LIBRARY MANAGEMENT SYSTEM

Team 5

Ahmed Yehia (Scrum Master)
Marwan Mohammed
Sama Hatem
Safia Adel

Banque Misr internship 2024 Graduation Project
DevOps Track

Egypt, September 2024

Contents

Table of Figures

Introduction

The **Library Management System** developed by Team 5 during the Banque Misr Internship 2024 aims to streamline library operations by offering an intuitive platform for both administrators and users. The project encapsulates the modern software development lifecycle by integrating core software engineering principles with DevOps practices. From backend application development to containerization, infrastructure management using Infrastructure as Code (IaC), and automated deployments via CI/CD pipelines, this project demonstrates a full stack of contemporary software tools and methodologies. This comprehensive system is designed to support both day-to-day operations of libraries and allow users to conveniently manage their borrowing and return processes.

This project also showcases the team's hands-on experience with cloud services like AWS (Amazon Web Services) and Kubernetes, ensuring scalability, resilience, and security for the application. By leveraging Amazon EKS (Elastic Kubernetes Service), the project enables efficient resource management while maintaining high availability. Additionally, continuous monitoring and logging were implemented using Prometheus and Grafana, facilitating real-time performance tracking and issue resolution.

The following document delves into the system's architecture, deployment process, and technologies used, outlining the steps taken to create a robust, scalable, and user-friendly library management system.

Abstract

This document outlines the development and deployment of a cloud-native **Library Management System**, created as part of the Banque Misr Internship 2024. The project is built using Python Flask for the backend, HTML/CSS/JavaScript for the frontend, and managed via Docker containers. The entire infrastructure is deployed on Amazon Web Services (AWS) using Elastic Kubernetes Service (EKS) for container orchestration. Infrastructure provisioning was automated through Terraform, a widely used Infrastructure as Code (IaC) tool, ensuring the scalability and maintainability of the system.

A key feature of the project is the CI/CD pipeline designed with Jenkins, which automates the building, testing, and deployment of the application. Prometheus and Grafana were also integrated for monitoring and visualization of application metrics. The system supports both administrators, who can manage the book inventory and user roles, and users, who can search, borrow, and return books. The project delivers a scalable, efficient, and user-friendly solution for managing library resources.

Part 1: Application Development

A simple Library Management website was developed with (CSS, HTML, and JavaScript) for the front end and Python Flask for handling the back end. Here is the breakdown of the application features:

1. Users for this application are either admins or users.
2. The application includes basic routes to get a list of books, retrieve a specific book, add a new book to the library(admin), and borrow and return a book (User).
3. Admin Users can add other admins.
4. Both admins and users can search for books either with the ISBN or with a keyword that is the title, author, or ISBN.

Tools Used:

1- Frontend

- **JavaScript**: Used for creating interactive client-side functionality
- **HTML**: Used for structuring and organizing content on the web page
- **CSS**: Used for styling and layout of the web page

2- Backend

- **Python**: Used as the programming language for the backend
- **Flask**: Used as the web framework for building the backend API

3- Database

- **JSON files**: Used as the database storage system, where data is stored in JSON format

User Manual:

Login Page

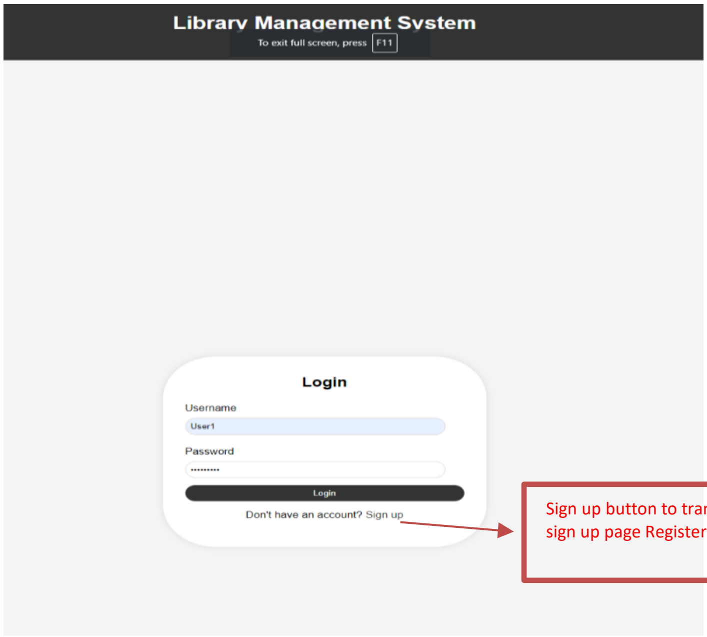
- The user is presented with a login page where they can enter their:
    - **Username**
    - **Password**
- Upon successful login, the system checks the database to determine the user's role.

User Roles

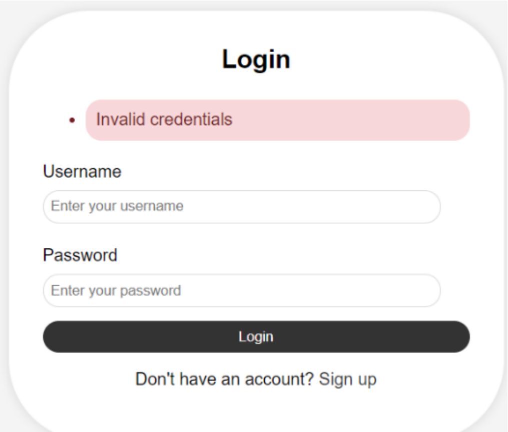
- There are two types of users in the system:
    - **Normal User**: A regular user with limited access and privileges.
    - **Admin User**: An administrator with elevated access and privileges.

Post-Login Redirection

- Once the user's role is determined, the system redirects them to their respective user page:
    - **Normal User**: Redirected to the normal user page with limited features and access.
    - **Admin User**: Redirected to the admin user page with elevated features and access.


Library Management System
To exit full screen, press F11
Login
Username
User1
Password
Login
Don't have an account? Sign up

Sign up button to transfer to sign up page Register new user



- Invalid credentials

Figure 2 Wrong Password Trigger

Figure 1 Login Page

Sign-up Page

- The user is presented with a sign-up page where they can enter their:
  - Username
  - Preferred password
  - Email address
- Upon successful sign-up, the system creates a new account for the user as a **Normal User**.

Default User Role

- All newly created users are assigned the role of **Normal User** by default.

Immediate Access

- The new user can access the system immediately through the **Normal User Page** with limited features and access.

Admin Promotion

- Normal users can be promoted to **Admin Users** by **existing admins** in the system.
- The promotion process is done through other admins in the system, granting the promoted user access to the **Admin Page** and elevated privileges.

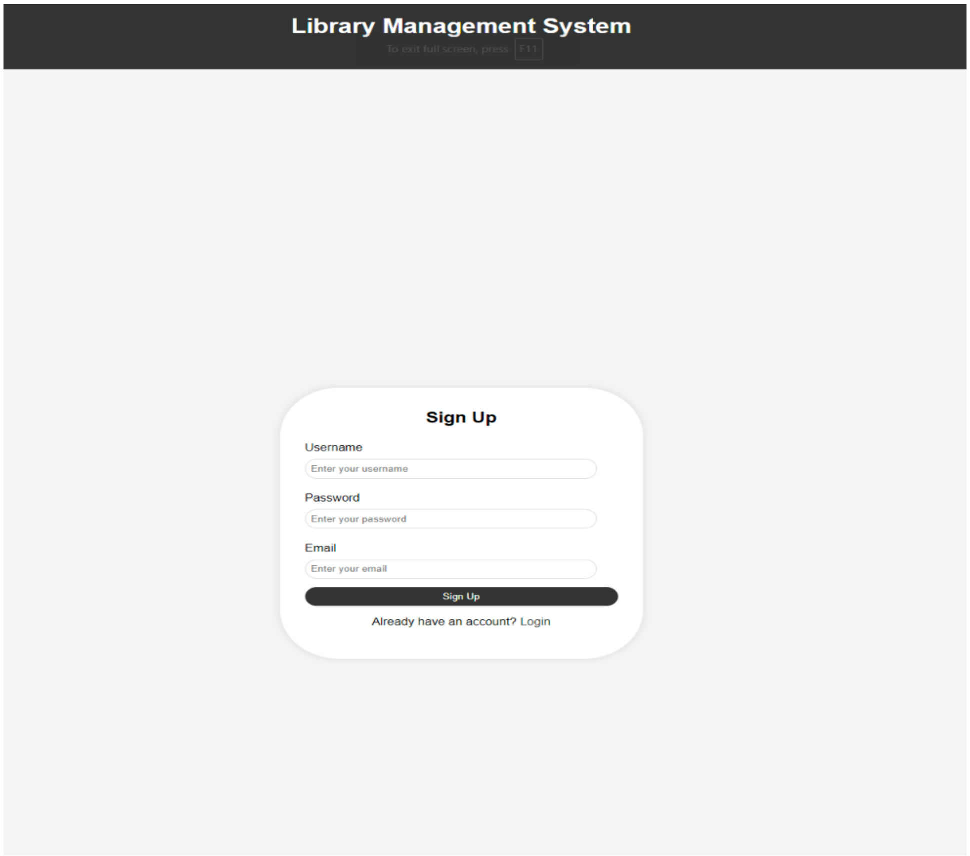


Figure 3 Sign Up Page

Admin User Page

Admin User Functionalities

- Manage books: add, search, view inventory, and remove
- Manage admins: add new admins to the system

- The Admin User Page provides several functionalities to manage the system, including:

Book Management

1- Add Book

- The admin can add a new book to the system by providing the following details:
  - **Book title, Author, Genre, Year**

    Note: The book is assigned automatically from the system to an ISBN that auto increments to each book

2- Search Book

- The admin can search for books using two filtration methods:
  1. **ISBN**: Search by International Standard Book Number (ISBN)
  2. **Keywords**: Search by author name or book title, with the ability to detect parts of the name and search for the rest

3- View Book Inventory

- The admin can view the current book inventory in the system.

4- Remove Book

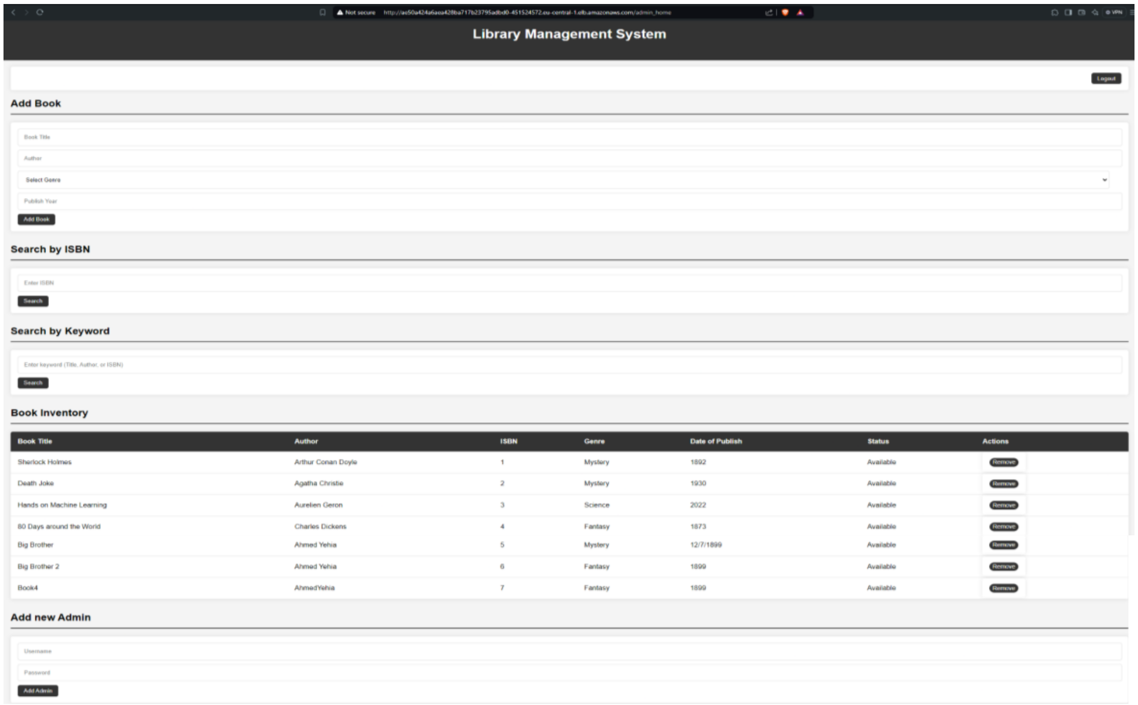
- The admin has the access to remove a book from the system's inventory.

