Docker Mastery Project: From Containers to Custom Images & Multi-Container Applications

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Environment & Tool: AWS, Docker, Docker Compose, Dockerfile
Project Link: https://github.com/Oluwaseunoa/DevOps-Projects/tree/main/Docker-Projects

1. Introduction

Containerization is a cornerstone technology in modern DevOps and DevSecOps practices. This comprehensive hands-on project provides a complete progression from foundational Docker concepts to advanced real-world application deployment.

The project is structured into **two distinct sessions**:

- **Session 1:** Core Docker Container Operations – Mastering lifecycle management, interactivity, data persistence, and cleanup using the official Ubuntu image.
- **Session 2:** Advanced Docker Application Development – Building a custom Node.js web application image with Dockerfile and orchestrating a full multi-container stack (Node.js app + MongoDB + Mongo Express) using Docker Compose.

This structured approach demonstrates end-to-end containerized application development, deployment, and verification.

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2. Project Objectives

- Master the Docker container lifecycle and essential management commands
- Build and version custom Docker images from scratch
- Orchestrate complex multi-container applications with Docker Compose
- Implement secure environment variable management and secret handling
- Achieve true data persistence using volumes and MongoDB
- Expose services securely and verify full-stack functionality in a cloud environment

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3. Prerequisites

- Docker Engine or Docker Desktop installed
- Basic knowledge of Linux commands and Node.js fundamentals
- Text editor (nano or VS Code)
- AWS EC2 Ubuntu instance with Docker and Docker Compose installed (for Session 2 deployment)
- Internet access for pulling images and package installation

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Session 1: Core Container Operations

This session covers 23 foundational steps focused on Ubuntu container management.

Step 1: View Existing Containers

Command: `docker ps -a`

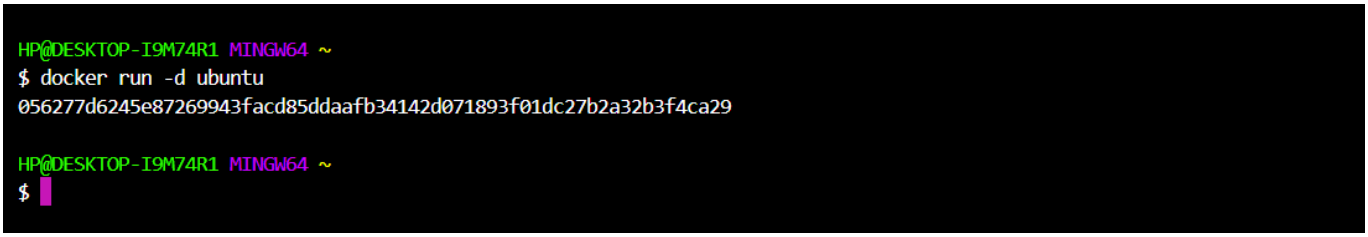
Step 2: Start a Stopped Container

Command: `docker start <container_id>`

Step 3: Run Container with Advanced Options (-e, -v, -p)

Step 4: Run Container in Detached Mode

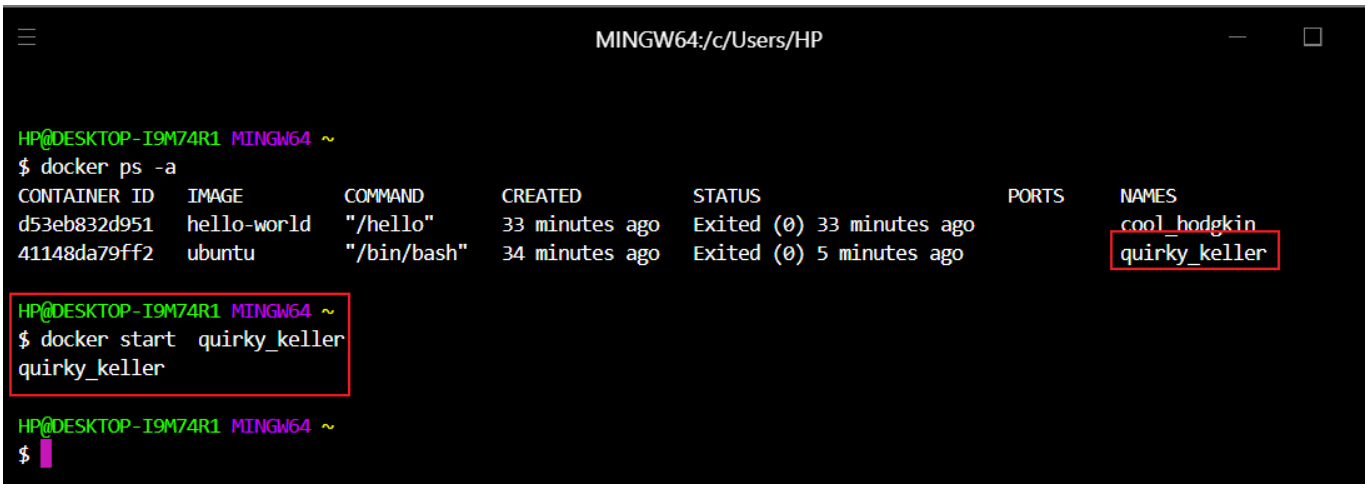
Command: `docker run -d ubuntu`



Step 5: Start Container by Name

Command:

```
docker ps -a
docker start <container_name>
```



Step 6: Stop Container by Name

Command: `docker stop <container_name>`

Step 7: Restart Container by Name

Command: `docker restart <container_name>`

Step 8: Remove a Container

Commands:

```
docker rm <container_name>
docker ps -a
```

Step 9: Pull the Ubuntu Image

Command: `docker pull ubuntu`

Step 10: Run Ubuntu in Interactive Mode

Command: `docker run -it --name my-ubuntu ubuntu bash`

Step 11: Verify OS Information

Command: `cat /etc/os-release`

```
root@8c0a1d9ae67b:/# cat /etc/os-release
PRETTY_NAME="Ubuntu 24.04.3 LTS"
NAME="Ubuntu"
VERSION_ID="24.04"
VERSION="24.04.3 LTS (Noble Numbat)"
VERSION_CODENAME=noble
ID=ubuntu
ID_LIKE=debian
HOME_URL="https://www.ubuntu.com/"
SUPPORT_URL="https://help.ubuntu.com/"
BUG_REPORT_URL="https://bugs.launchpad.net/ubuntu/"
PRIVACY_POLICY_URL="https://www.ubuntu.com/legal/terms-and-policies/privacy-policy"
UBUNTU_CODENAME=noble
LOGO=ubuntu-logo
root@8c0a1d9ae67b:/#
```

Step 12: Navigate File System

Commands:

```
pwd
ls
```

```
root@8c0a1d9ae67b:/# pwd
/
root@8c0a1d9ae67b:/# ls
bin  boot  dev  etc  home  lib  lib64  media  mnt  opt  proc  root  run  sbin  srv  sys  tmp  usr  var
root@8c0a1d9ae67b:/#
```

Step 13: Create and Enter Directory

Commands:

```
mkdir my-folder
cd my-folder && pwd
```

```
root@8c0a1d9ae67b:/# mkdir my-folder
root@8c0a1d9ae67b:/# cd my-folder
```

Step 14: Create and View File

Commands:

```
echo "This is Ubuntu in docker" > file1.txt && cat file1.txt
```

```
root@8c0a1d9ae67b:/my-folder# echo "This is Ubuntu in docker" > file.txt
root@8c0a1d9ae67b:/my-folder# cat file.txt
This is Ubuntu in docker
```

Step 15: Delete Directory

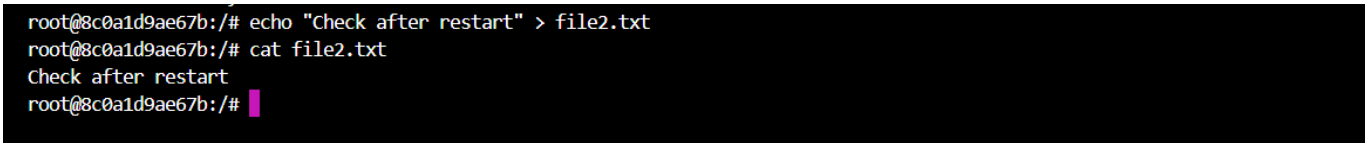
Commands:

```
cd ..
rm -rf my-folder
```

