Systems Development

- **Others:** Some software development experience or an undergrad course in software/systems engineering or similar courses

Minimum Prerequisites

1. Basic idea on: Abstraction, Modularization/Decomposition, Coupling, Cohesion, etc.
2. Some programming language(s) (eg:, python, JS etc.)
3. Basic OO principles and implementations: Encapsulation, inheritance, Polymorphism
4. At least 1 OOP language, & 1 RDBMS.
5. Idea about various phases in SDLC
6. Minimal knowledge of practices: Version control, bug tracking, task management, etc.

Software Development Lifecycle



This course is about Software Design!

Lets take an Example Scenario

Assume that you have been appointed to XYZ.com which is an e-commerce company. You have been asked to develop the authentication feature for the e-commerce system.

It can be broken down to something like this!

Write a simple program that takes two strings, inputString1 and inputString2 as inputs and compares them with userName and password respectively. If the strings match, then output should be True, else False

Sample input

user password

Sample Output

True

This is a simple string match program!!!

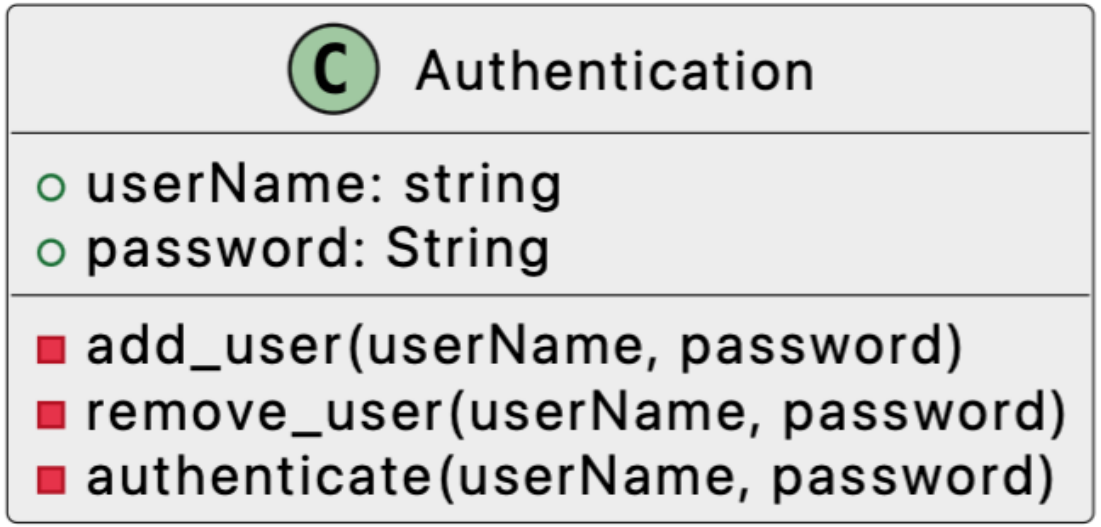
```
boolean compare(inputString1, inputString2)
{
.......
}
```

Not at this level!!

What kind of design? - Lets' go little more higher

Modify the above into an authentication module. You should be able to add two new strings (username, password) and the program should be able to find a match given two strings.

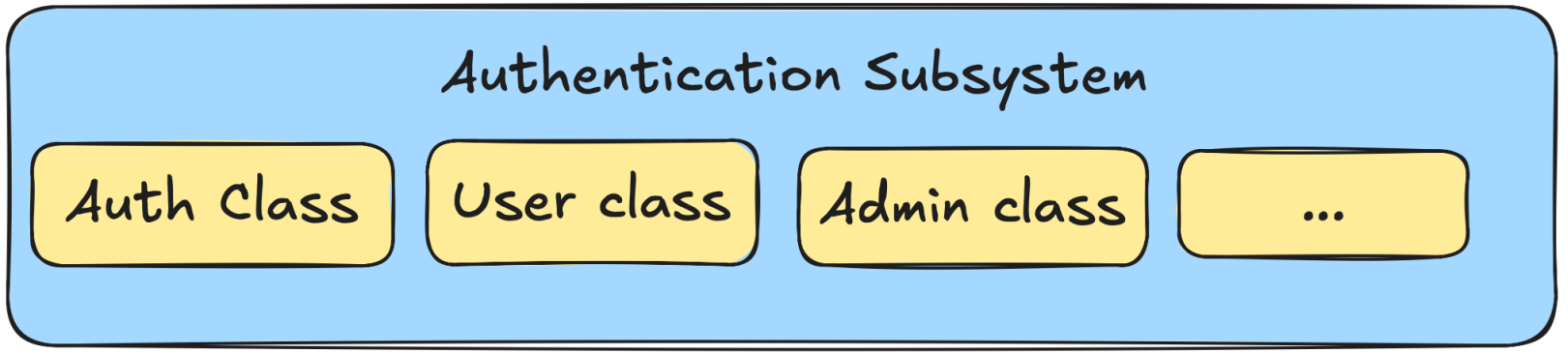
Little at this level!!