Admin Management

Add New Admin

- The admin can add a new admin to the system by entering the new admin's **Username & Password**

- The new admin will be added to the admins database.



Library Management System

Add Book

Search by ISBN

Search by Keyword

Book Inventory

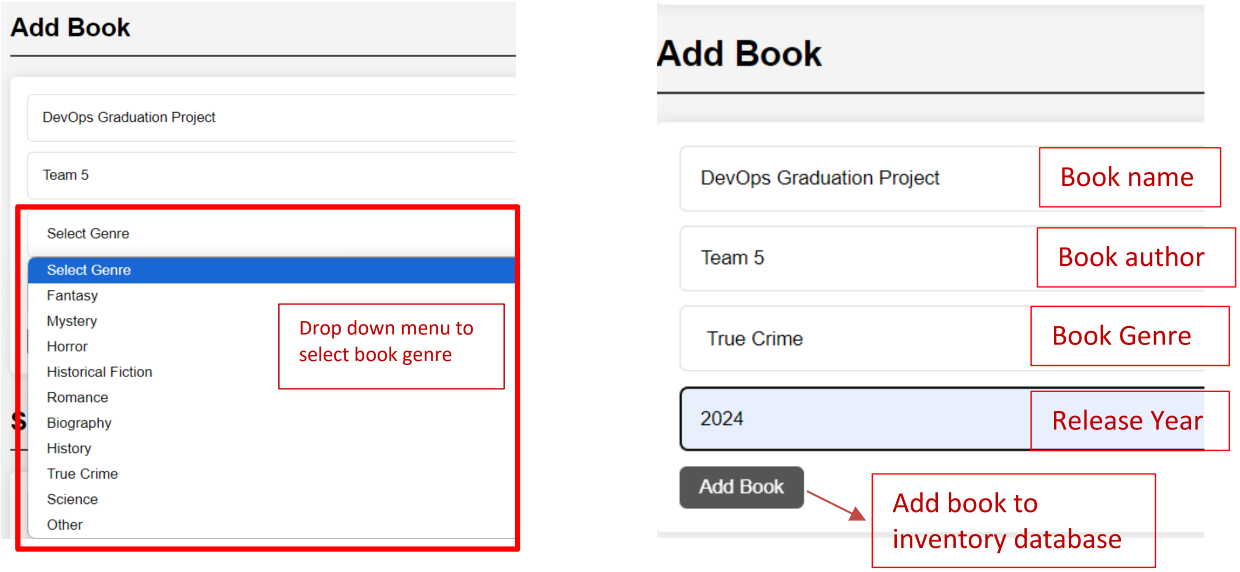
Book Title	Author	ISBN	Genre	Date of Publish	Status	Actions
Sherlock Holmes	Arthur Conan Doyle	1	Mystery	1892	Available	Remove
Death Joke	Agatha Christie	2	Mystery	1930	Available	Remove
Hands on Machine Learning	Aurelien Geron	3	Science	2022	Available	Remove
80 Days around the World	Charles Dickens	4	Fantasy	1873	Available	Remove
Big Brother	Ahmed Yehia	5	Mystery	12/7/1899	Available	Remove
Big Brother 2	Ahmed Yehia	6	Fantasy	1899	Available	Remove
Book4	AhmedYehia	7	Fantasy	1899	Available	Remove

Add new Admin

Not secure http://ae50a424a6aea428ba717b23795adbd0-451524572.eu-central-1.elb.amazonaws.com/admin_home
Logout
Book Title
Author
Select Genre
Publish Year
Add Book
Enter ISBN
Search
Enter keyword (Title, Author, or ISBN)
Search
Username
Password
Add Admin

Figure 4 Admin Page

Adding a book to the inventory



Add Book

DevOps Graduation Project

Team 5

Select Genre

Add Book

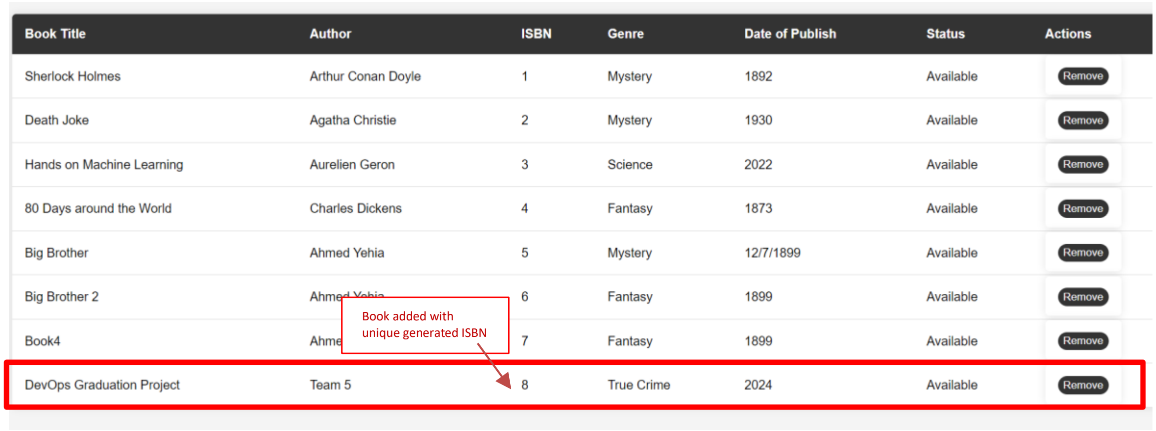
DevOps Graduation Project

Team 5

True Crime

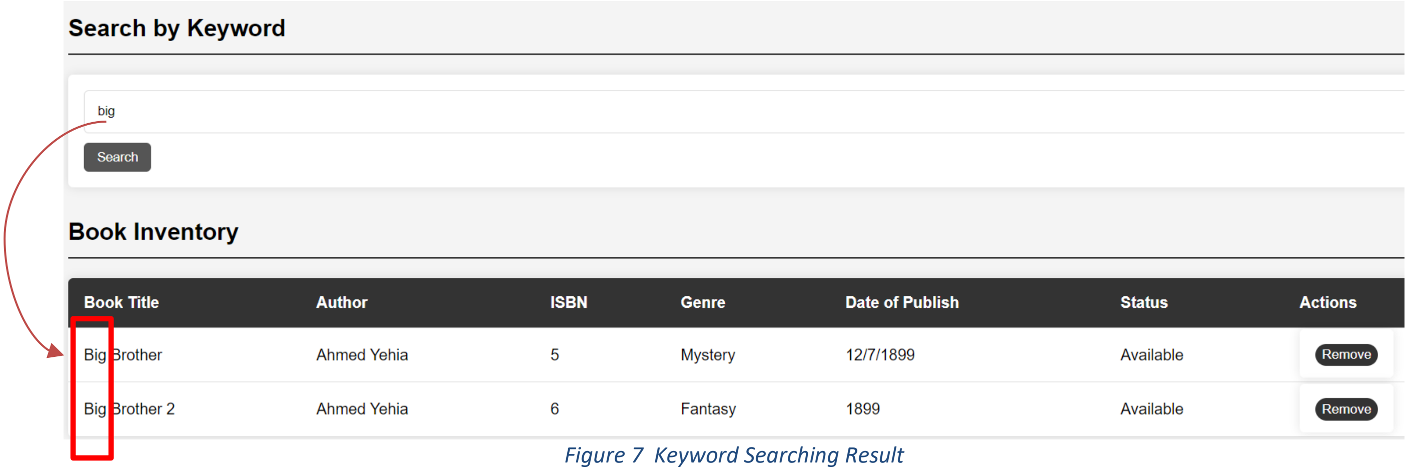
2024

Figure 5 Adding book to the inventory



Book Title	Author	ISBN	Genre	Date of Publish	Status	Actions
Sherlock Holmes	Arthur Conan Doyle	1	Mystery	1892	Available	Remove
Death Joke	Agatha Christie	2	Mystery	1930	Available	Remove
Hands on Machine Learning	Aurelien Geron	3	Science	2022	Available	Remove
80 Days around the World	Charles Dickens	4	Fantasy	1873	Available	Remove
Big Brother	Ahmed Yehia	5	Mystery	12/7/1899	Available	Remove
Big Brother 2	Ahmed Yehia	6	Fantasy	1899	Available	Remove
Book4	Ahme	7	Fantasy	1899	Available	Remove
DevOps Graduation Project	Team 5	8	True Crime	2024	Available	Remove

Figure 6 book added successfully to inventory



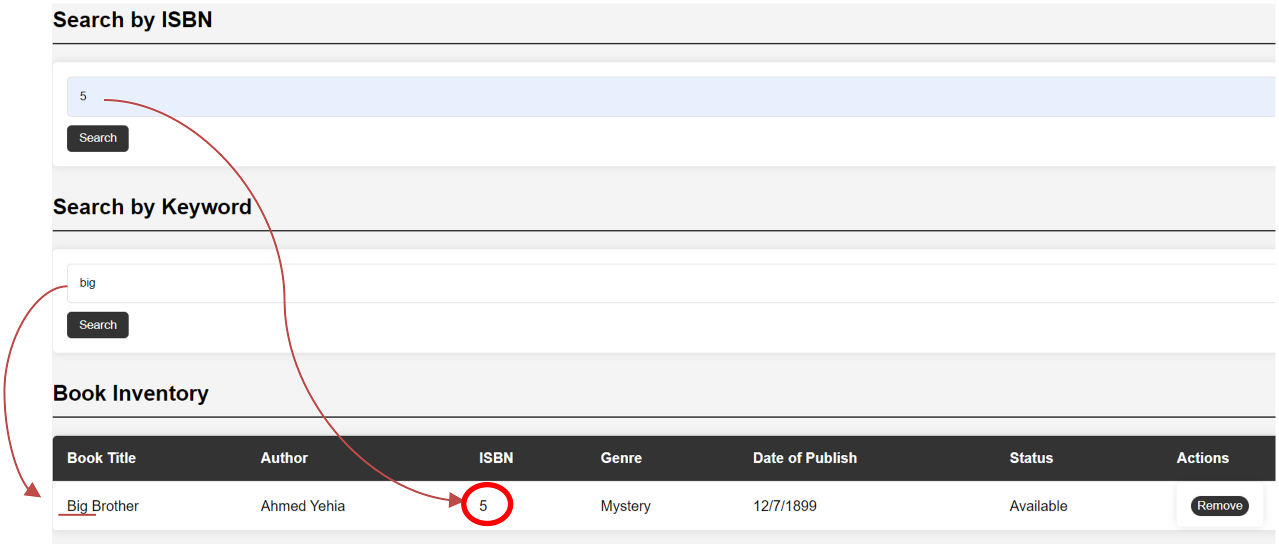
Search by Keyword

big

Book Inventory

Book Title	Author	ISBN	Genre	Date of Publish	Status	Actions
Big Brother	Ahmed Yehia	5	Mystery	12/7/1899	Available	Remove
Big Brother 2	Ahmed Yehia	6	Fantasy	1899	Available	Remove

Figure 7 Keyword Searching Result



Search by ISBN

5

Search

Search by Keyword

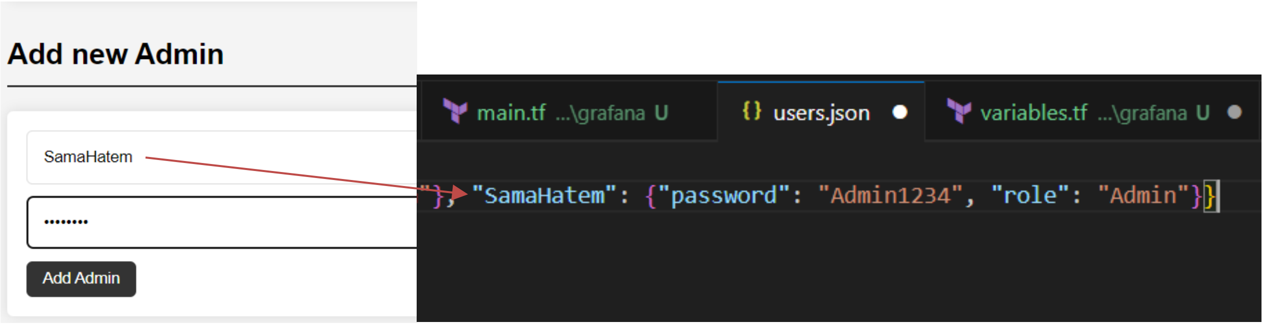
big

Search

Book Inventory

Book Title	Author	ISBN	Genre	Date of Publish	Status	Actions
Big Brother	Ahmed Yehia	5	Mystery	12/7/1899	Available	Remove

Figure 8 Searching Result applying ISBN filter



Add new Admin

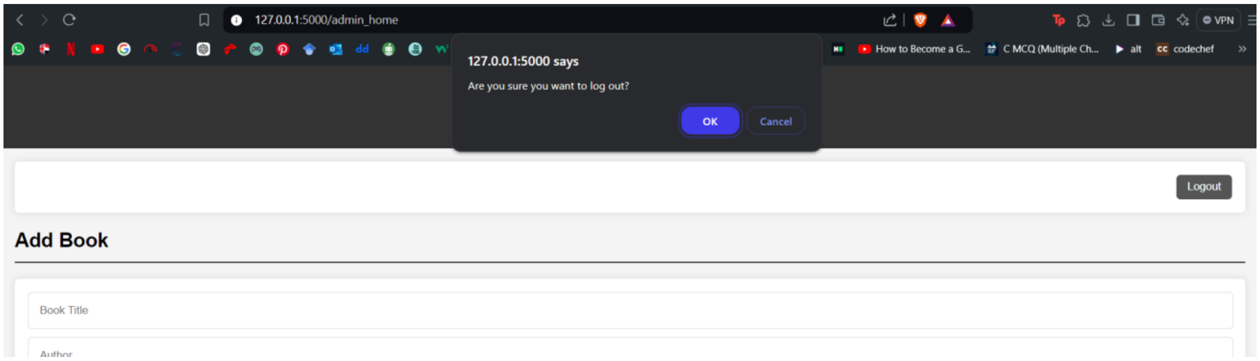
SamaHatem

••••••••

Add Admin

```
"}, "SamaHatem": {"password": "Admin1234", "role": "Admin"}}
```

Figure 9 Adding admin to the system database



127.0.0.1:5000 says

Are you sure you want to log out?