Step 16: Create Persistence Test File

Commands:

```
echo "Check after restart" > file2.txt
cat file2.txt
```

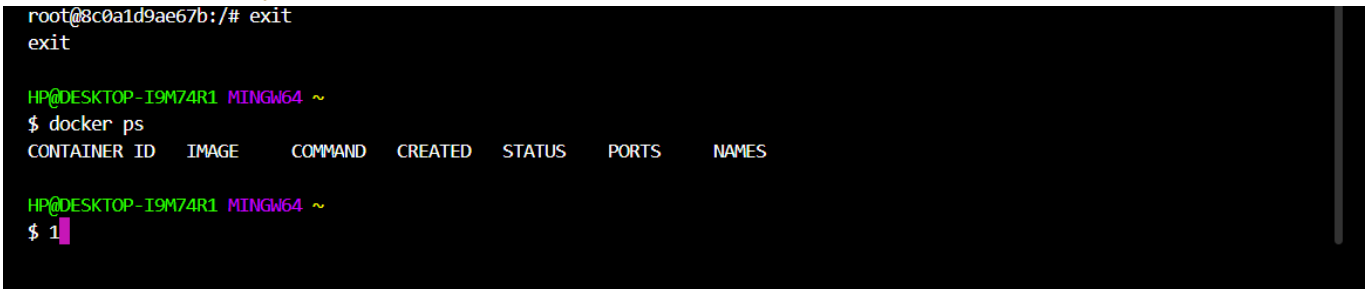


Step 17: Exit the Container

Command: `exit`

Step 18: Confirm Container Stopped

Command: `docker ps`



Step 19: Restart and Reattach

Commands:

```
docker start my-ubuntu
docker attach my-ubuntu
```

```
HP@DESKTOP-I9M74R1 MINGW64 ~
$  docker restart my-ubuntu
my-ubuntu

HP@DESKTOP-I9M74R1 MINGW64 ~
$ docker attach my-ubuntu
root@8c0a1d9ae67b:/#
```

Step 20: Verify File Persistence

Commands: `ls -ltr file2.txt`

```
root@8c0a1d9ae67b:/# ls -ltr file2.txt
-rw-r--r-- 1 root root 20 Dec 19 12:15 file2.txt
root@8c0a1d9ae67b:/#
```

Step 21: Exit Again and Confirm Stopped

Commands:

```
exit
docker ps
```

```
root@8c0a1d9ae67b:/# exit
exit

HP@DESKTOP-I9M74R1 MINGW64 ~
$ docker ps
CONTAINER ID   IMAGE     COMMAND   CREATED   STATUS    PORTS     NAMES

HP@DESKTOP-I9M74R1 MINGW64 ~
$
```

Step 22: List All Containers Before Cleanup

Command: `docker ps -a`

```
HP@DESKTOP-I9M74R1 MINGW64 ~
$ docker ps -a
CONTAINER ID   IMAGE         COMMAND    CREATED          STATUS                      PORTS     NAMES
8c0a1d9ae67b   ubuntu        "bash"     53 minutes ago   Exited (0) 7 minutes ago              my-ubuntu
d53eb832d951   hello-world   "/hello"   2 hours ago      Exited (0) 2 hours ago                cool_hodgkin

HP@DESKTOP-I9M74R1 MINGW64 ~
$
```

Step 23: Remove the Container

Commands:

```
docker rm my-ubuntu && docker ps -a
```

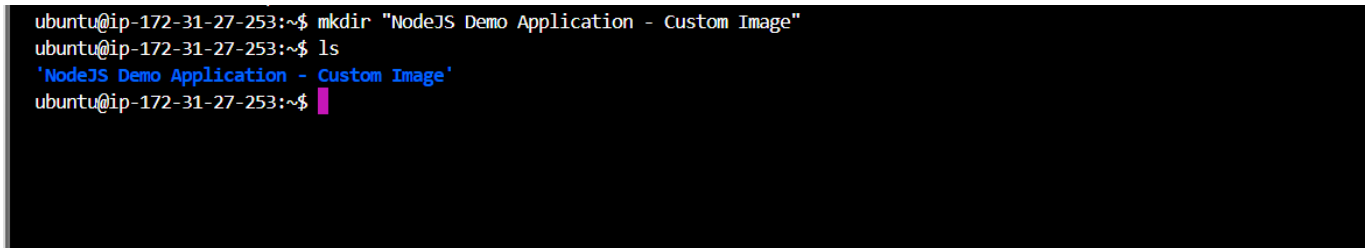
Session 2: Building & Orchestrating a Custom Node.js Profile Editor Application

This session demonstrates building a full-stack web application with persistent data storage, deployed on an AWS EC2 instance.

Step 24: Create Project Directory

Command:

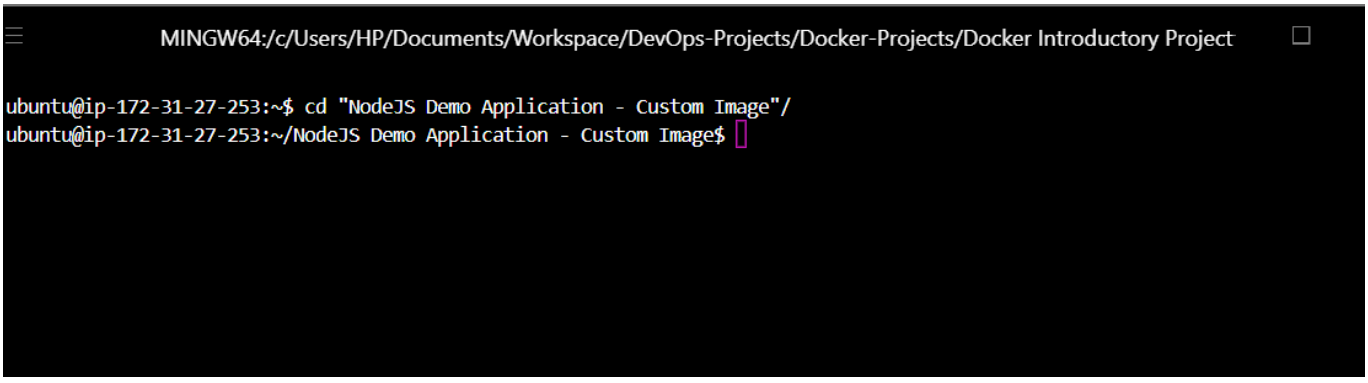
```
mkdir "NodeJS Demo Application - Custom Image"
ls
```



Step 25: Navigate into Project Folder

Command:

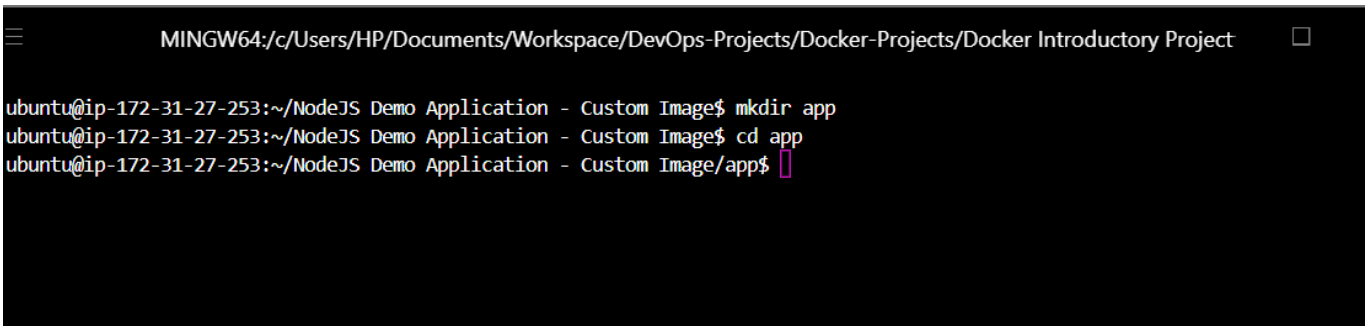
```
cd "NodeJS Demo Application - Custom Image"
```



Step 26: Create and Enter app Directory

Commands:

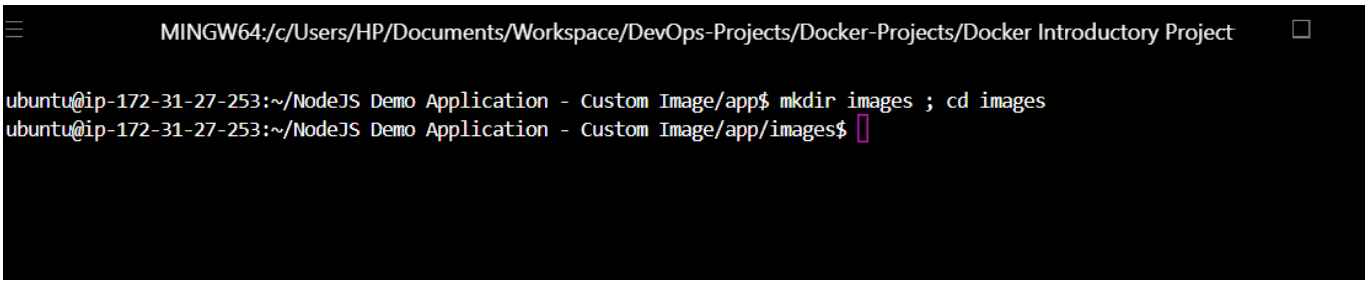
```
mkdir app
cd app
```



Step 27: Create `images` Directory

Commands:

