CI/CD Pipeline Implementation with Student Management System

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CMSE 520: Software Evolution and Maintenance

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Oct 31, 2024

Contents

Problem Definition

Modern software development faces challenges in consistently and reliably delivering updates from development to production environments. Manual deployment processes are error-prone, time-consuming, and can lead to environment inconsistencies. While implementing Continuous Integration and Continuous Deployment (CI/CD) pipelines is a solution to these challenges, setting up such pipelines involves complex integration of multiple tools and practices.

This project addresses these challenges by demonstrating a complete CI/CD pipeline implementation using a simple CRUD application. The project will showcase how various DevOps tools and practices integrate to create an automated software delivery pipeline, from code commit to deployment. By using a basic web application (managing student records) as the demonstration platform, the focus remains on the CI/CD implementation rather than application complexity.

The solution will demonstrate:

- Automated build and test processes triggered by code changes
- Containerization for consistent environments
- Automated deployment to a local Kubernetes cluster
- Database integration within the CI/CD pipeline
- Basic monitoring and logging capabilities

This should give future developers and maintainers a practical reference for implementing similar pipelines in their own projects.

List of Functional Requirements

- Source Control Management and Code Integration

    - The system must automatically trigger pipeline processes when code is committed to GitHub
    - All code changes must be version controlled and tracked
    - The system must maintain separate branches for development and production code
    - Database migration scripts must be version controlled alongside code changes
- Automated Build and Test Execution
    - The system must automatically build the application when new code is committed
    - The system must execute unit tests and integration tests automatically
    - The system must fail the build if any tests fail
    - Test results must be logged and accessible
- Automated Deployment Process
    - The system must automatically create Docker containers for both frontend and backend
    - The system must deploy the containerized application to local Kubernetes cluster
    - The system must execute database migrations during the deployment process
    - The system must support rollback capabilities if deployment fails
- Student Record Management (CRUD Operations)
    - The system must store and manage student records with the following properties: StudentId (unique identifier), FirstName, LastName, DateOfBirth, and Email
    - The system must allow creating, retrieving, updating, and deleting student records

List of Non-Functional Requirements

- Deployment Performance

    - The complete CI/CD pipeline execution (from commit to deployment) must complete within 10 minutes
    - Container images must not exceed 500MB in size
    - Database migration scripts must execute within 30 seconds
- Reliability and Stability
    - The system must maintain data consistency during deployments
    - The pipeline must provide clear error messages when builds or deployments fail
    - Failed deployments must automatically rollback to the last stable version
    - Pipeline status and logs must be retained for at least 30 days
- Maintainability
    - All Docker configurations must be defined in Dockerfile and docker-compose files
    - Kubernetes configurations must be defined as YAML manifests
    - Pipeline configurations must be version controlled using GitHub Actions YAML files
    - Code must follow standard naming conventions and include comments
- Monitoring and Logging
    - Pipeline execution status must be visible through GitHub Actions dashboard
    - Deployment logs must be accessible through Kubernetes dashboard

List of Actors and Their Services

Developer Services:

- Commit code changes to GitHub repository
- Create and commit database migration scripts
- Review pipeline execution status and logs

- Execute tests locally
- Access deployment logs and monitoring metrics
- Rollback deployments if needed

CI/CD Pipeline (System Actor) Services:

- Automatically trigger builds on code commits
- Execute automated tests
- Build Docker containers
- Apply database migrations
- Deploy applications to Kubernetes
- Provide status updates and logs
- Perform automatic rollbacks on failure