OK Cancel

Logout

Add Book

Book Title

Author

Figure 10 Logout Verification

Normal User Page

- The Normal User Page provides several functionalities to interact with the library system, including:

Library Inventory

- The user can view the current library inventory in the system.

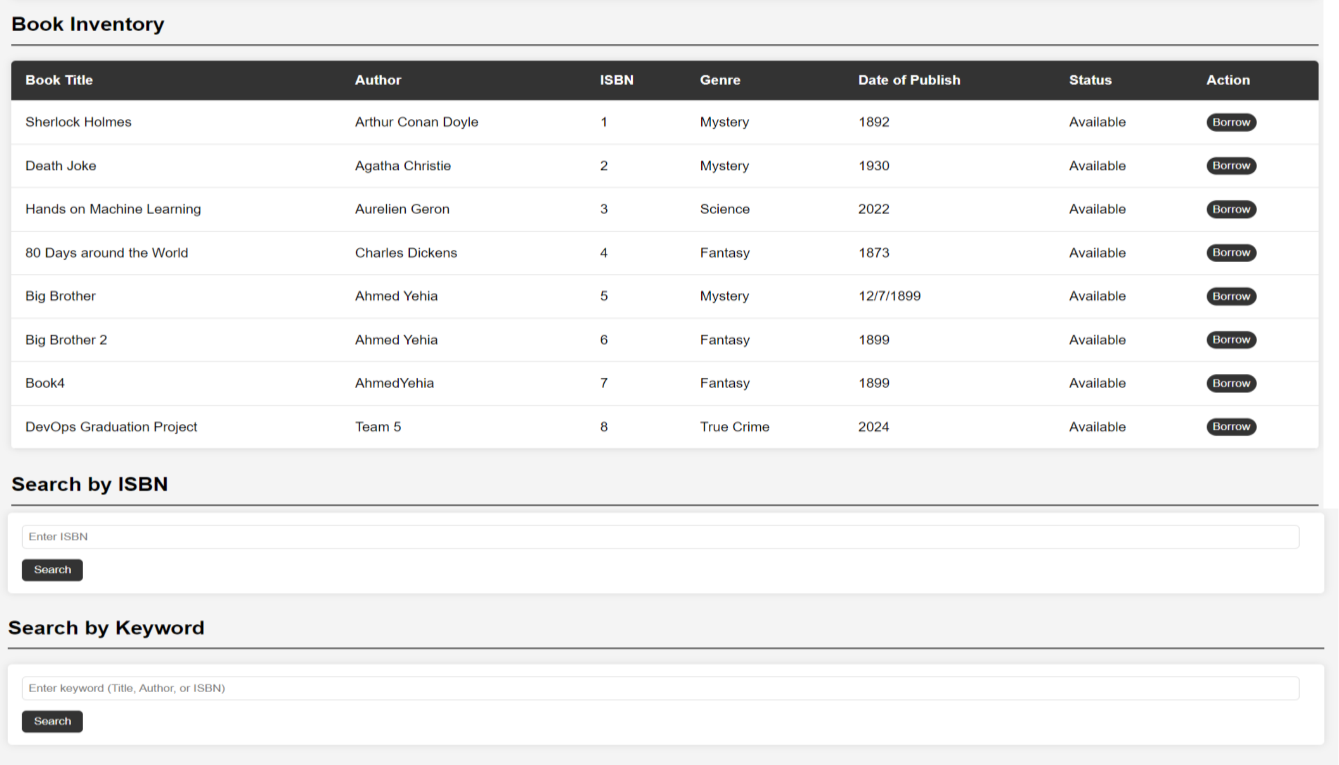
Search Book

- The user can search for books using two filteration methods:

1. ISBN: Search by International Standard Book Number (ISBN)
2. Keywords: Search by author name or book title

Borrow/Return Books

- The user can borrow or return books from the library inventory.
- If a book is borrowed, its status will be updated to reflect this in the Book Status.



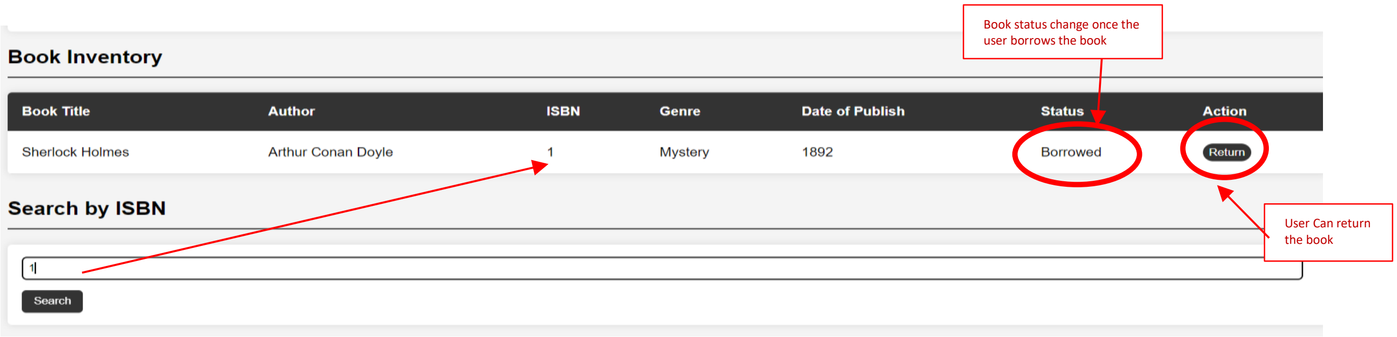
Book Inventory

Book Title	Author	ISBN	Genre	Date of Publish	Status	Action
Sherlock Holmes	Arthur Conan Doyle	1	Mystery	1892	Available	Borrow
Death Joke	Agatha Christie	2	Mystery	1930	Available	Borrow
Hands on Machine Learning	Aurelien Geron	3	Science	2022	Available	Borrow
80 Days around the World	Charles Dickens	4	Fantasy	1873	Available	Borrow
Big Brother	Ahmed Yehia	5	Mystery	12/7/1899	Available	Borrow
Big Brother 2	Ahmed Yehia	6	Fantasy	1899	Available	Borrow
Book4	AhmedYehia	7	Fantasy	1899	Available	Borrow
DevOps Graduation Project	Team 5	8	True Crime	2024	Available	Borrow

Search by ISBN

Search by Keyword

Figure 11 Normal User Page



Book status change once the user borrows the book

Book Inventory

Book Title	Author	ISBN	Genre	Date of Publish	Status	Action
Sherlock Holmes	Arthur Conan Doyle	1	Mystery	1892	Borrowed	Return

Search by ISBN

User Can return the book

Figure 12 Search for a borrowed book

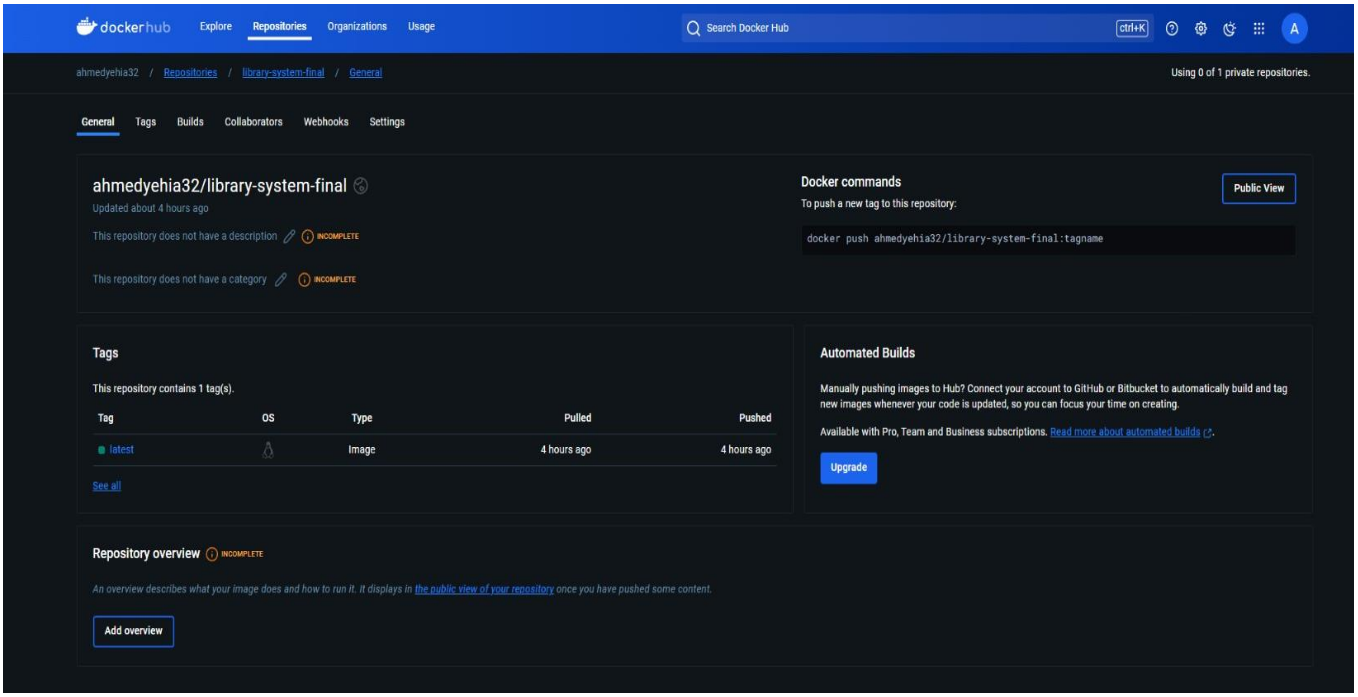
Part 2: Dockerization:

- **Base Image:** The Dockerfile starts with a base image, which provides a foundation for the new image.
- **Working Directory:** The working directory is set to **/app**, which will be the root directory for the application code.
- **Copying Application Code:** The application code is copied into the container at the **/app** directory.
- **Installing Dependencies:** The dependencies specified in the **requirements.txt** file are installed using pip.
- **Exposing Port:** The necessary port (**5000**) is exposed, allowing the application to be accessed from outside the container.

Building and Deploying the Docker Image

- **Building the Docker Image:** The Dockerfile is used to build a Docker image locally.
- **Testing the Docker Image:** The Docker image is tested locally to ensure it works as expected.
- **Pushing to Docker Hub:** The Docker image is pushed to Docker Hub, making it available for use in the Kubernetes deployment.

The resulting Docker image, is used in the Kubernetes deployment configuration to create a container running the library management system application.



ahmedyehia32 / Repositories / library-system-final / General

Using 0 of 1 private repositories.

ahmedyehia32/library-system-final

Updated about 4 hours ago

This repository does not have a description INCOMPLETE

This repository does not have a category INCOMPLETE

Docker commands

To push a new tag to this repository:

```
docker push ahmedyehia32/library-system-final:tagname
```

Tags

This repository contains 1 tag(s).