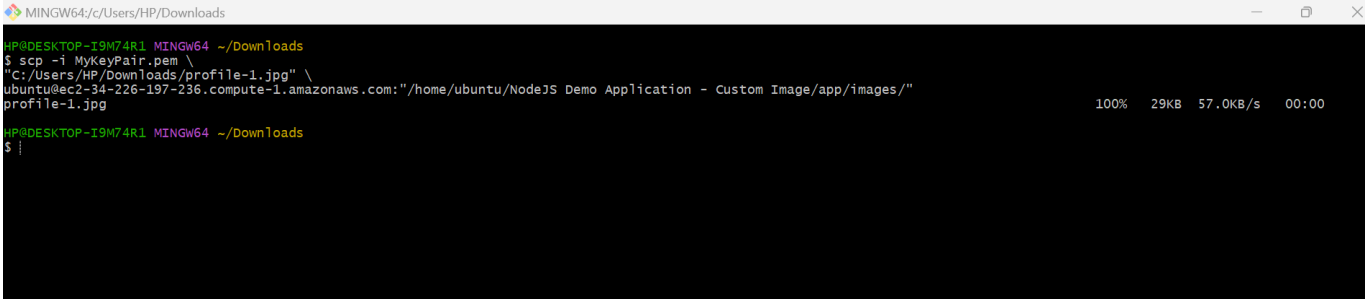
```
mkdir images ; cd images
```



Step 28: Upload Profile Image via SCP

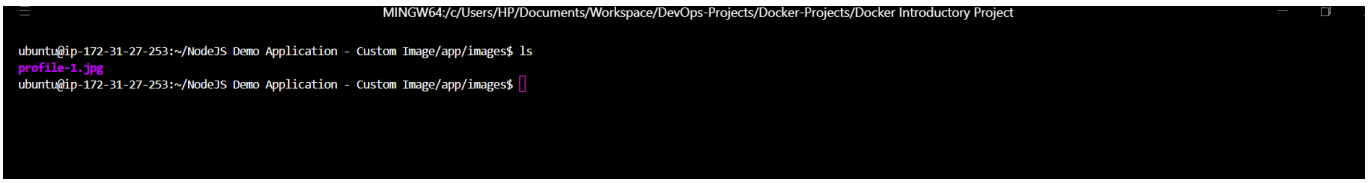
Command (from local machine):

```
scp -i your-key.pem profile-1.jpg ubuntu@<ec2-ip>:~/NodeJS\ Demo\ Application\ -\
Custom\ Image/app/images/
```



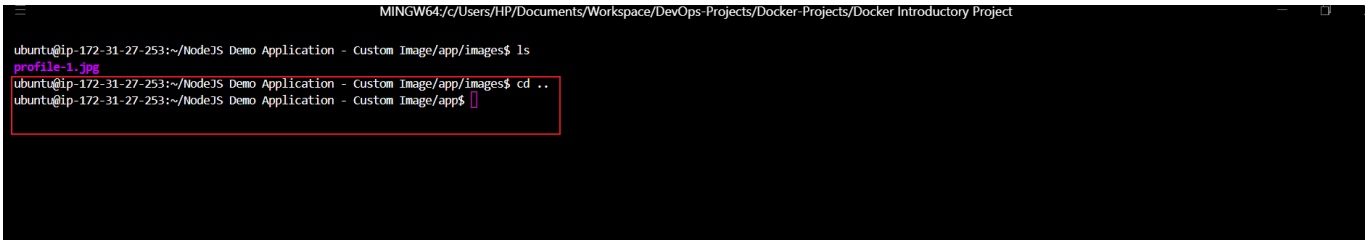
Step 29: Verify Image Upload

Command: `ls`



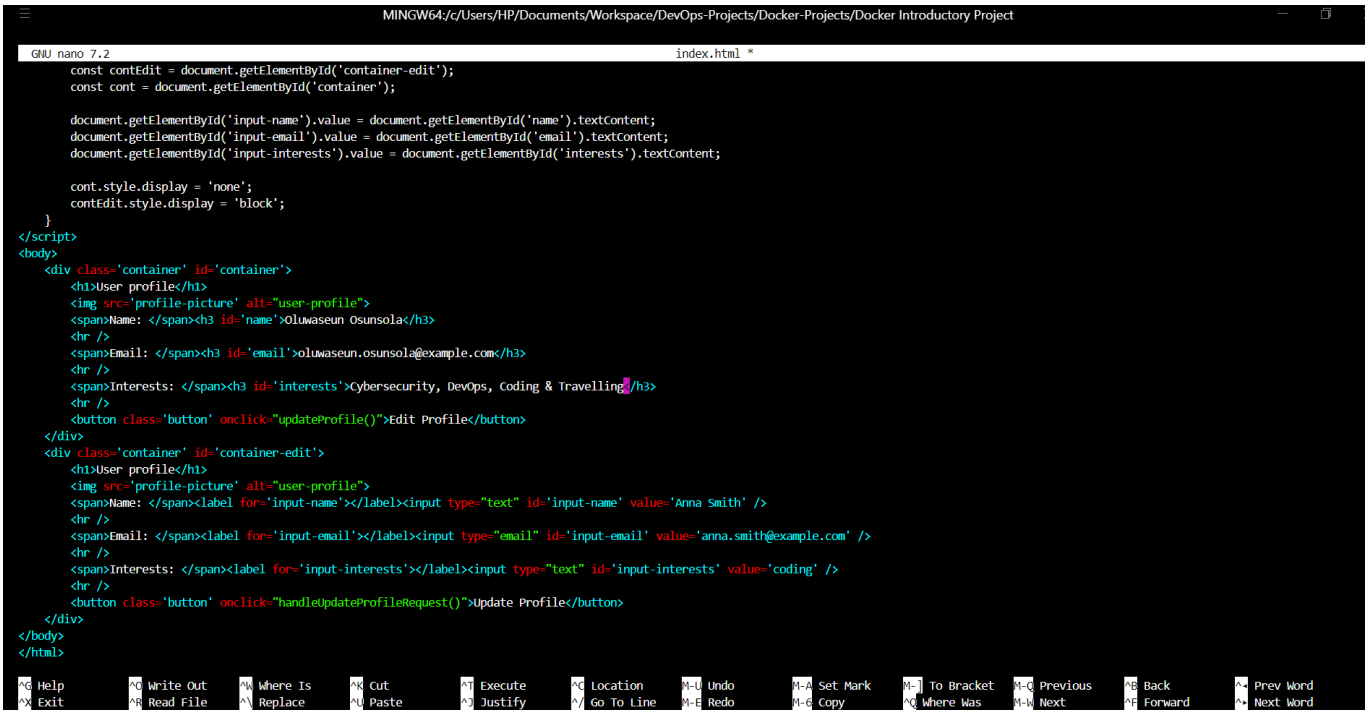
Step 30: Return to `app` Directory

Command: `cd ..`



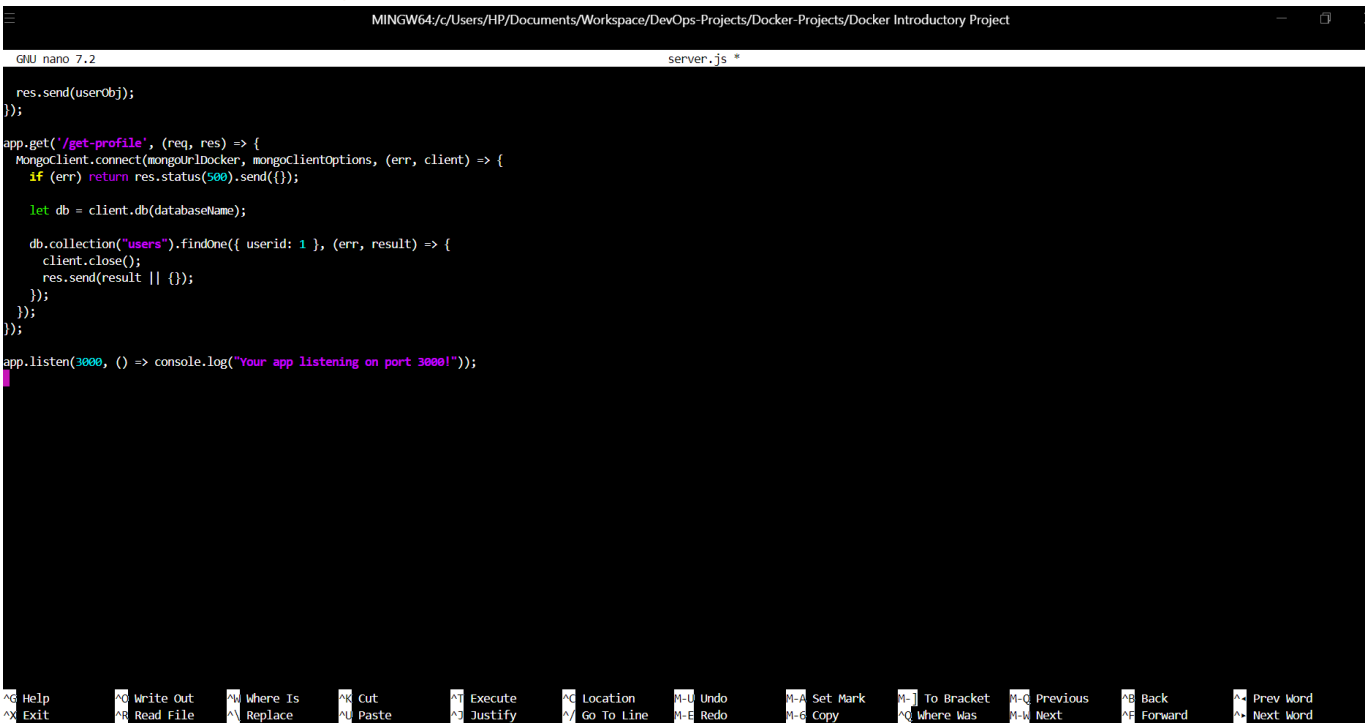
Step 31: Create `index.html` (Frontend)