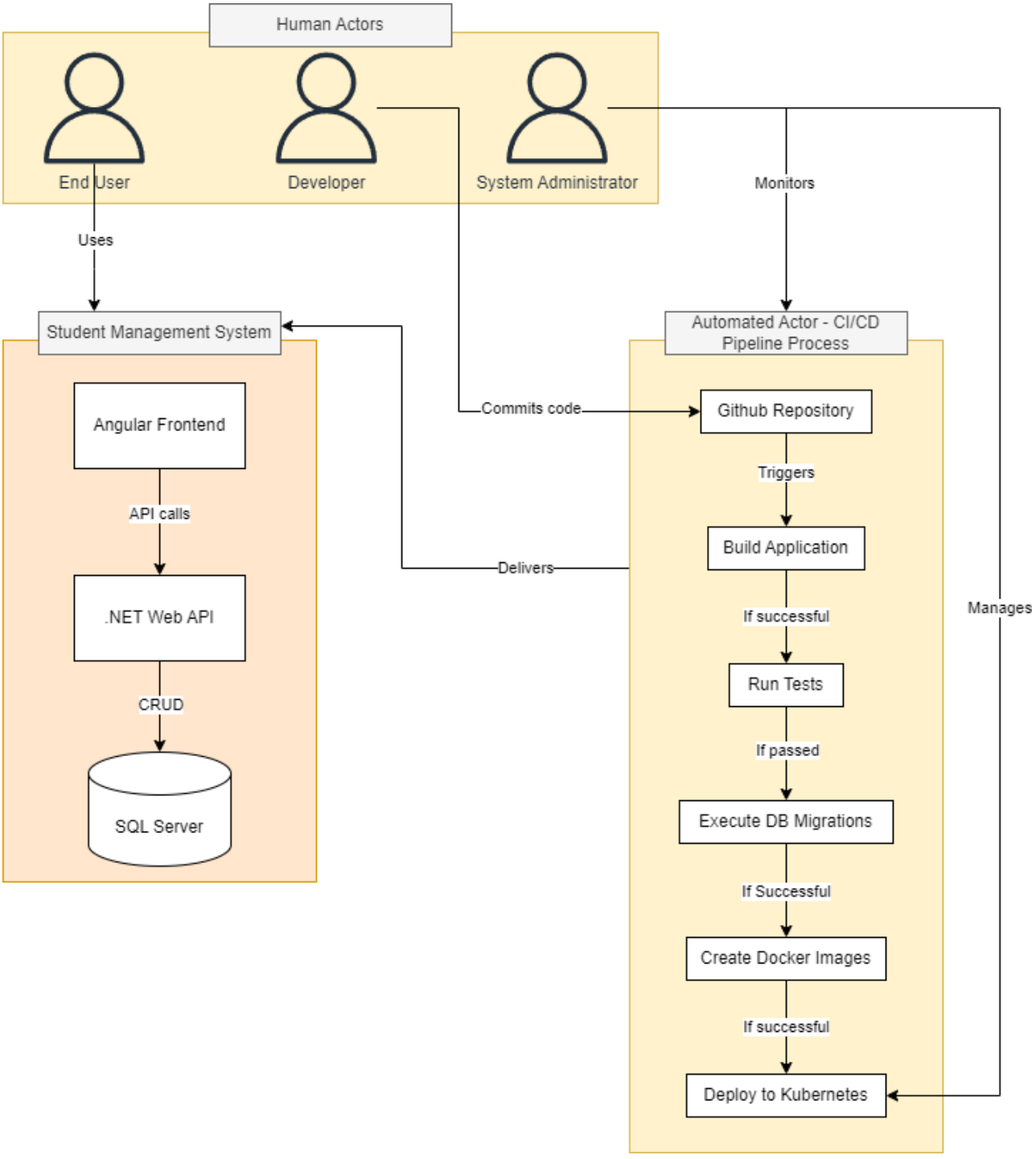
End User (Student Management System User) Services:

- View student records
- Add new student records
- Update existing student records
- Delete student records

System Administrator Services:

- Monitor system health and performance
- Access Kubernetes dashboard
- View application logs
- Manage container registry
- Configure pipeline settings
- Maintain infrastructure components

Context diagram of the system



Tools to be used

Development Tools

- Visual Studio 2022 (Backend development)
- Visual Studio Code (Frontend development)
- Git (Version control client)

Framework & Languages

- .NET 8 (Backend framework)
- Angular (Frontend framework)
- SQL Server (Database)

Pipeline & Containerization Tools

- GitHub (Source code repository & version control)
- GitHub Actions (CI/CD pipeline automation)
- Docker Desktop (Containerization)
- Kubernetes (Container orchestration)
- Minikube/Docker Desktop's Kubernetes (Local Kubernetes cluster)

Testing Tools

- XUnit (Unit testing framework)
- Moq (Mocking framework for testing)

Monitoring & Management Tools

- Kubernetes Dashboard (Container management)
- Docker Desktop Dashboard (Container monitoring)

Feasibility Analysis

Technical Feasibility

- All required tools are freely available and well-documented
- Development team has experience with .NET and SQL Server
- Local deployment using Docker Desktop and Kubernetes eliminates cloud service costs
- The technology stack is modern and widely supported by the developer community
- Project complexity is manageable as it focuses on basic CRUD operations

Resource Feasibility

- No additional hardware required beyond development machine
- All tools have community/free editions available
- Local deployment eliminates ongoing infrastructure costs
- Development can be completed using existing development machines

Operational Feasibility

- Local deployment simplifies operations and maintenance
- Docker ensures consistent environments across development and deployment
- Automated pipeline reduces manual intervention and potential errors
- Basic CRUD operations make the system easy to maintain
- Rollback capabilities ensure system can recover from failures

Timeline Feasibility

- Project scope is limited to essential CRUD operations
- Using well-known frameworks reduces development time
- CI/CD automation will speed up deployment processes