What kind of design? - Lets' go little more higher

Modify the above into an authentication subsystem. Any user should be able to register and login. The system should support multiple types of user

Yes, this level!!



What kind of design? - Lets' go even further higher

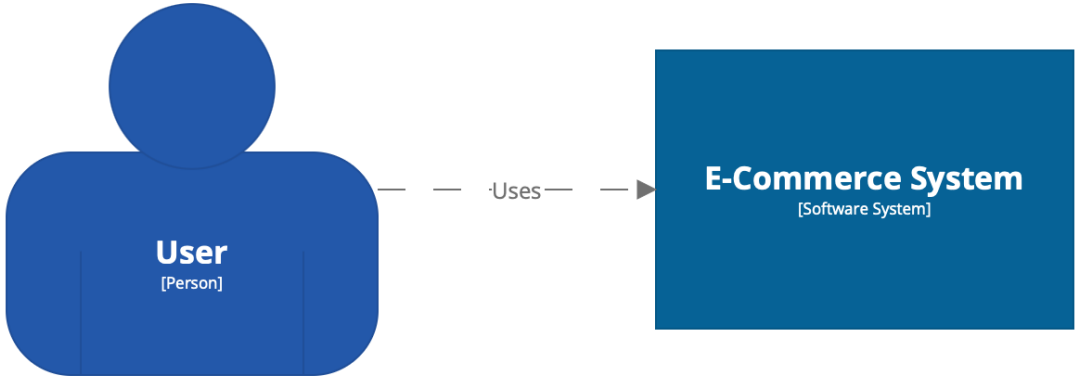
Assume that there is another sub system that allows users to add payment information and make payments. Now, integrate this with the authentication system.

Yes, this level!!

[Container] E-Commerce System
Thursday 2 January, 2025 at 9:28 PM India Standard Time

What kind of design? - Lets' go even further higher

What is the highest level of abstraction we can go into



[System Context] E-Commerce System
Thursday 2 January, 2025 at 9:29 PM India Standard Time

Yes, starting from this level!!

What all needs to be considered? – scalability, performance, reliability,....

Why Design is important?

- It is like technical kernel of Software engineering
- Ensures traceability between requirements and final product
- Allows to have a complete picture of the software before construction
- Allows to discuss, confirm, reason and perform different analysis even before development - **why?**

Source: google images

*"Software is **not limited by physics**, like buildings are. It is **limited by imagination**, **by design**, by organization. In short, it is limited by properties of people, not by properties of the world. We have **met the enemy, and he is us**"*