Command: `nano index.html`



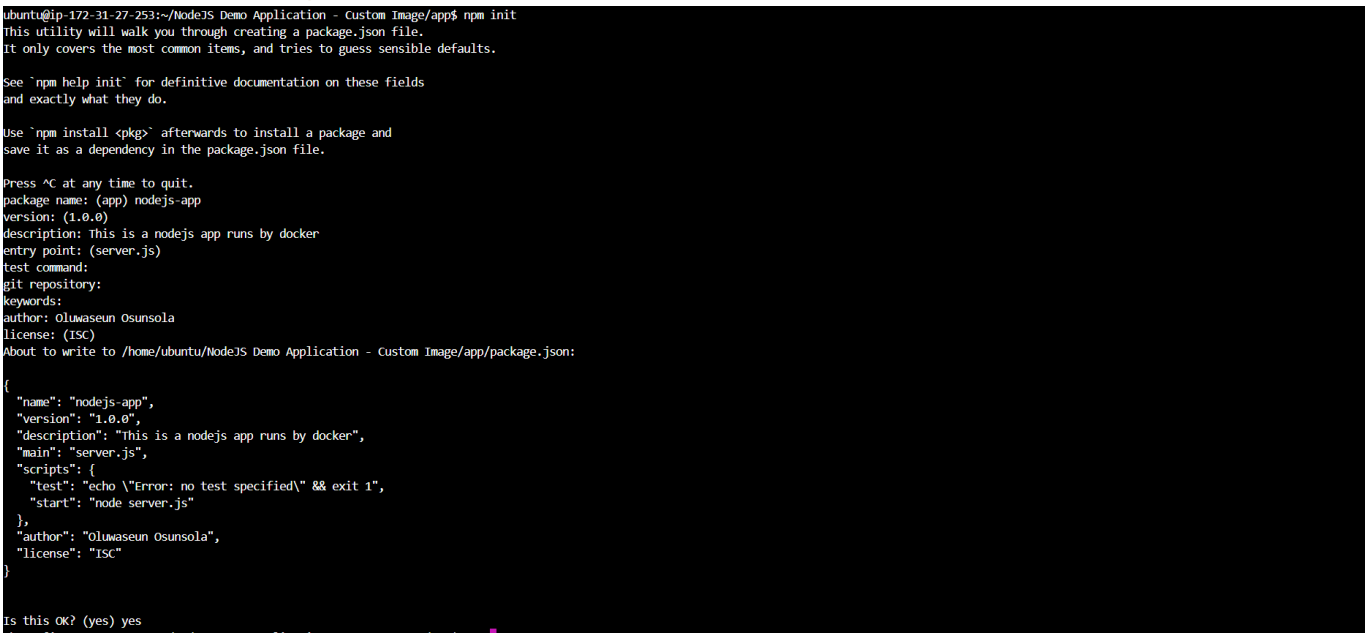
Step 32: Create `server.js` (Express Backend)