Tag	OS	Type	Pulled	Pushed
latest		Image	4 hours ago	4 hours ago

Automated Builds

Manually pushing images to Hub? Connect your account to GitHub or Bitbucket to automatically build and tag new images whenever your code is updated, so you can focus your time on creating.

Available with Pro, Team and Business subscriptions. Read more about automated builds.

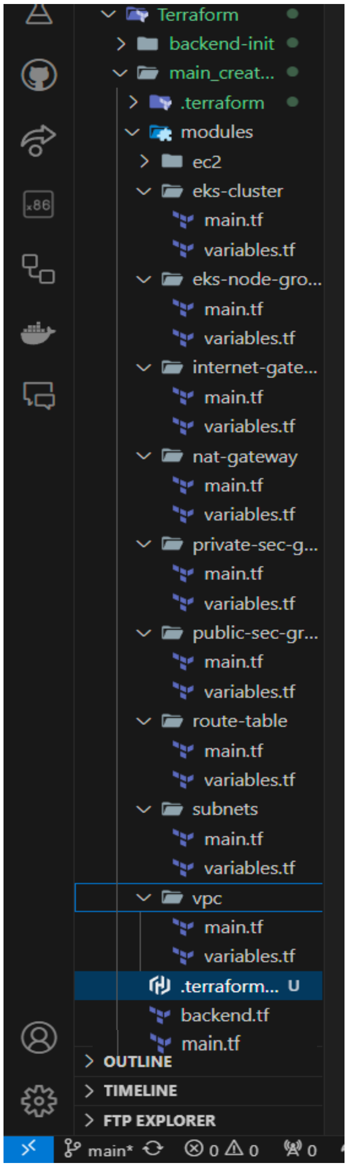
Repository overview INCOMPLETE

An overview describes what your image does and how to run it. It displays in the public view of your repository once you have pushed some content.

Figure 13 Docker image on dockerhub

Part 3: Infrastructure as Code with Terraform

Terraform was used to create our infrastructure on AWS, we had two Terraform modules, one for creating the backend which is the S3 bucket for storing the state file, and the DynamoDB table for preventing multiple changes to the state file at the same time, and the other for creating our main infrastructure(VPC, subnets, Internet gateway, Nat gateway, EKS), our main module contains a module for every AWS resource.



```
Terraform
  backend-init
  main_creat...
    .terraform
    modules
      ec2
      eks-cluster
        main.tf
        variables.tf
      eks-node-gro...
        main.tf
        variables.tf
      internet-gate...
        main.tf
        variables.tf
      nat-gateway
        main.tf
        variables.tf
      private-sec-g...
        main.tf
        variables.tf
      public-sec-gr...
        main.tf
        variables.tf
      route-table
        main.tf
        variables.tf
      subnets
        main.tf
        variables.tf
      vpc
        main.tf
        variables.tf
    .terraform... U
    backend.tf
    main.tf
OUTLINE
TIMELINE
FTP EXPLORER
main*  ⊗ 0 ⚠ 0  0
```

Figure 14 Terraform Modules

Modules details:

1. VPC Configuration

- **Module: team5_vpc**
- **Source: ./modules/vpc**
- **Description:** Creates a Virtual Private Cloud (VPC) with the specified CIDR block.
- **Parameters:**
    - **cidr_block**: **10.0.0.0/16** - The IP address range for the VPC.
    - **name**: **team5-vpc** - Name of the VPC.

2. Subnet Configuration

- **Public Subnet 1: team5_public_subnet1**
    - **Source: ./modules/subnets**
    - **Parameters:**
        - **vpc_id**: Refers to the VPC ID created by **team5_vpc**.
        - **cidr_block**: **10.0.1.0/24** - IP address range for the subnet.
        - **availability_zone**: **eu-central-1a** - AWS availability zone.
        - **map_public_ip_on_launch**: **true** - Automatically assign public IP addresses.
        - **name**: **team5-public-subnet1** - Name of the subnet.
- **Public Subnet 2: team5_public_subnet2**
    - **Source: ./modules/subnets**
    - **Parameters:**
        - **vpc_id**: Refers to the VPC ID created by **team5_vpc**.
        - **cidr_block**: **10.0.2.0/24** - IP address range for the subnet.
        - **availability_zone**: **eu-central-1b** - AWS availability zone.
        - **map_public_ip_on_launch**: **true** - Automatically assign public IP addresses.
        - **name**: **team5-public-subnet2** - Name of the subnet.
- **Private Subnet 1: team5_private_subnet1**
    - **Source: ./modules/subnets**
    - **Parameters:**
        - **vpc_id**: Refers to the VPC ID created by **team5_vpc**.
        - **cidr_block**: **10.0.3.0/24** - IP address range for the subnet.
        - **availability_zone**: **eu-central-1a** - AWS availability zone.
        - **map_public_ip_on_launch**: **false** - Do not assign public IP addresses.
        - **name**: **team5-private-subnet1** - Name of the subnet.
- **Private Subnet 2: team5_private_subnet2**
    - **Source: ./modules/subnets**
    - **Parameters:**
        - **vpc_id**: Refers to the VPC ID created by **team5_vpc**.
        - **cidr_block**: **10.0.4.0/24** - IP address range for the subnet.
        - **availability_zone**: **eu-central-1b** - AWS availability zone.
        - **map_public_ip_on_launch**: **false** - Do not assign public IP addresses.
        - **name**: **team5-private-subnet2** - Name of the subnet.

3. Internet Gateway

- **Module: team5_internet_gateway**
- **Source: ./modules/internet-gateway**
- **Parameters:**
    - **vpc_id**: Refers to the VPC ID created by **team5_vpc**.
    - **name**: **team5-igw** - Name of the Internet Gateway.

4. NAT Gateway

- **Module: team5_nat_gateway**
- **Source: ./modules/nat-gateway**
- **Parameters:**
    - **subnet_id**: Refers to the public subnet ID where the NAT Gateway is deployed (**team5_public_subnet1**).
    - **name**: **team5-nat-gateway** - Name of the NAT Gateway.

5. Route Tables

- **Modules:**
  - **Public Route Table: team5_public_route_table**
    - **Source: ./modules/route-table**
    - **Parameters:**
      - **vpc_id: Refers to the VPC ID created by team5_vpc.**
      - **cidr_block: 0.0.0.0/0 - Route all traffic.**
      - **gateway_id: Refers to the Internet Gateway ID created by team5_internet_gateway.**
      - **name: team5-public-route-table - Name of the route table.**
  - **Private Route Table: team5_private_route_table**
    - **Source: ./modules/route-table**
    - **Parameters:**
      - **vpc_id: Refers to the VPC ID created by team5_vpc.**
      - **cidr_block: 0.0.0.0/0 - Route all traffic.**
      - **nat_gateway_id: Refers to the NAT Gateway ID created by team5_nat_gateway.**
      - **name: team5-private-route-table - Name of the route table.**

Route Table Associations

- **Public Subnet Associations:**
  - **team5_public_subnet_a_assoc:**
    Associates team5_public_subnet1 with team5_public_route_table.
  - **team5_public_subnet_b_assoc:**
    Associates team5_public_subnet2 with team5_public_route_table.
- **Private Subnet Associations:**
  - **team5_priv_subnet_a_assoc:**
    Associates team5_private_subnet1 with team5_private_route_table.
  - **team5_priv_subnet_b_assoc:**
    Associates team5_private_subnet2 with team5_private_route_table.

6. IAM Roles for EKS

- **IAM Role for EKS Cluster:**
    - **Resource: aws_iam_role.eks_cluster_role**
    - **Description:** Role for the EKS cluster to assume.
    - **Assume Role Policy:** Allows the EKS service to assume the role.
    - **Policy Attachments:**
        - **AmazonEC2FullAccess**
        - **AmazonEKSClusterPolicy**
        - **AmazonEKSServicePolicy**
- **IAM Role for EKS Node Group:**
    - **Resource: aws_iam_role.team5_eks_node_role**
    - **Description:** Role for the EKS node group.
    - **Assume Role Policy:** Allows EC2 instances to assume the role.
    - **Managed Policies:**
        - **AmazonEKSWorkerNodePolicy**
        - **AmazonEC2ContainerRegistryReadOnly**
        - **AmazonEC2ContainerServiceRole**
        - **AmazonEKS_CNI_Policy**

7. EKS Cluster and Node Group

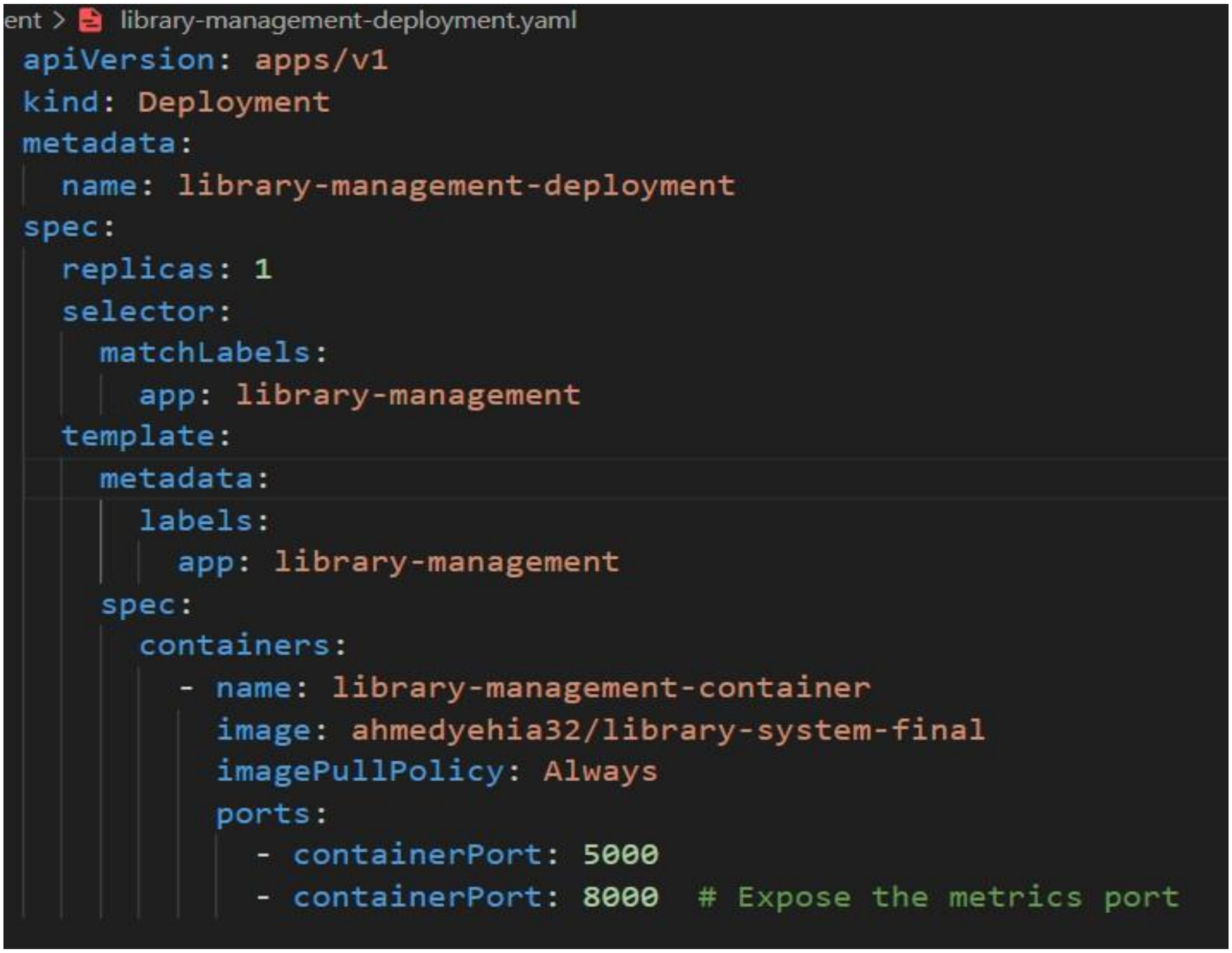
- **EKS Cluster:**
  - **Module: eks_cluster**
  - **Source: ./modules/eks-cluster**
  - **Parameters:**
    - **cluster_name**: **team5-eks-cluster** - Name of the EKS cluster.
    - **cluster_role_arn**: ARN of the IAM role for the EKS cluster.
    - **subnet_ids**: List of subnet IDs for the cluster.
- **EKS Node Group:**
  - **Module: eks_node_group**
  - **Source: ./modules/eks-node-group**
  - **Parameters:**
    - **cluster_name**: Name of the EKS cluster (**team5-eks-cluster**).
    - **node_group_name**: **team5-node-group -** Name of the node group.
    - **node_role_arn**: ARN of the IAM role for the node group.
    - **subnet_ids**: List of public subnet IDs for the node group.
    - **desired_size**: **1 -** Desired number of nodes.
    - **max_size**: **1 -** Maximum number of nodes.
    - **min_size**: **1 -** Minimum number of nodes.