Ralph Jhonson

Martin Fowler, ***Who needs an Architect?*** IEEE Software, 2003

Source: Googe images

SE - Major Principles

Abstraction

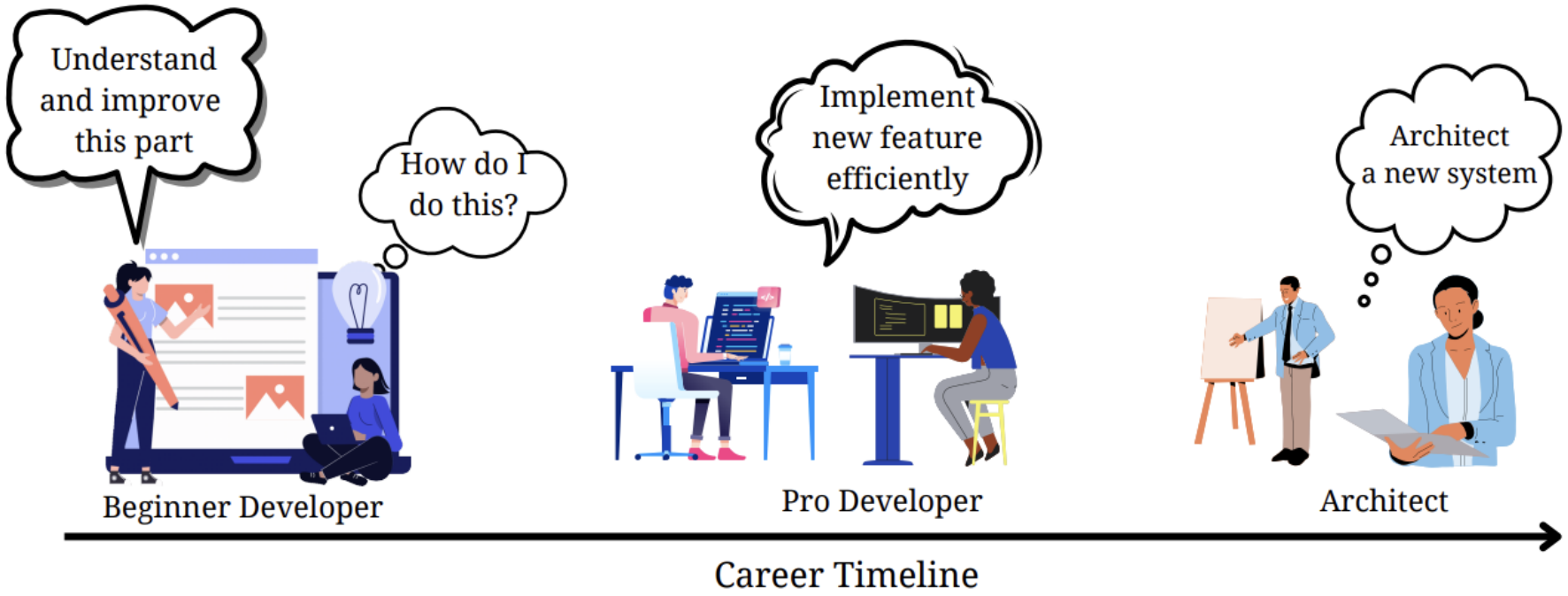
1. Focus on the relevant parts of the problem
2. Helps simplifying the problem and look at a larger picture

Decomposition

1. Decompose problem into small and independent pieces
2. Each pieces can be solved separately
3. The overall solution can be attained by solving smaller pieces and putting them together

What will you learn?

Course Outline



This Course

Modeling	Design Principles	Architectural Framework
Refactoring	Design Patterns	Architectural Patterns

Course Outline

How to comprehend existing software subsystems?

- Applying principles of refactoring

How to design software systems through abstractions and decompositions?

- Design Patterns and Architectural Patterns

How to apply them to your application?

- Deal with subsystems at higher level of abstraction provided by patterns

What if there is no exact match for a given problem?

- Evaluate alternatives and analyze trade-offs

How to capture and document the design decisions?

- Both at low level and high level

Across the above, if and how GenAI can really help

GenAI can be an aid – Lot of changes to come in!

Code generation models

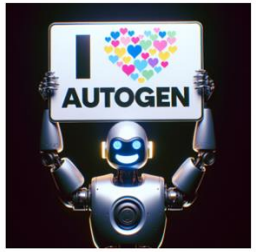
AI Programming Assistants

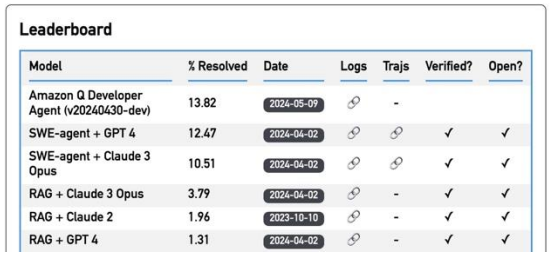
Tools

autocoderover

Vercel v0

Multi-agent frameworks





Leaderboard

Model	% Resolved	Date	Logs	Trajs	Verified?	Open?
Amazon Q Developer Agent (v20240430-dev)	13.82	2024-05-09		-		
SWE-agent + GPT 4	12.47	2024-04-02			✓	✓
SWE-agent + Claude 3 Opus	10.51	2024-04-02			✓	✓
RAG + Claude 3 Opus	3.79	2024-04-02		-	✓	✓
RAG + Claude 2	1.96	2023-10-10		-	✓	✓
RAG + GPT 4	1.31	2024-04-02		-	✓	✓

Leaderboards

Some of our works in GenAI for SE (Design-Centric)

Can LLMs Generate Architectural Design Decisions? - An Exploratory Empirical study