Command: `nano server.js`



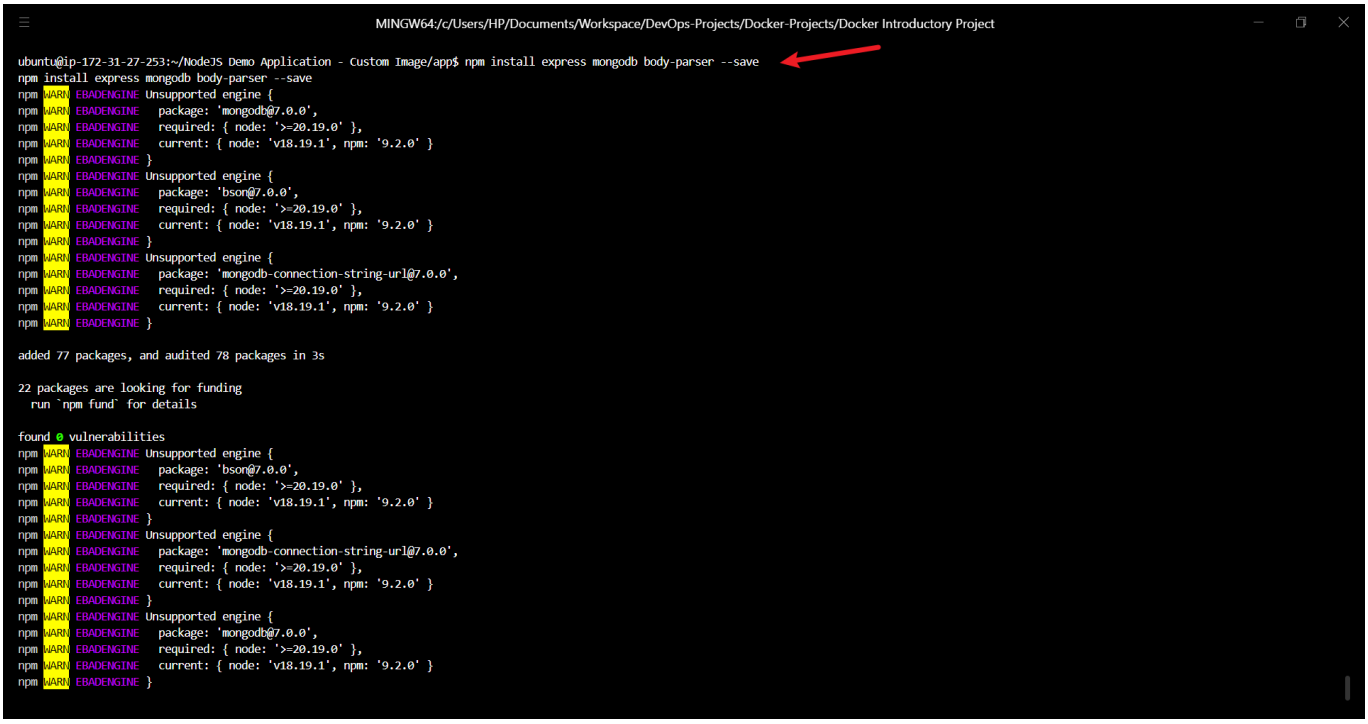
Step 33: Initialize npm Project

Command: `npm init -y`



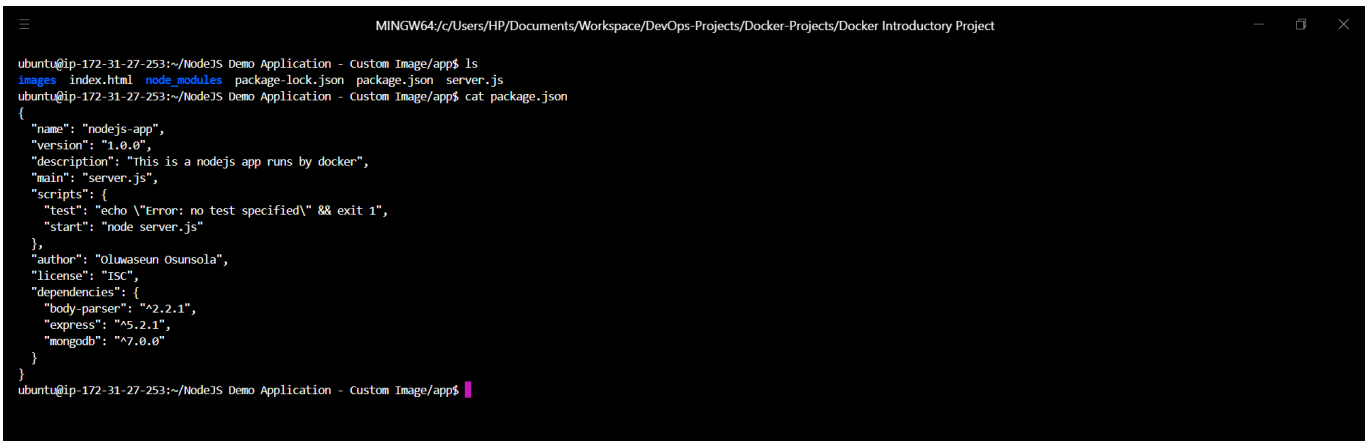
Step 34: Install Dependencies

Command: `npm install express body-parser mongodb dotenv`



Step 35: Verify Installed Packages

Commands: `ls && cat package.json`



Step 36: Return to Project Root

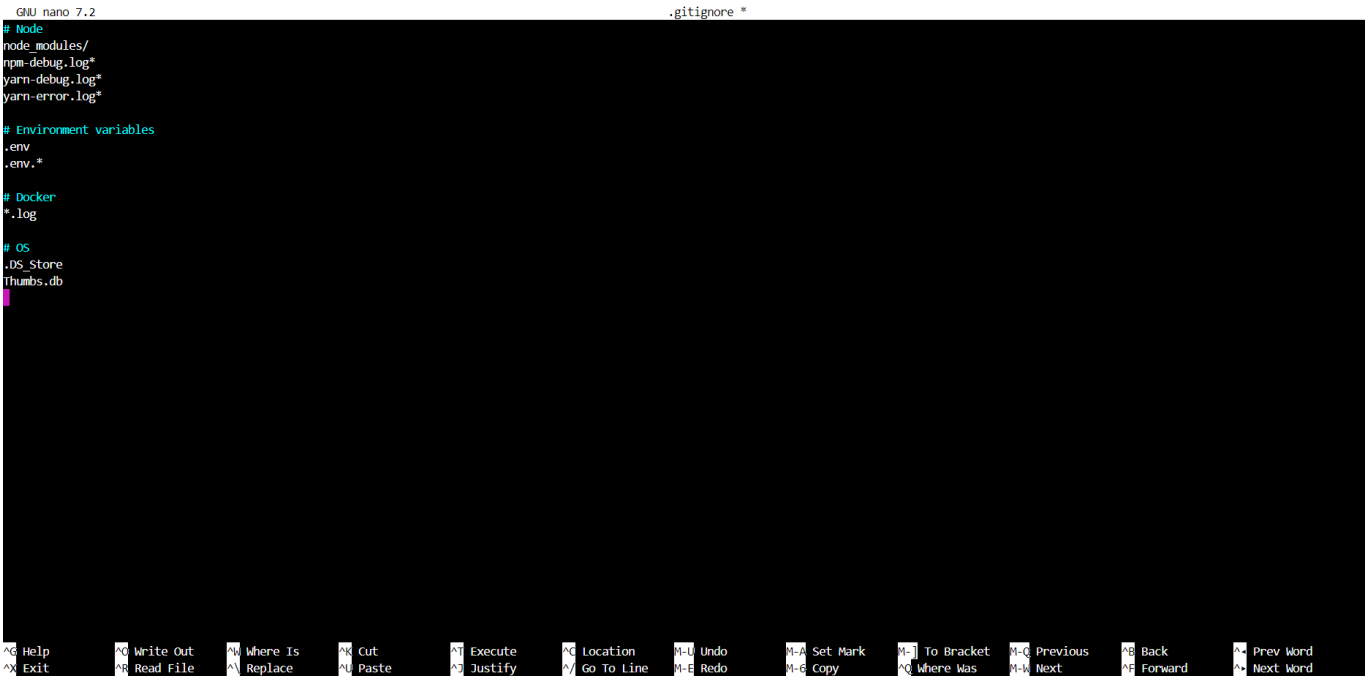
Command: `cd ..`

Step 37: Create `.env` File

Secure storage of MongoDB credentials.

Step 38: Create `.gitignore`

Content: `node_modules/`, `.env`

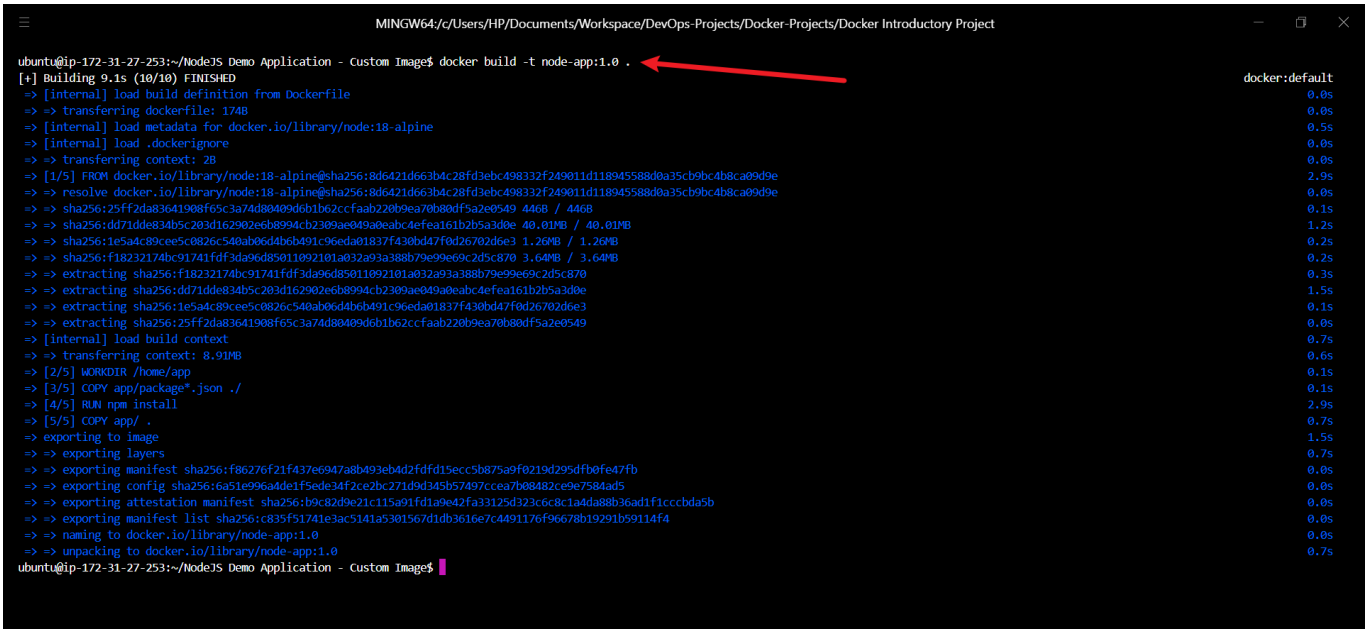


Step 39: Create `Dockerfile`

Multi-stage build for Node.js application.