Part 4: Kubernetes Deployment on EKS:

The website was deployed on Amazon Elastic Kubernetes Service (EKS), after applying the terraform code for creating the infrastructure, we configured our deployment.yaml and service.yaml files for deploying our website on the created EKS cluster.

Yaml Files

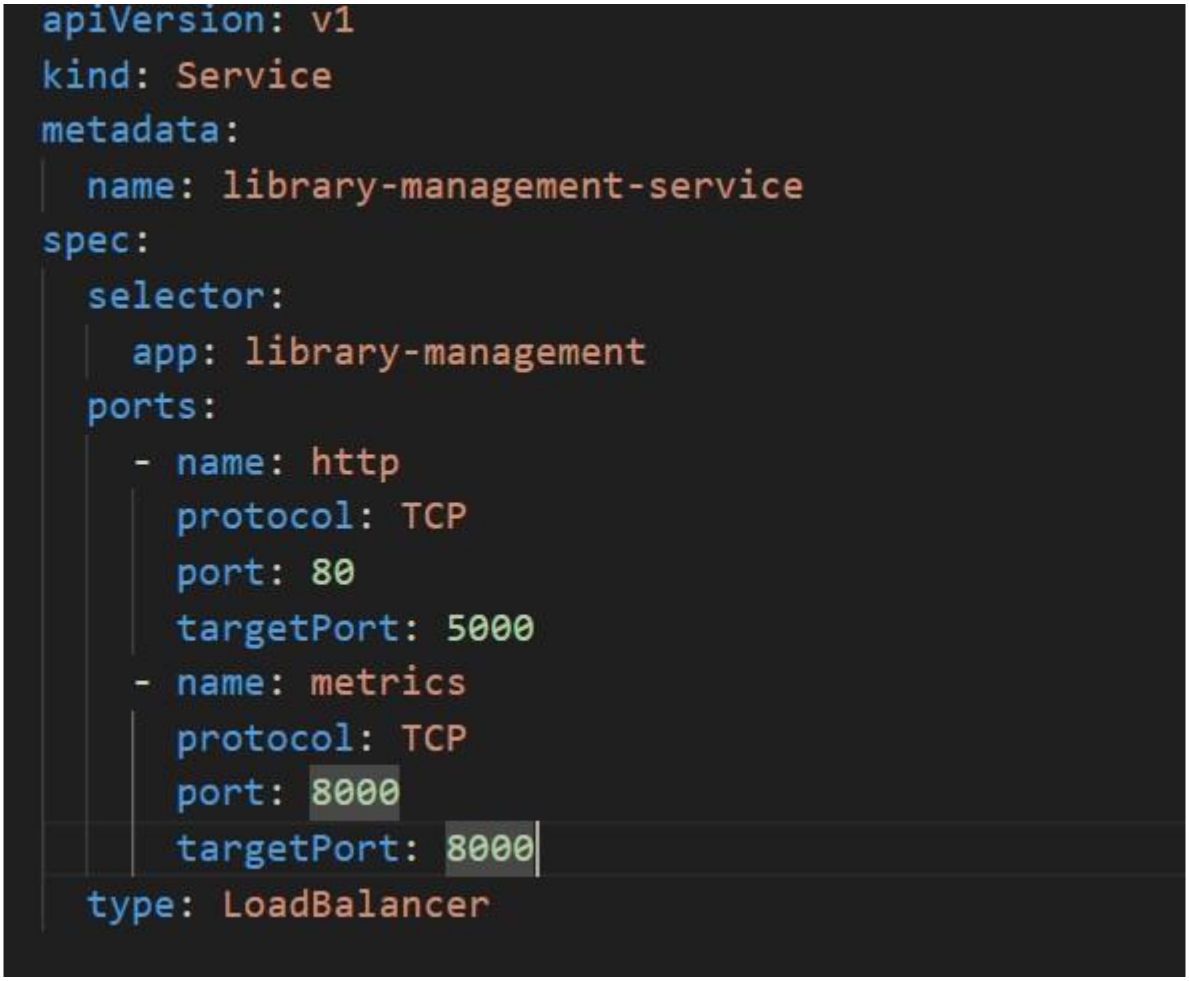
1-library-management-deployment.yaml file:



```yaml
apiVersion: apps/v1
kind: Deployment
metadata:
  name: library-management-deployment
spec:
  replicas: 1
  selector:
    matchLabels:
      app: library-management
  template:
    metadata:
      labels:
        app: library-management
    spec:
      containers:
        - name: library-management-container
          image: ahmedyehia32/library-system-final
          imagePullPolicy: Always
          ports:
            - containerPort: 5000
            - containerPort: 8000  # Expose the metrics port
```

Figure 15 Deployment Yaml File

2-service.yaml file:



```yaml
apiVersion: v1
kind: Service
metadata:
  name: library-management-service
spec:
  selector:
    app: library-management
  ports:
    - name: http
      protocol: TCP
      port: 80
      targetPort: 5000
    - name: metrics
      protocol: TCP
      port: 8000
      targetPort: 8000
  type: LoadBalancer
```

Figure 16 Service Yaml File

Deployment Configuration (library-management-deployment.yaml)

- **API Version: apps/v1** - The API version used to manage deployments in Kubernetes.
- **Kind: Deployment** - Specifies that this YAML defines a Kubernetes Deployment object.
- **Metadata:**
  - **Name: library-management-deployment** - The name assigned to the Deployment object.
- **Spec:**
  - **Replicas: 1** - Defines the number of pod replicas to be created.
  - **Selector:** Ensures the Deployment targets pods that match specific labels:
    - **Match Labels: app: library-management** - Identifies the pods managed by the deployment based on this label.
  - **Template:** Defines the specifications for the pods that will be created by the Deployment.
    - **Metadata:**
      - **Labels: app: library-management** - Specifies the labels applied to each pod.
    - **Spec:** Defines the container configuration for each pod.
      - **Containers:**
        - **Name: library-management-container** - The name of the container within the pod.
        - **Image: ahmedyehia32/library-system-final** - The Docker image to be used.
        - **Image Pull Policy: Always** - Ensures the image is always pulled from the registry.
        - **Ports:**
          - **Container Port: 5000** - The port number inside the container where the application is accessible.
          - **Container Port: 8000** - Designated for exposing metrics from the application, typically used for Prometheus to scrape.

Service Configuration (service.yaml)

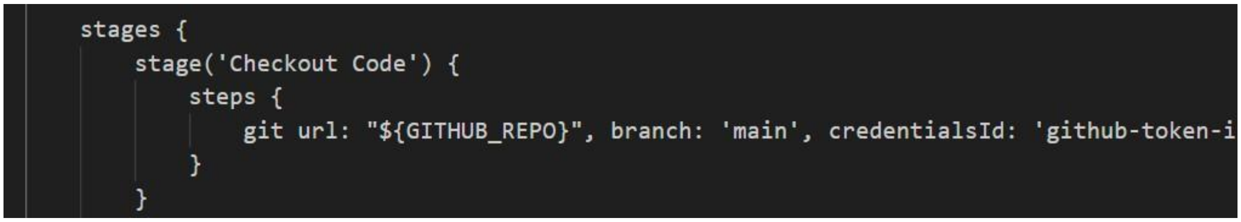
- **API Version: v1** - The version for Kubernetes Service API.
- **Kind: Service** - Specifies that this YAML defines a Kubernetes Service object.
- **Metadata:**
  - **Name: library-management-service** - The name of the service, which will be used to reference this service within the cluster.
- **Spec:**
  - **Selector:**
    - **App: library-management** - This selector matches the labels on the pods created by the deployment, allowing the service to route traffic to them.
  - **Ports:**
    - **Protocol: TCP** - The protocol used by the service to communicate with the pods.
    - **Port: 80** - The port that external clients will use to access the service.
    - **Target Port: 5000** - The port on the container where the application is running.
    - **Type: LoadBalancer** - Specifies that this service is exposed to the internet via a load balancer, making it accessible outside the Kubernetes cluster.
  - **Note:** Port **8000** is used for metrics collection, routing traffic directly to port **8000** on the backend pods, which is used by Prometheus to scrape metrics from the application.

Part 5: CI/CD Pipeline Setup:

Our (CICD) pipeline involves automating the process of integrating code changes and deploying our website. We implemented our (CICD) pipeline using Jenkins. We configured the pipeline to automatically build, and deploy code whenever the pipeline is executed.

Pipeline Stages:

1. Checkout Code

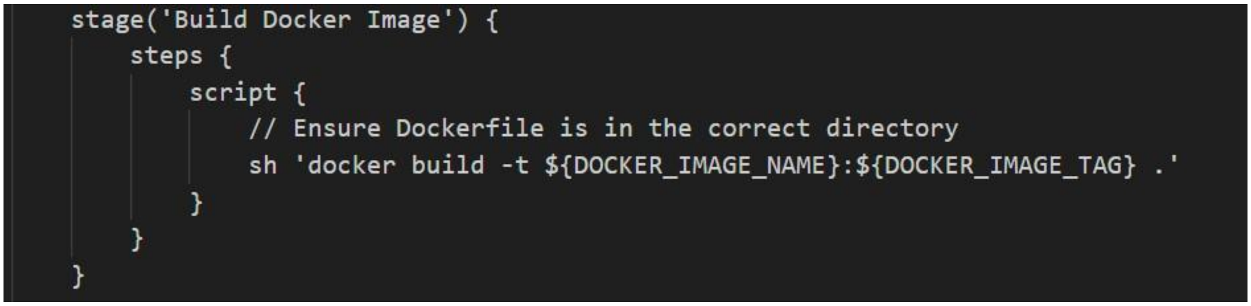


```
    stages {
        stage('Checkout Code') {
            steps {
                git url: "${GITHUB_REPO}", branch: 'main', credentialsId: 'github-token-i
            }
        }
```

Figure 17 Pipeline 1. Checkout Code

Description: This stage checks out the code from the specified GitHub repository (GITHUB_REPO) using the provided credentials (github-token-id). The pipeline will pull the mainbranch.

2- Build Docker Image:

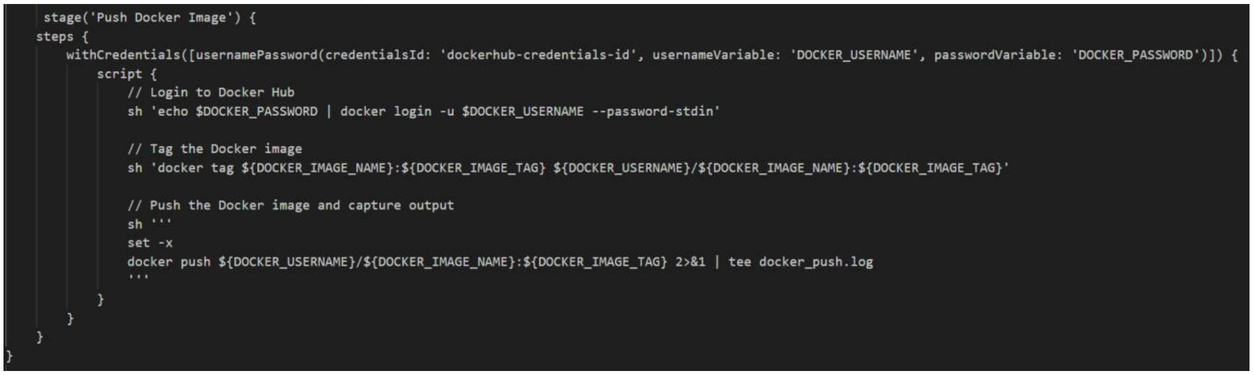


```
    stage('Build Docker Image') {
        steps {
            script {
                // Ensure Dockerfile is in the correct directory
                sh 'docker build -t ${DOCKER_IMAGE_NAME}:${DOCKER_IMAGE_TAG} .'
            }
        }
    }
```

Figure 18 Pipeline Build Docker Image

- **Description**: In this stage, Jenkins builds a Docker image using the Dockerfilelocated at the root of the project. The image is tagged as ${DOCKER_IMAGE_NAME}:${DOCKER_IMAGE_TAG}, which is library-system-final:latest by default.