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Vasudeva Varma
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***Abstract*—Architectural Knowledge Management (AKM) involves the organized handling of information related to architectural decisions and design within a project or organization. An essential artefact of AKM is the Architecture Decision Records (ADR), which documents key design decisions. ADRs are documents that capture decision context, decision made and various aspects related to a design decision, thereby promoting transparency, collaboration, and understanding. Despite their benefits, ADR adoption in software development has been slow due to challenges like time constraints and inconsistent uptake. Recent advancements in Large Language Models (LLMs) may help bridge this adoption gap by facilitating ADR generation. However, the effectiveness of LLM for ADR generation or understanding is something that has not been explored. To this end, in this work, we perform an exploratory study which aims to investigate the feasibility of using LLM for the generation of ADRs given the decision context. In our exploratory study, we utilize GPT and T5-based models with 0-shot, few-shot, and fine-tuning approaches to generate the Decision of an ADR given its Context. Our results indicate that in a 0-shot setting, state-of-the-art models such as GPT-4 generate relevant and accurate Design Decisions, although they fall short of human-level performance. Additionally, we observe that more cost-effective models like GPT-3.5 can achieve similar outcomes in a few-shot setting, and smaller models such as Flan-T5 can yield comparable results after fine-tuning. To conclude, this exploratory study suggests that LLM can generate Design Decisions, but further research is required to attain human-level generation and establish standardized widespread adoption.**

***Index Terms*—ADR, LLM**

I. Introduction

been a crucial reason restricting a wider adoption of AKM approaches, and more research is needed for automatically capturing this knowledge [3].

An *Architecture Decision Record (ADR)* is a crucial part of AKM. It entails the idea that software architecture is considered a set of Design Decisions [4]. It is a document used in software development to capture and document important *Architecture Design Decisions (ADD)*, made during the design and development of a software system. A detail explanation is given in Section II Despite the well-established benefits of ADRs, their adoption has been slow to non-existent as described by Georg *et al.* [5]. Unsuccessful adoption of ADRs in software development can occur due to several factors, including inadequate tool support, effort needed to capture Architecture Knowledge (AK), interruptions to the design process caused by documenting AK, and uncertainty regarding which AK needs documentation. [5].

Large Language models (LLMs) excel in comprehending contexts and generating text accordingly. Over the recent years due to advancement of LLMs, text generation has become more accessible. This paper delves into the exploration of whether LLMs can effectively generate Architectural Decision Records (ADRs). While the prospect of generating entire ADRs from a codebase remains a task for future endeavours, the focus of this work is on utilizing LLMs to generate Design Decisions from decisions Contexts as these are recognized as the core components of an ADR[1].

In the realm of *Natural Language Processing (NLP)*,

LLMs for Generation of Architectural Components: An Exploratory Empirical Study in the Serverless World

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***Abstract*—Recently, the exponential growth in capability and pervasiveness of Large Language Models (LLMs) has led to significant work done in the field of code generation. However, this generation has been limited to code snippets. Going one step further, our desideratum is to automatically generate architectural components. This would not only speed up development time, but would also enable us to eventually completely skip the development phase, moving directly from design decisions to deployment. To this end, we conduct an exploratory study on the capability of LLMs to generate architectural components for Functions as a Service (FaaS), commonly known as serverless functions. The small size of their architectural components make this architectural style amenable for generation using current LLMs compared to other styles like monoliths and microservices. We perform the study by systematically selecting open source serverless repositories, masking a serverless function and utilizing state of the art LLMs provided with varying levels of context information about the overall system to generate the masked function. We evaluate correctness through existing tests present in the repositories and use metrics from the Software Engineering (SE) and Natural Language Processing (NLP) domains to evaluate code quality and the degree of similarity between human and LLM generated code respectively. Along with our findings, we also present a discussion on the path forward for using GenAI in architectural component generation.**

***Index Terms*—Architectural Component Generation, LLM, Serverless.**

Hou et al. [5]. They have been used for software development, maintenance, requirements engineering, and more, with code generation and program repair being the most common applications [5]. There have also been several commercial tools such as ChatGPT, GitHub Copilot, and the Cursor IDE. However, this code generation has been in the context of generating low level code snippets, with the generation of software architecture components using LLMs being an unexplored space.