Step 40: Build Custom Image

Command: `docker build -t node-app:1.0 .`

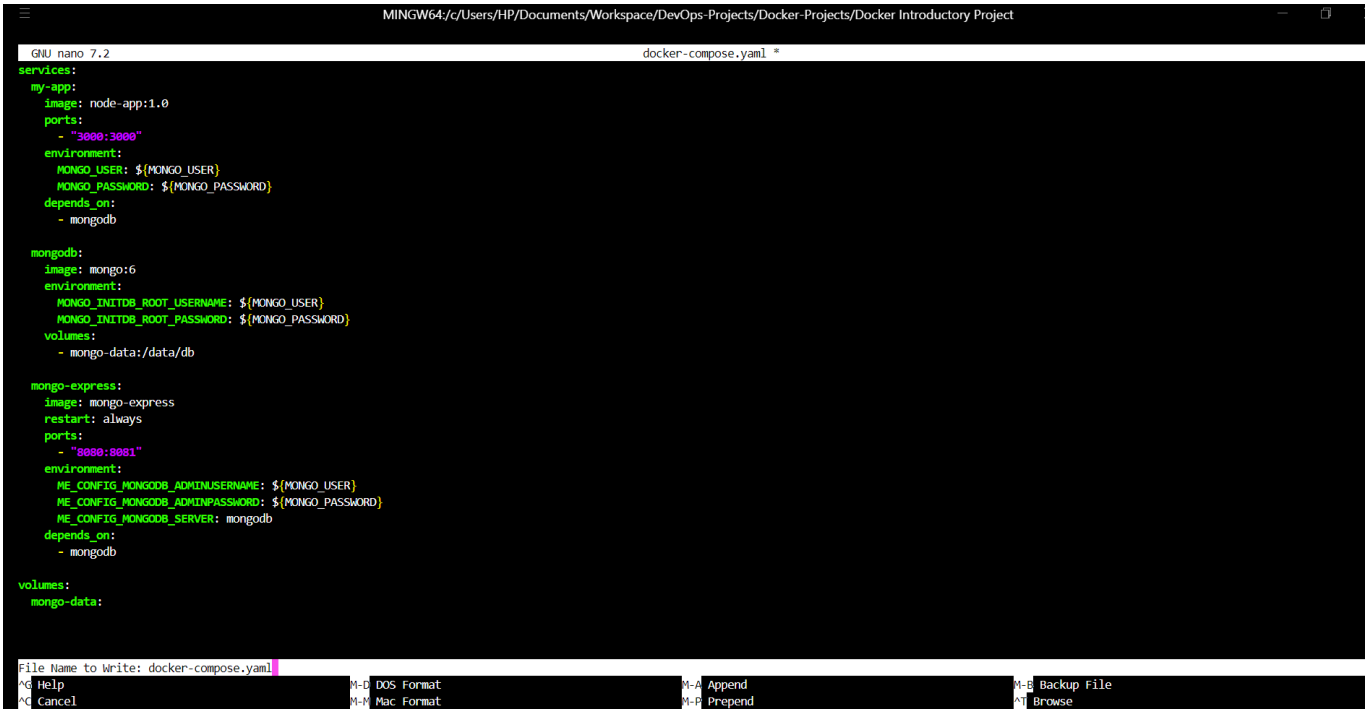


Step 41: Verify Custom Image

Command: `docker images`

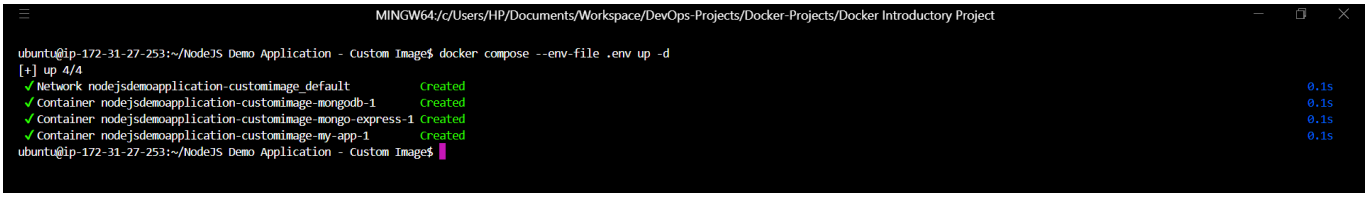
Step 42: Create `docker-compose.yml`

Orchestrates `my-app`, `mongodb`, and `mongo-express` services with volumes and networks.