3- Push Docker Image:

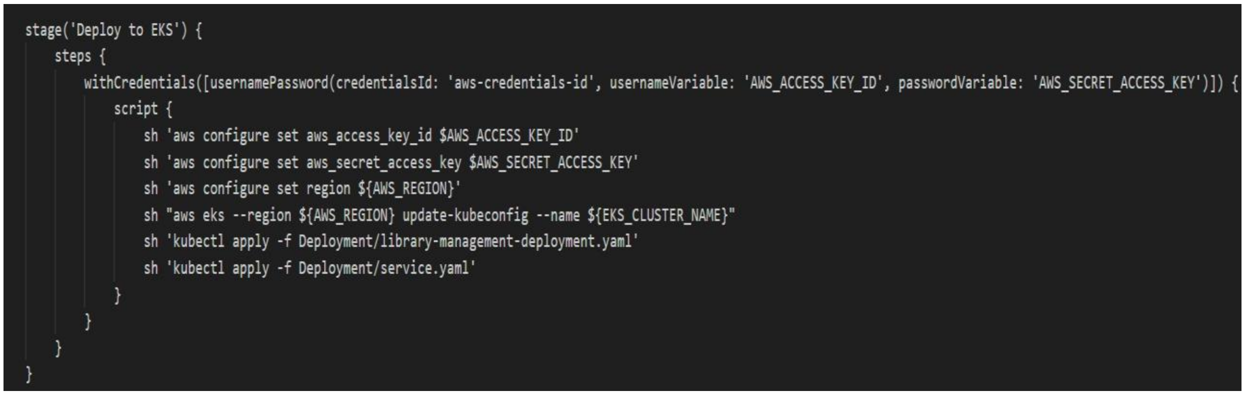


```
 stage('Push Docker Image') {
 steps {
     withCredentials([usernamePassword(credentialsId: 'dockerhub-credentials-id', usernameVariable: 'DOCKER_USERNAME', passwordVariable: 'DOCKER_PASSWORD')]) {
         script {
             // Login to Docker Hub
             sh 'echo $DOCKER_PASSWORD | docker login -u $DOCKER_USERNAME --password-stdin'

             // Tag the Docker image
             sh 'docker tag ${DOCKER_IMAGE_NAME}:${DOCKER_IMAGE_TAG} ${DOCKER_USERNAME}/${DOCKER_IMAGE_NAME}:${DOCKER_IMAGE_TAG}'

             // Push the Docker image and capture output
             sh '''
             set -x
             docker push ${DOCKER_USERNAME}/${DOCKER_IMAGE_NAME}:${DOCKER_IMAGE_TAG} 2>&1 | tee docker_push.log
             '''
         }
     }
 }
}
```

Figure 19 pipeline Push Docker Image:

- **Description**:
    - ○ Logs in to Docker Hub using credentials (dockerhub credentials-id).
    - ○ Tags the built Docker image with the Docker Hub repository name.
    - ○ Pushes the Docker image to Docker Hub and logs the output.

4- Deploy to EKS:

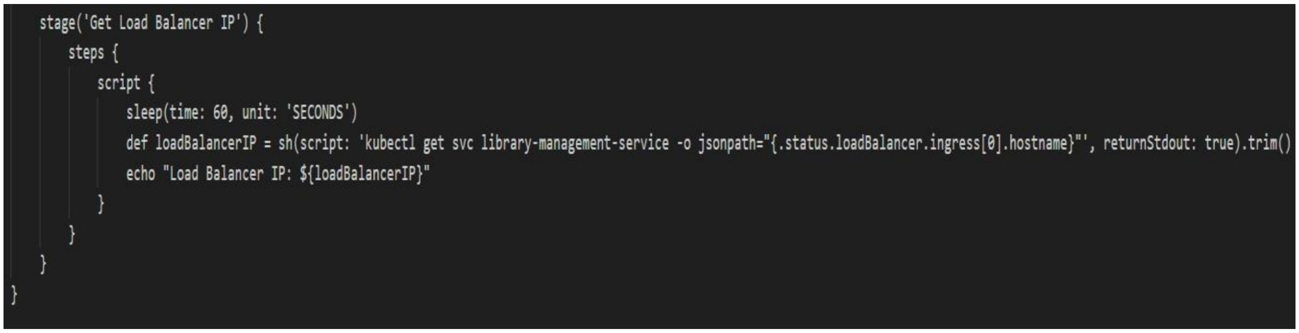


```
stage('Deploy to EKS') {
    steps {
        withCredentials([usernamePassword(credentialsId: 'aws-credentials-id', usernameVariable: 'AWS_ACCESS_KEY_ID', passwordVariable: 'AWS_SECRET_ACCESS_KEY')]) {
            script {
                sh 'aws configure set aws_access_key_id $AWS_ACCESS_KEY_ID'
                sh 'aws configure set aws_secret_access_key $AWS_SECRET_ACCESS_KEY'
                sh 'aws configure set region ${AWS_REGION}'
                sh "aws eks --region ${AWS_REGION} update-kubeconfig --name ${EKS_CLUSTER_NAME}"
                sh 'kubectl apply -f Deployment/library-management-deployment.yaml'
                sh 'kubectl apply -f Deployment/service.yaml'
            }
        }
    }
}
```

Figure 20 Pipeline Deploy to EKS

- **Description**:
    - ○ Configures AWS CLI with credentials (aws-credentials-id), sets the region, and updates the kubeconfig to connect to the EKS cluster.
    - ○ Uses kubectl applyto deploy the application in Kubernetes by applying the library-management-deployment.yamland service.yamlfiles.

5-Get the Load Balancer IP:



```
    stage('Get Load Balancer IP') {
        steps {
            script {
                sleep(time: 60, unit: 'SECONDS')
                def loadBalancerIP = sh(script: 'kubectl get svc library-management-service -o jsonpath="{.status.loadBalancer.ingress[0].hostname}"', returnStdout: true).trim()
                echo "Load Balancer IP: ${loadBalancerIP}"
            }
        }
    }
}
```

Figure 21Pipelie Loadbalancer

Description:

- Waits for 60 seconds to ensure the Load Balancer is fully initialized.
- Retrieves the Load Balancer IP address or hostname from the library-management-serviceusing kubectl.
- Displays the Load Balancer IP/hostname in the console output.

Bonus Task: Set Up Monitoring and Logging:

Overview

Prometheus and Grafana are popular tools for monitoring and visualizing metrics. Prometheus is used to collect and store metrics data, while Grafana is used to visualize this data through dashboards.

Components:

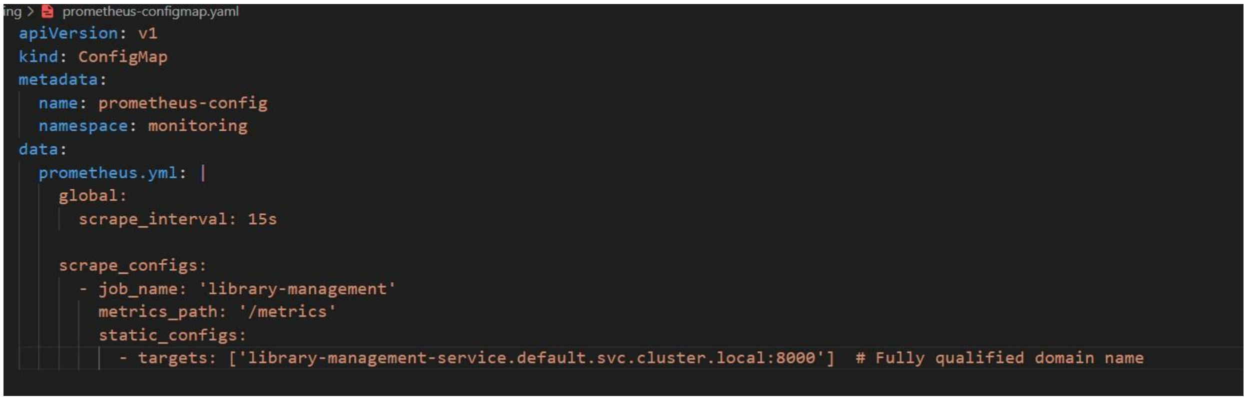
1- Prometheus: A monitoring system and time-series database.

2- Grafana: An open-source platform for monitoring and observability, which supports various data sources including Prometheus.

Setup Prometheus

Prometheus ConfigMap (prometheus-configmap.yaml)

1- Create a ConfigMap to provide the Prometheus



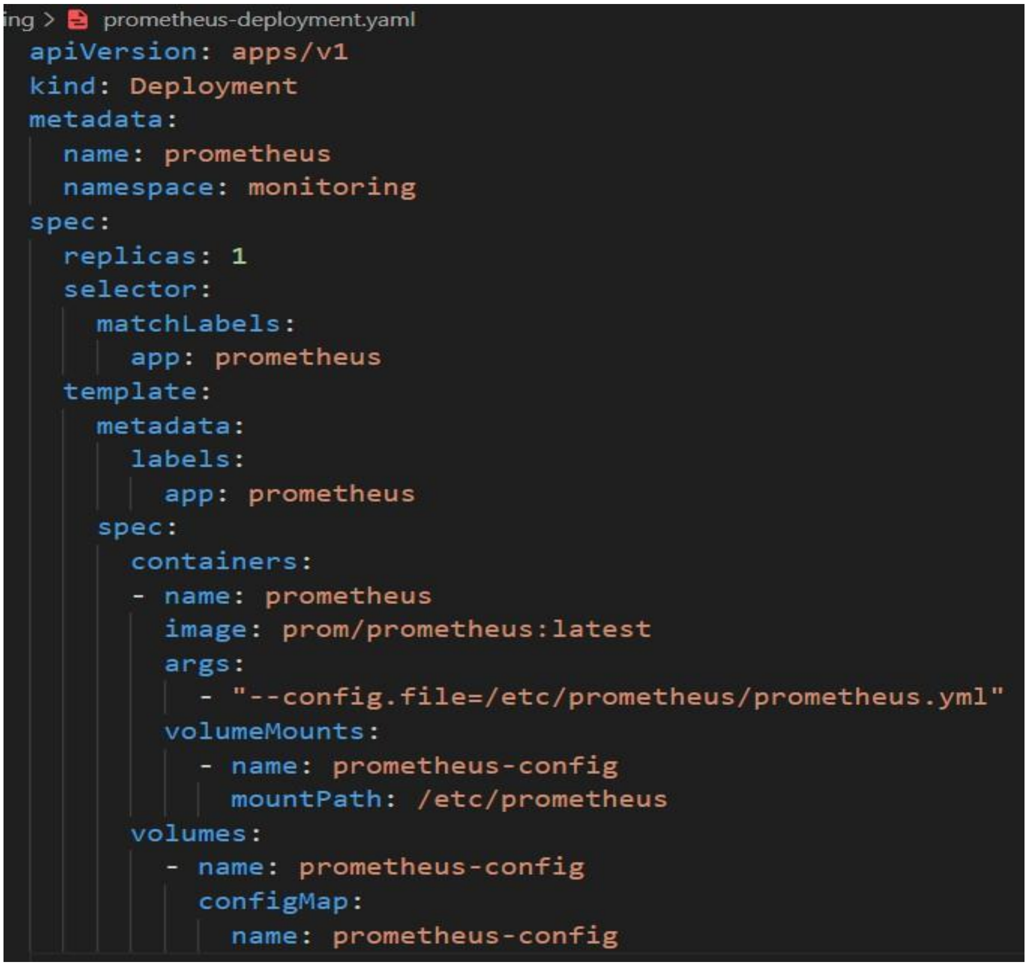
ing > prometheus-configmap.yaml

```yaml
apiVersion: v1
kind: ConfigMap
metadata:
  name: prometheus-config
  namespace: monitoring
data:
  prometheus.yml: |
    global:
      scrape_interval: 15s

    scrape_configs:
      - job_name: 'library-management'
        metrics_path: '/metrics'
        static_configs:
          - targets: ['library-management-service.default.svc.cluster.local:8000']  # Fully qualified domain name
```

Figure 22 configuration to the Prometheus deployment.

Prometheus Deployment (prometheus-deployment.yaml)

2- Defines the deployment of Prometheus.