To this end, we conduct an exploratory empirical study on the capability of LLMs to generate architectural components in the context of Functions-as-a-Service (FaaS), commonly referred to as serverless functions. FaaS supports event-driven architectural style and enables easy development due to the abstractions provided by the cloud provider, who manages the infrastructure for running the basic units of FaaS, called serverless functions. We choose serverless functions primarily due to the small size of their architectural component, as opposed to microservices or monoliths, where a single component may consist of thousands or even millions of lines of code. We believe that this can provide a first step when evaluating the architectural component generation capabilities of LLMs. We emphasize that the architectural components we

Discussions during SE course last year resulted in something!

Reimagining Self-Adaptation in the Age of Large Language Models

Raghav Donakanti, Prakhar Jain, Shubham Kulkarni, Karthik Vaidhyanathan
Software Engineering Research Center, *IIIT Hyderabad*, India
raghav.donakanti@students.iiit.ac.in, prakhar.jain@research.iiit.ac.in, shubham.kulkarni@research.iiit.ac.in,
karthik.vaidhyanathan@iiit.ac.in

***Abstract*—Modern software systems are subjected to various types of uncertainties arising from context, environment, etc. To this end, self-adaptation techniques have been sought out as potential solutions. Although recent advances in self-adaptation through the use of ML techniques have demonstrated promising results, the capabilities are limited by constraints imposed by the ML techniques, such as the need for training samples, the ability to generalize, etc. Recent advancements in Generative AI (GenAI) open up new possibilities as it is trained on massive amounts of data, potentially enabling the interpretation of uncertainties and synthesis of adaptation strategies. In this context, this paper presents a vision for using GenAI, particularly Large Language Models (LLMs), to enhance the effectiveness and efficiency of architectural adaptation. Drawing parallels with human operators, we propose that LLMs can autonomously generate similar, context-sensitive adaptation strategies through its advanced natural language processing capabilities. This method allows software systems to understand their operational state and implement adaptations that align with their architectural requirements and environmental changes. By integrating LLMs into the self-adaptive system architecture, we facilitate nuanced decision-making that mirrors human-like adaptive reasoning. A case study with the SWIM exemplar system provides promising results, indicating that LLMs can potentially handle different adaptation scenarios. Our findings suggest that GenAI has significant potential to improve software systems' dynamic adaptability and resilience.**

***Index Terms*—Self-Adaptation, Software Architecture, Generative AI, LLM, Software Engineering**

The concept of autonomic computing, as proposed by Kephart and Chess [5], sought to enhance the autonomy of software systems through various strategies. Despite these efforts, a persistent challenge has been the ability of systems to dynamically generate new configurations and components. The advent of GenAI, particularly the capabilities of LLMs, introduces the possibility of developing adaptation strategies directly. This is supplemented by the fact that modern software systems generate vast amounts of data, including logs, metrics, and traces, which system administrators traditionally leverage for tasks such as root cause analysis and resource allocation. This data, encompassing code, APIs, JSON, XML, and more, can be converted into various natural language formats, enabling Large Language Models (LLMs) to interpret the data and generate adaptive responses akin to those formulated by human experts. To this end, this paper introduces an innovative framework, MSE-K (Monitor, Synthesize, Execute) that integrates Large Language Models (LLMs) into the self-adaptation process, enabling software systems to autonomously generate and implement contextually relevant and actionable architectural adaptation strategies aligned with their operational goals. This approach seeks to overcome the limitations of current self-adaptation mechanisms, paving the way for more efficient and intelligent software systems [6].

As an initial validation, we performed evaluations of our

Possibilities are always endless!!

Teaching and Learning Methodology

- Problem based learning methodology

- A blend of conceptual lectures with group/individual activities

- This has been a working formula
  - Learners engage in the materials
  - Hands on activities enables deeper understanding
  - Resembles the true career situation

Start forming the teams!!

Meet the Team

Karthik

Rudra

Meghana

Ronak

Shashwat

Shrikara

Vineeth

Distribution of Grades

Component	Weightage
Final Exam	25%
Mid-term Quiz	15%
Take home/In-class activities	15%
3 Unit Projects (3*15)	45%
Bonus	5%

Note: The instructor reserve the right to make minor changes
No extension requests please – **Extra days and soft deadlines!!**

Course Logistics

- Course announcements, management - moodle
- All resources, information and materials -

https://karthikv1392.github.io/cs6401_se/

- At any point, feel free to contact either the instructor or TA
- Instructor office hours (Thursday 11:00 AM to 12:00 PM)
- Feedbacks are always welcome!!

Thank You

Course website: karthikv1392.github.io/cs6401_se

Email: karthik.vaidhyanathan@iiit.ac.in
Web: https://karthikvaidhyanathan.com