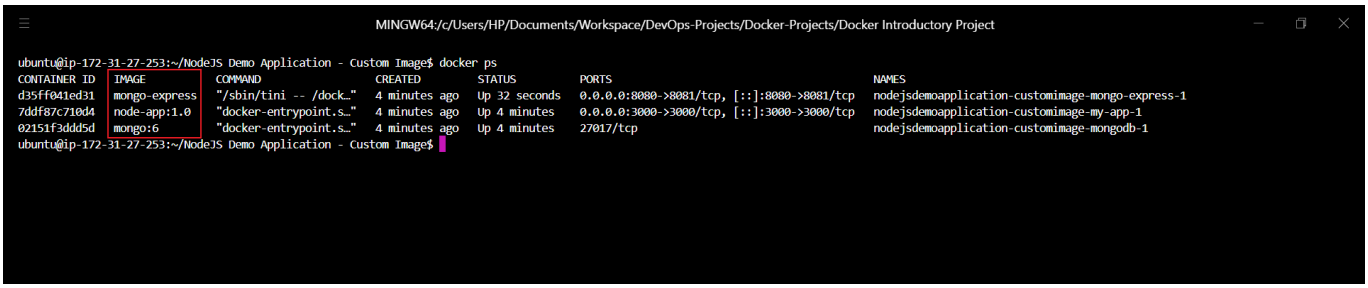
Step 43: Start Application Stack

Command: `docker compose --env-file .env up -d`



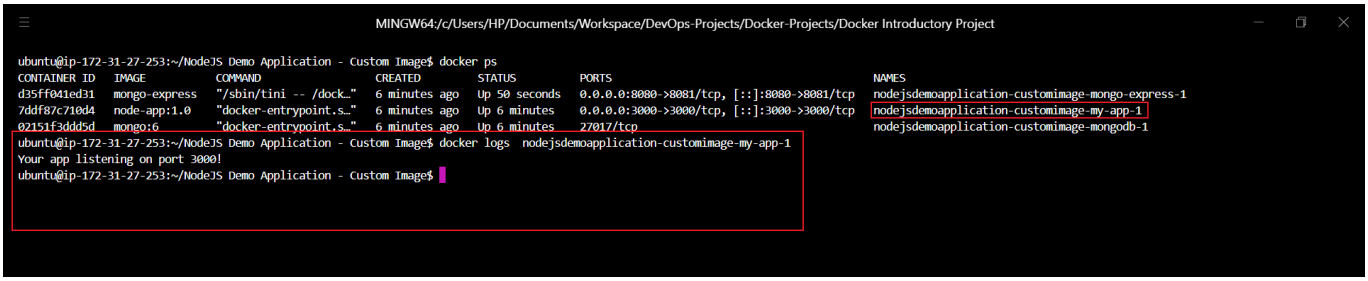
Step 44: Verify Running Containers

Command: `docker ps`



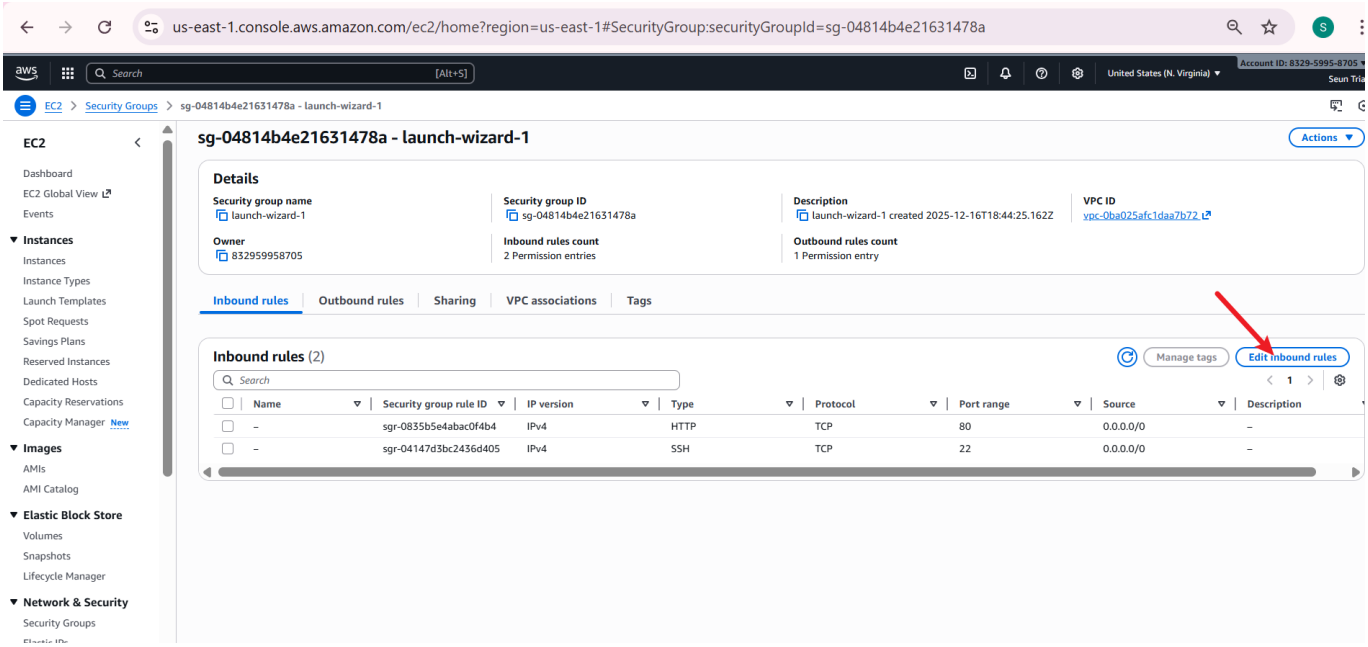
Step 45: Check Application Logs

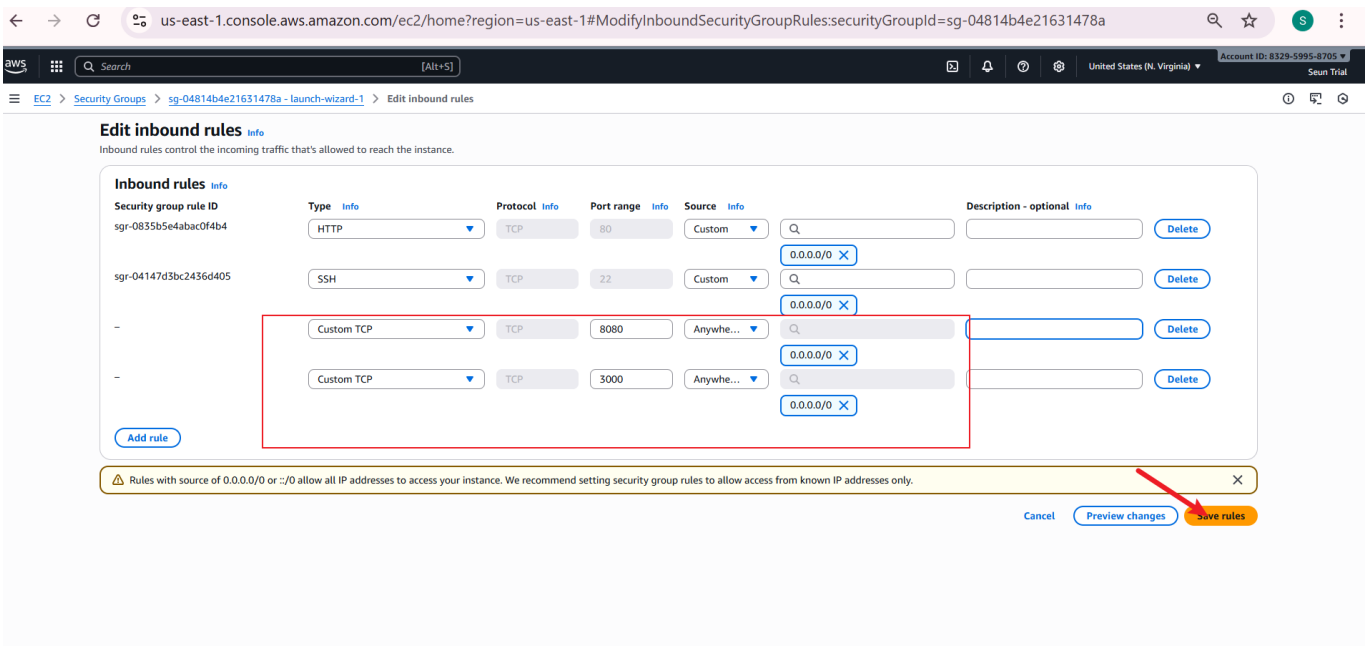
Command: `docker logs <container-name>`



Step 46: Configure EC2 Security Group

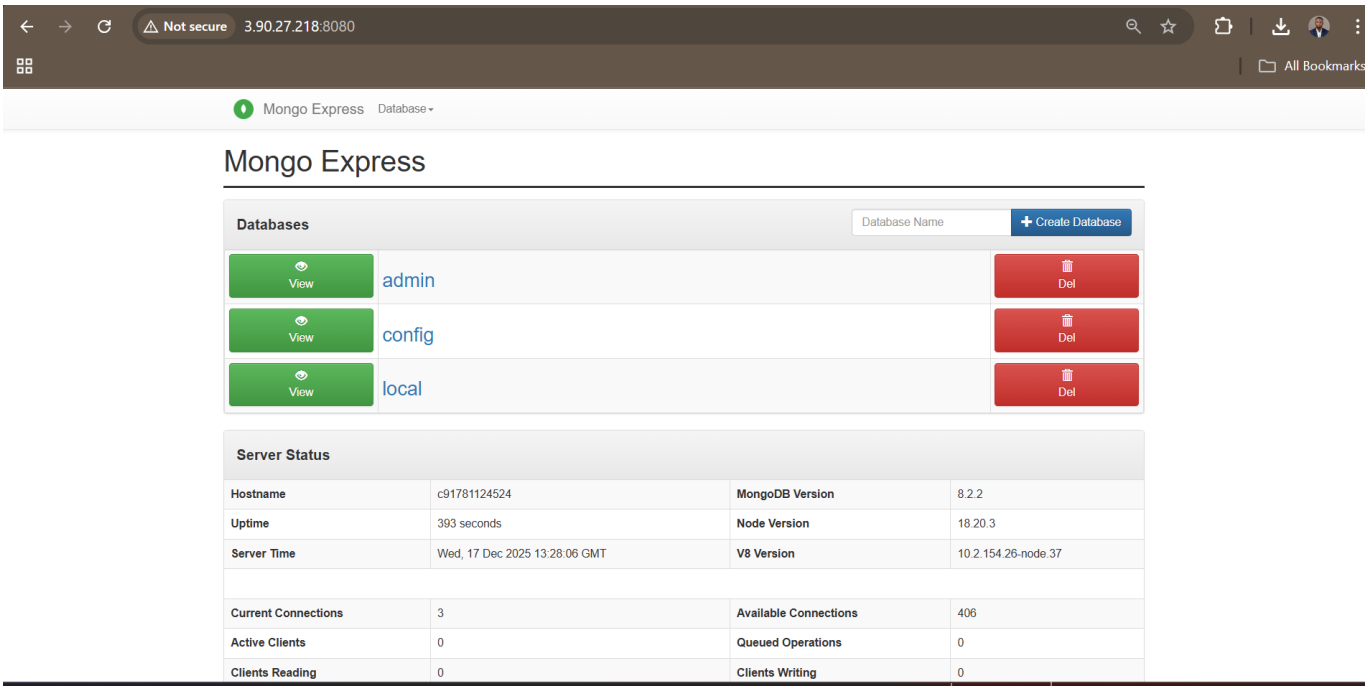
Open ports 3000 and 8080.