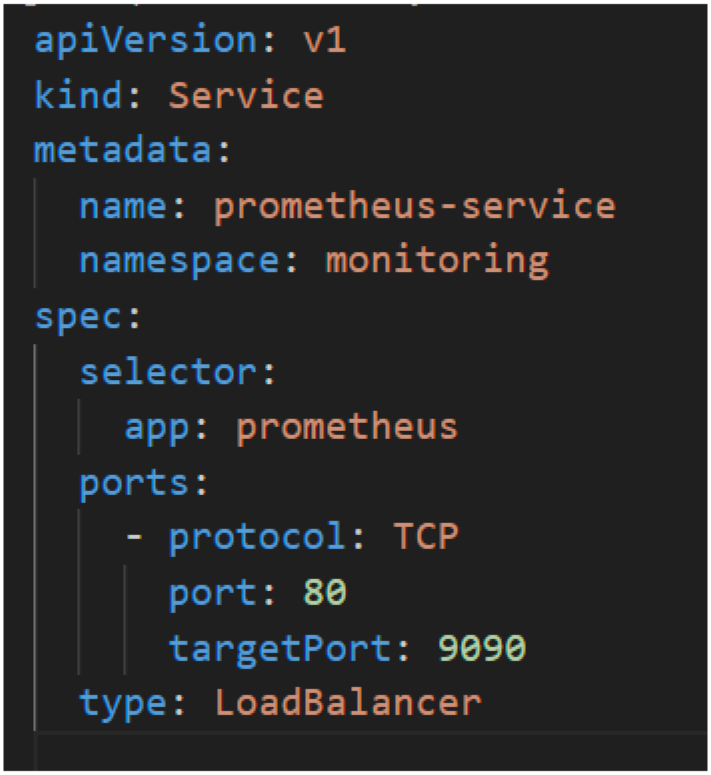
ing > prometheus-deployment.yaml

```yaml
apiVersion: apps/v1
kind: Deployment
metadata:
  name: prometheus
  namespace: monitoring
spec:
  replicas: 1
  selector:
    matchLabels:
      app: prometheus
  template:
    metadata:
      labels:
        app: prometheus
    spec:
      containers:
      - name: prometheus
        image: prom/prometheus:latest
        args:
          - "--config.file=/etc/prometheus/prometheus.yml"
        volumeMounts:
          - name: prometheus-config
            mountPath: /etc/prometheus
      volumes:
        - name: prometheus-config
          configMap:
            name: prometheus-config
```

Figure 23 Prometheus deployment yaml file.

Prometheus Service (prometheus-service.yaml)

3- Defines the service for Prometheus.



```yaml
apiVersion: v1
kind: Service
metadata:
  name: prometheus-service
  namespace: monitoring
spec:
  selector:
    app: prometheus
  ports:
    - protocol: TCP
      port: 80
      targetPort: 9090
  type: LoadBalancer
```

Figure 24 Promethues service File

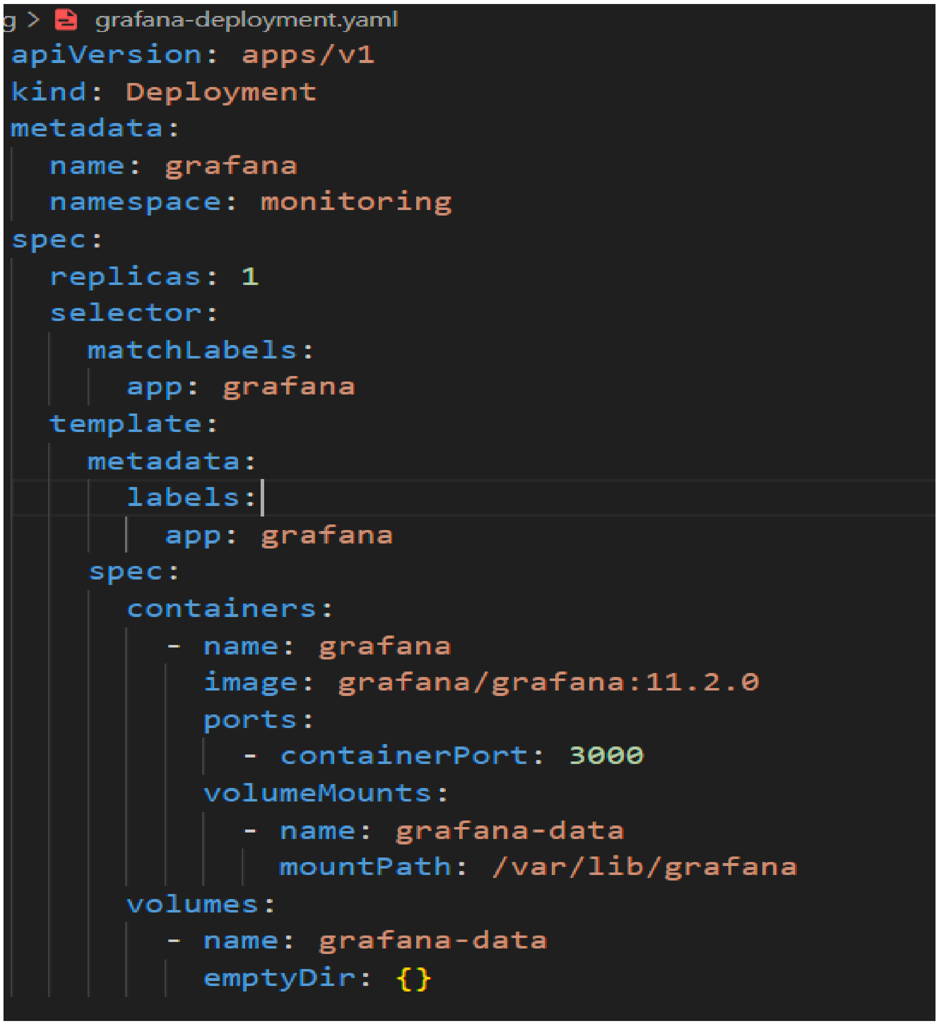
Deployment Commands to apply the configurations:

```
kubectl apply -f prometheus-configmap.yaml
kubectl apply -f prometheus-deployment.yaml
kubectl apply -f prometheus-service.yaml
```

Grafana Setup

1- **Grafana Deployment** (grafana-deployment.yaml)

Defines the deployment of Grafana.



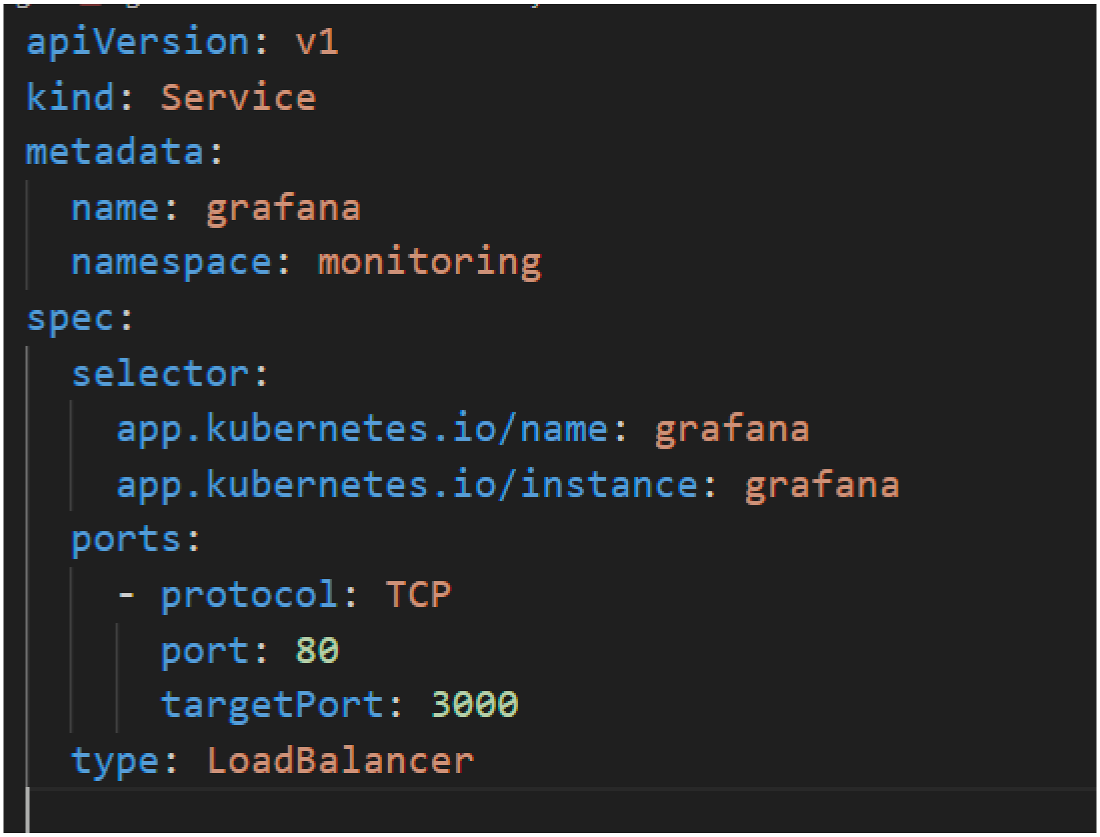
```yaml
apiVersion: apps/v1
kind: Deployment
metadata:
  name: grafana
  namespace: monitoring
spec:
  replicas: 1
  selector:
    matchLabels:
      app: grafana
  template:
    metadata:
      labels:
        app: grafana
    spec:
      containers:
        - name: grafana
          image: grafana/grafana:11.2.0
          ports:
            - containerPort: 3000
          volumeMounts:
            - name: grafana-data
              mountPath: /var/lib/grafana
      volumes:
        - name: grafana-data
          emptyDir: {}
```

Figure 25 Grafana Deployment yaml file

2- Grafana Service with LoadBalancer

(grafana-service loadbalancer.yaml)

Defines the service for Grafana with a LoadBalancer to expose it.



```yaml
apiVersion: v1
kind: Service
metadata:
  name: grafana
  namespace: monitoring
spec:
  selector:
    app.kubernetes.io/name: grafana
    app.kubernetes.io/instance: grafana
  ports:
    - protocol: TCP
      port: 80
      targetPort: 3000
  type: LoadBalancer
```

Figure 26 Grafana Service Loadbalancer Yaml File

Deployment Commands Apply configurations:

```
kubectl apply -f grafana-deployment.yaml

kubectl apply -f grafana-service-loadbalancer.yaml
```

Integrating Prometheus with Grafana

Access Grafana

Get the external IP address of the Grafana service: kubectl get svc grafana -n monitoring
Navigate to the Grafana URL provided by the LoadBalancer.

Add Prometheus as a Data Source

Log in to Grafana (default credentials: admin/admin). Go to Configuration (Gear icon) > Data Sources.

Add Data Source and select Prometheus.

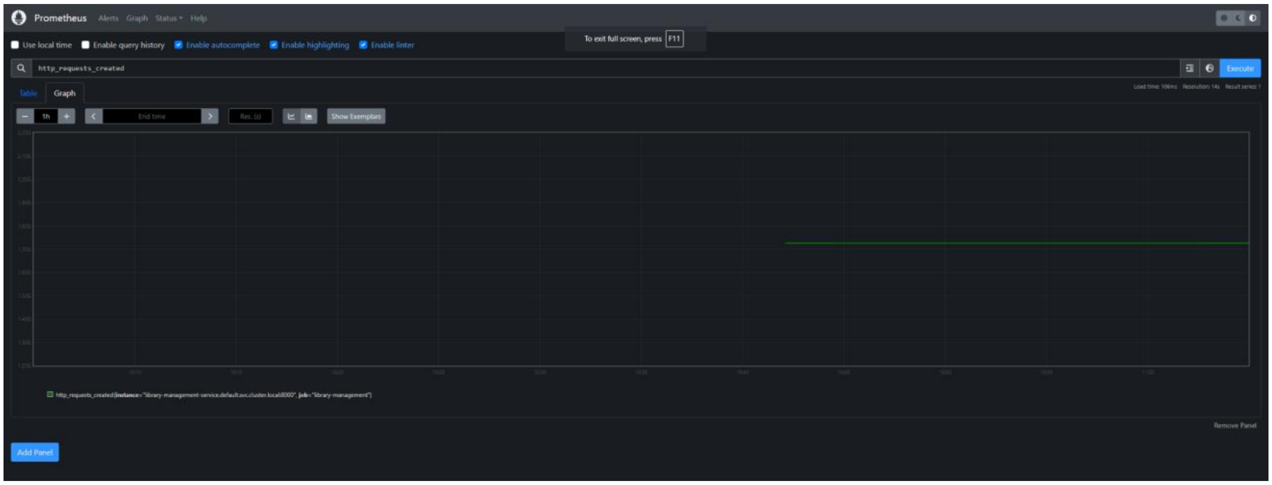
Configure Prometheus URL to http://prometheus:9090 (assuming Prometheus is within the same namespace or adjust accordingly if using an external IP).

Create Dashboards

Go to Dashboards and click New Dashboard.

Add Panels and configure queries to visualize metrics from Prometheus.