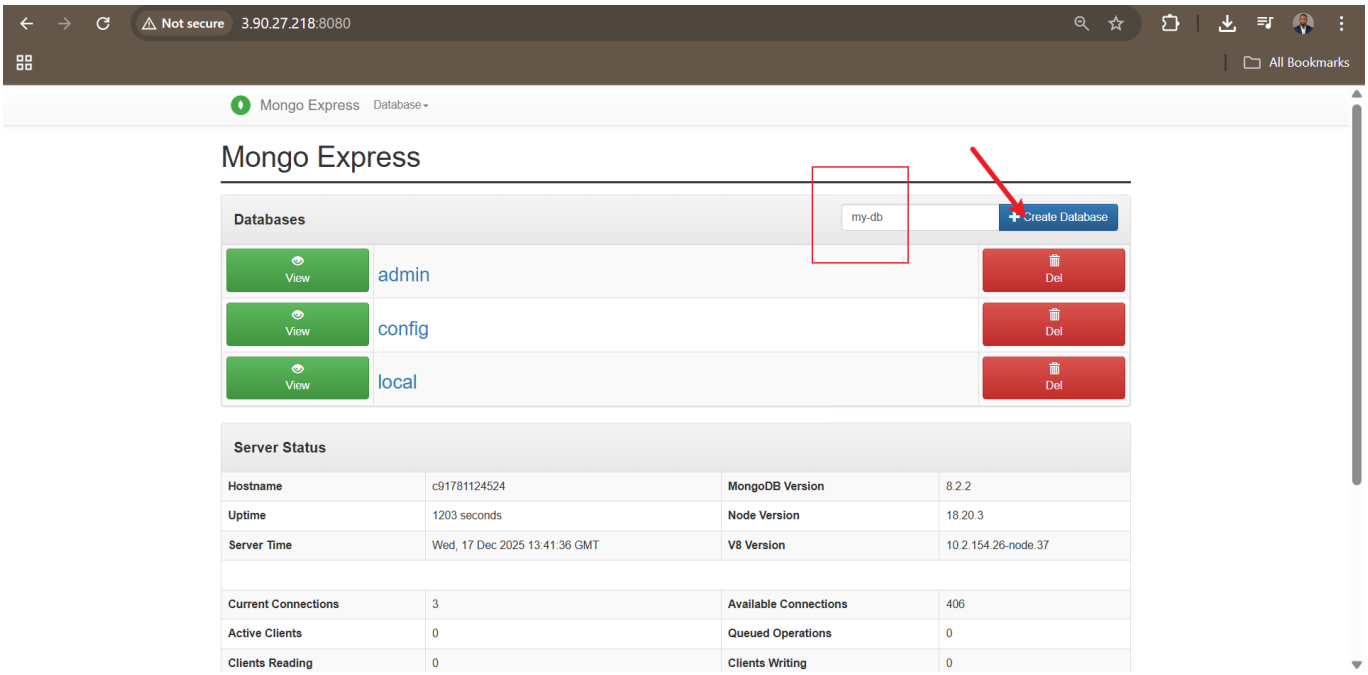


Step 48: Access Mongo Express Admin UI

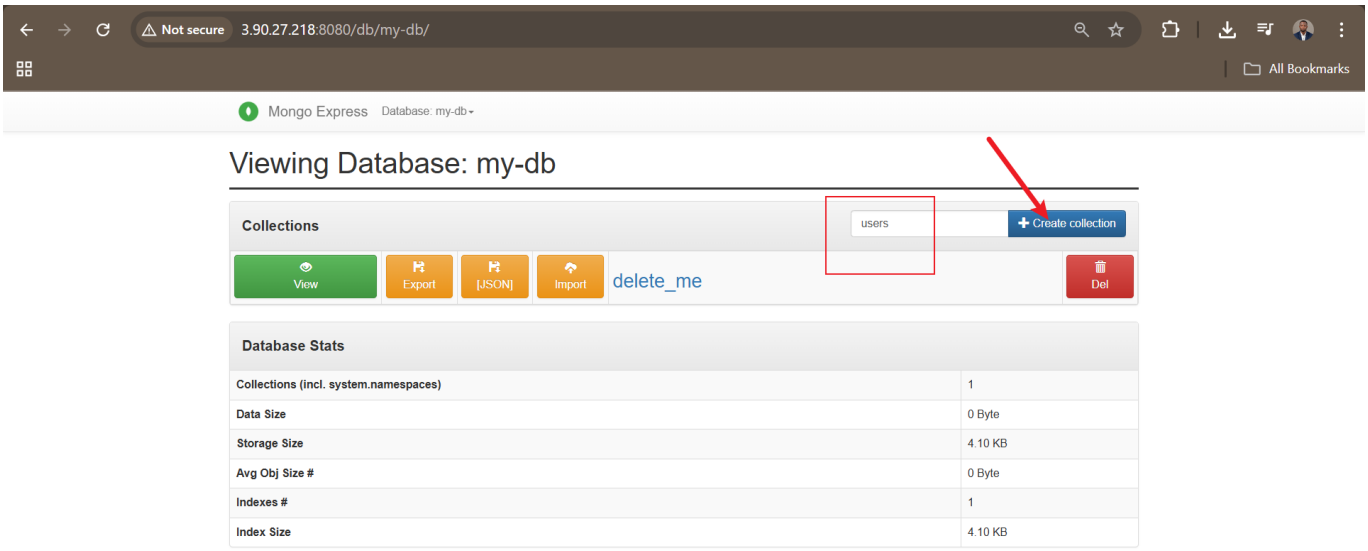
`http://<ec2-public-ip>:8080`



Step 49: Create Database `my-db`

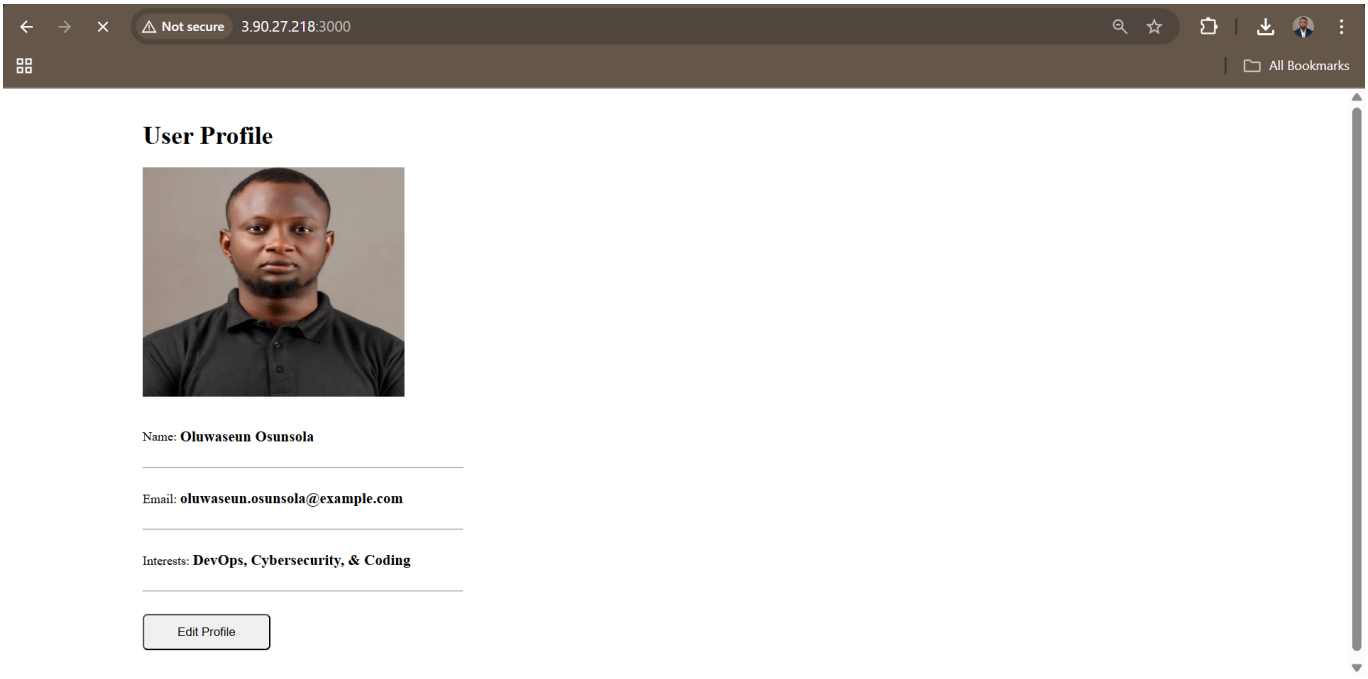


Step 50: Create `users` Collection



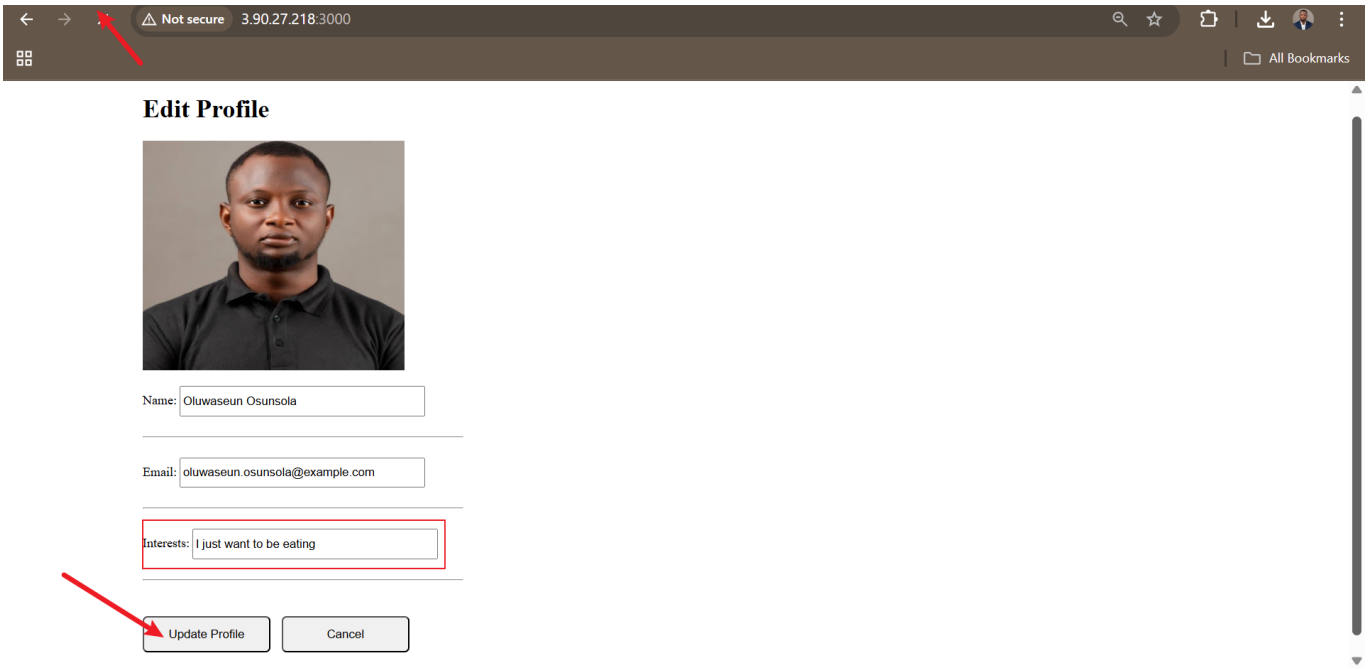
Step 51: Access Profile Editor Application

`http://<ec2-public-ip>:3000`



Step 52: Test Data Persistence

Edit profile → Save → Reload → Changes persist via MongoDB



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4. Key Learning Outcomes

- Complete mastery of Docker container lifecycle and management commands
- Ability to build optimized, versioned custom images using Dockerfile
- Proficiency in orchestrating multi-container applications with Docker Compose
- Secure handling of environment variables and secrets
- Implementation of persistent storage across container restarts
- Real-world deployment and networking configuration in cloud environments
- Full-stack application integration with database persistence

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5. Conclusion

This dual-session Docker Mastery Project successfully bridges foundational container operations with advanced production-grade application development and orchestration.

Session 1 established strong command-line proficiency and deep understanding of container behavior, persistence, and lifecycle management.
Session 2 elevated these skills into a complete DevOps workflow: building custom images, managing dependencies securely, orchestrating interdependent services, and deploying a fully functional, persistent web application in the cloud.

The hands-on execution across 52 documented steps demonstrates professional-level competency in containerization—critical for roles in **DevOps**, **DevSecOps**, and **Cloud Engineering**.

This project serves as a solid portfolio piece showcasing practical expertise in modern container technologies and prepares for advanced topics such as CI/CD pipelines, image security scanning, Kubernetes orchestration, and production monitoring.

Future Enhancements:

- Integrate CI/CD with GitHub Actions and Docker Hub
- Add image vulnerability scanning (Trivy/Grype)
- Implement HTTPS with Nginx reverse proxy and Let's Encrypt
- Scale with Docker Swarm or migrate to Kubernetes
- Add authentication and input validation for enhanced security

Mastery of these concepts positions you at the forefront of cloud-native development and infrastructure management.