Example Query for HTTP Requests: http_requests_total
Some Screenshots from Prometheus:

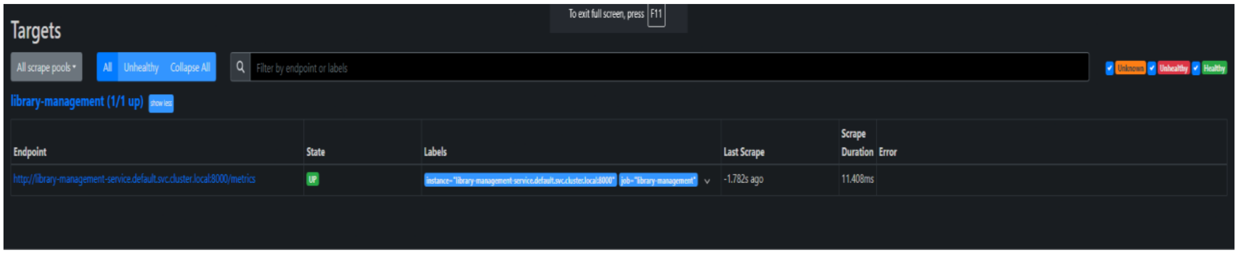


☐ Use local time ☐ Enable query history ☑ Enable autocomplete ☑ Enable highlighting ☑ Enable linter

```
http_requests_created
```

http_requests_created{instance="library-management-service.default.svc.cluster.local:8000", job="library-management"}

Figure 27 Promethues Chart



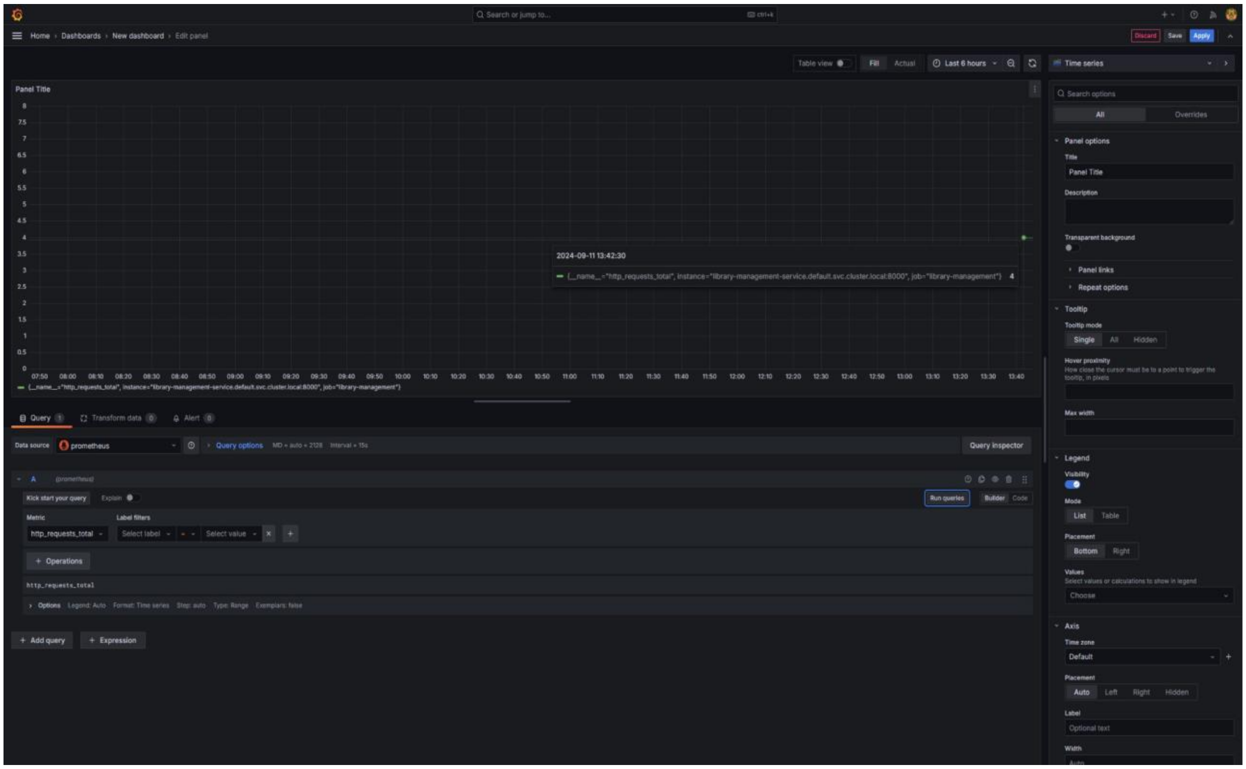
Targets

library-management (1/1 up)

Endpoint	State	Labels	Last Scrape	Scrape Duration	Error
http://library-management-service.default.svc.cluster.local:8000/metrics	UP	instance="library-management-service.default.svc.cluster.local:8000" job="library-management"	-1.782s ago	11.408ms	

Figure 28 Promethues Target

Some Screenshots from Grafana:



2024-09-11 13:42:30

{__name__="http_requests_total", instance="library-management-service.default.svc.cluster.local:8000", job="library-management"} 4

Data source: prometheus

Query options MD = auto = 2128 Interval = 15s

A (prometheus)

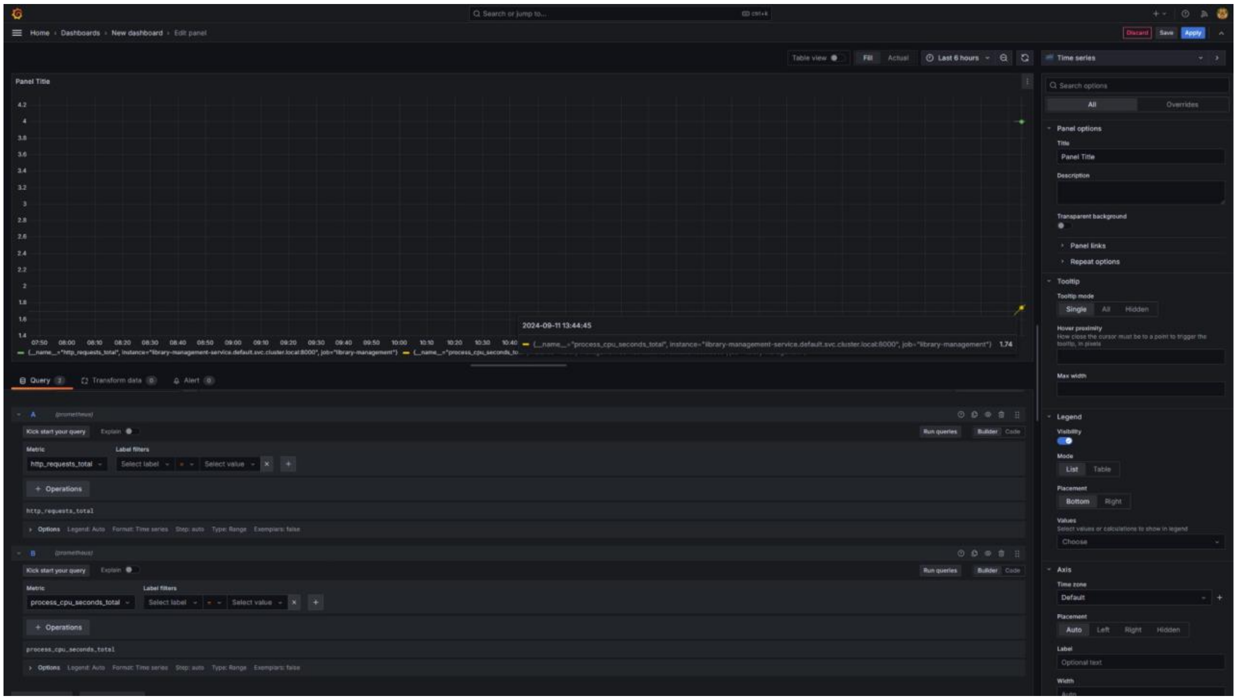
Metric: http_requests_total

Label filters: Select label = Select value

```
http_requests_total
```

Options Legend: Auto Format: Time series Step: auto Type: Range Exemplars: false

Figure 29 Number of http Request



2024-09-11 13:44:45

{__name__="process_cpu_seconds_total", instance="library-management-service.default.svc.cluster.local:8000", job="library-management"} 1.74

{__name__="http_requests_total", instance="library-management-service.default.svc.cluster.local:8000", job="library-management"}

A (prometheus)

Metric: http_requests_total

Label filters: Select label = Select value

```
http_requests_total
```

Options Legend: Auto Format: Time series Step: auto Type: Range Exemplars: false

B (prometheus)

Metric: process_cpu_seconds_total

Label filters: Select label = Select value

```
process_cpu_seconds_total
```

Options Legend: Auto Format: Time series Step: auto Type: Range Exemplars: false

Figure 30 Process CPU second

Terraform Pipeline (Bonus task)

Terraform Infrastructure Setup

Terraform was used to create the infrastructure on AWS, consisting of two main modules:

Backend Module

- **S3 Bucket:** Stores the Terraform state file.
- **DynamoDB Table:** Prevents multiple changes to the state file at the same time.

Figure 14: *Terraform Modules*

Main Infrastructure Module

- **VPC:** Virtual Private Cloud for the infrastructure.
- **Subnets:** Organize and segment the network.
- **Internet Gateway:** Enables communication between the VPC and the internet.
- **NAT Gateway:** Allows outbound internet access from private subnets.
- **EKS:** Elastic Kubernetes Service cluster for the Kubernetes deployment.

Pipeline Stages

The pipeline consists of the following stages:

1. Checkout SCM

Purpose: This stage checks out the code from the specified Git repository and branch.

- Configuration:
    - Uses GitSCM plugin for checking out the code.
    - Branch: */main
    - Repository URL: https://github.com/Ahmedyehia12/LibraryManagmentSystem
    - Credentials ID: c6d6be8b-c4b5-450b-a13c-1b8aca95fc69 (used for authentication with the Git repository).

2. Setup Plugin Cache Directory

Setup Plugin Cache Directory Stage

- Purpose: This stage sets up a directory for caching Terraform plugins, which can speed up the Terraform operations by avoiding repeated downloads.
- Configuration:
    - Creates a cache directory at /var/lib/jenkins/.terraform.d/plugin-cache using the mkdir command.

3. Terraform Init – Backend

Terraform Init - Backend Stage

- Purpose: Initializes the Terraform configuration for the backend, which is responsible for managing the remote state.
- Configuration:
    - Runs within the Terraform/backend-init directory.
    - Uses AWS credentials (aws-creds) to access AWS resources needed for the backend setup.
    - Executes terraform init to initialize the backend configuration.

4. Terraform Apply - Backend

Terraform Apply - Backend Stage

- Purpose: Applies the Terraform configuration for the backend to set up the remote state storage.
- Configuration:
    - Runs within the Terraform/backend-init directory.
    - Uses AWS credentials (aws-creds).
    - Executes terraform apply -auto-approve to automatically apply the configuration without manual approval.
- Post Action:
    - On failure, the stage will:
        - Set the build result to FAILURE.
        - Echo a failure message.
        - Destroy the resources created during this stage using terraform destroy -auto-approve.

5. Terraform Init - Main Creation

Terraform Init - Main Creation Stage

- Purpose: Initializes the main Terraform configuration responsible for creating infrastructure.
- Conditions:
    - Only runs if the previous stages did not result in failure.
- Configuration:
    - Runs within the Terraform/main_creation directory.
    - Uses AWS credentials (aws-creds).
    - Executes terraform init to initialize the main creation configuration.
- Post Action:
    - On failure, the stage will:
        - Set the build result to FAILURE.
        - Echo a failure message.
        - Clean up resources created in the backend stage by destroying them using terraform destroy -auto-approve.

5. Terraform Apply - Main Creation

Figure 25: Terraform Apply - Main Creation Stage

- Purpose: Applies the main Terraform configuration to create the required infrastructure.
- Conditions:
    - Only runs if the previous stages did not result in failure.
- Configuration:
    - Runs within the Terraform/main_creation directory.
    - Uses AWS credentials (aws-creds).
    - Executes terraform apply -auto-approve to automatically apply the configuration.
- Post Action:
    - On failure, the stage will:
        - Set the build result to FAILURE.
        - Echo a failure message.
        - Destroy the resources created in the main creation and backend stages using terraform destroy -auto-approve.

Post Actions

- Always:
    - Cleans up the workspace (cleanWs()), ensuring that the workspace is clean after every pipeline run. This helps to avoid issues caused by leftover files from previous builds.
- Failure:
    - Echoes 'Pipeline failed!' to indicate that the pipeline encountered errors.
- Success:
    - Echoes 'Pipeline succeeded!' to indicate that all stages were completed successfully.