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VR-DevOps: Visualizing and Interacting with DevOps Pipelines in Virtual Reality

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- Professor of Computer Science at Aalen University in Germany since 2004, teaching in the areas of software engineering.
- 14 years of software industry experience (in Silicon Valley and Germany).
- Research interest is to leverage technologies, methods, techniques, and tools to innovate, automate, support, and improve the production and quality of software for society.

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Background on DevOps

- DevOps [1][2] is a methodology that combines development (Dev) and operations (Ops) with automation to improve the quality and speed of software deliveries.
  - While there is no universally agreed to definition, key principles include Continuous Integration (CI), Continuous Delivery (CD), shared ownership, workflow automation, and rapid feedback.
- Both the code and tool integration and automation that DevOps addresses has become indispensable to modern software development.
- It has been reported that 83% of developers surveyed reported being involved in DevOps-related activities [3].
- Lately, Security (Sec) has often been included in DevOps, denoted at the stage where it is primarily considered, e.g., DevSecOps [4].

Problem and Challenges VR-DevOps Seeks to Address

Problem: Despite the popularity of DevOps, there are *no visualization standards for pipelines*

Each platform and vendor has their own, can thus be difficult for non-developers to grasp - and hence collaborate regarding - the current state of pipeline runs, and the processes involved in software development, testing, and delivery.

Challenge: Collaboration and communication among stakeholders

- In their systematic review of the DevOps field, Khan et al. [5] identified a lack of collaboration and communication among stakeholders as the primary critical challenge.
- Our contribution leverages VR towards enabling more **intuitive DevOps visualization and interaction capabilities for comprehending and analyzing DevOps pipelines,** thereby supporting **enhanced collaboration and communication** among a **larger spectrum of stakeholders**

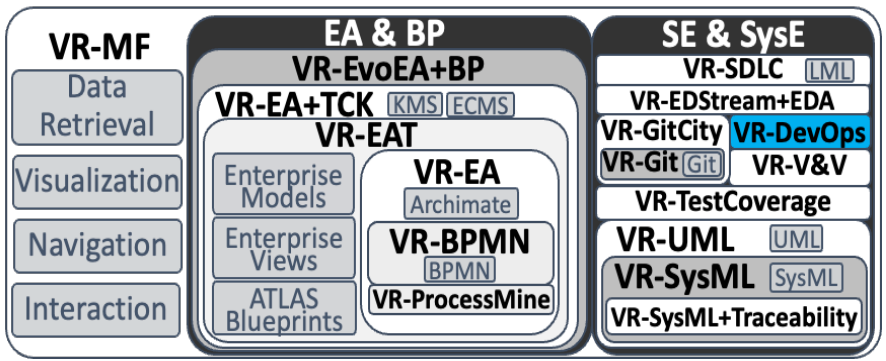
Challenge: DevOps landscape extremely fragmented

- A further challenge is the finding by Giamattei et al. [6] that the landscape for DevOps tools is extremely fragmented, and stakeholders end up accessing various custom webpages or logs.
- Hence, a further goal of our solution concept is to **unify the visualization and information access** across heterogeneous DevOps tools.

VR-DevOps Solution Concept in Relation to our other VR Solutions

- VR-DevOps is based on our generalized VR Modeling Framework (VR-MF) (detailed in [10]).
  - VR-MF provides a VR-based domain-independent hypermodeling framework addressing four aspects requiring special attention when modeling in VR: visualization, navigation, interaction, and data retrieval.

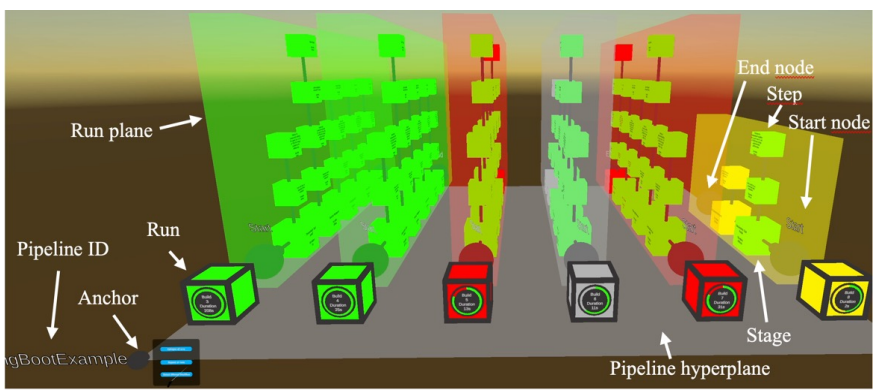
- In the Software Engineering (SE) and Systems Engineering (SysE) areas
  - VR-DevOps (shown in blue)
  - VR-V&V (Verification and Validation) [14] visualizes aspects related to quality assurance
  - VR-TestCoverage [15] visualizes tests coverage
  - VR-Git [7] and VR-GitCity [8] offer different ways of visualizing Git repositories
- In the Enterprise Architecture (EA) and Business Process (BP) space
  - VR-EA [16] supports mapping EA models to VR
    - Including both ArchiMate as well as BPMN via VR-BPMN [10]
  - VR-EAT [17] adds enterprise repository integration
    - Atlas and IT blueprint integration
  - VR-EA+TCK [18] adds knowledge and content integration
  - VR-EvoEA+BP [19] adds EA evolution and Business Process animation
  - VR-ProcessMine [20] supports process mining in VR



Since DevOps (or DevSecOps or DevOpsUse) can be viewed as inter-disciplinary, at least for software organizations we view the EA and BP area as potentially applicable for VR-DevOps to support synergies, more holistic insights, and enhanced collaboration across the enterprise and organizational space.

Solution Concept

- VR-DevOps is a solution concept for visualizing and interacting with heterogenous DevOps pipelines in Virtual Reality (VR).
- VR provides an unlimited immersive space for visualizing and analyzing a growing and complex set of models and their interrelationships simultaneously in a 3D spatial structure viewable from different perspectives.



Visualization in VR

- A horizontal *pipeline hyperplane* represents a pipeline, holding vertical semi-transparent colored boxes called run planes (see figure), which are ordered chronologically left to right.
- A *run plane* represents a pipeline run, which is colored based on status (green=success, yellow=in progress, red=error, grey= aborted).
- Hyperplanes also enable inter-project pipeline differentiation for larger portfolio scenarios involving multiple pipelines.
- The bottom of each run plane encloses a directed graph of sequential stages (cubes) of the pipeline between a start (black sphere) and an end (black sphere)
- Vertically stacked smaller cubes linked with lines above each stage show the internal steps within a stage.
- A cube with black borders is used to represent the entire run, and is all that is shown when a run is collapsed (e.g., to reduce visual clutter); on its front various details are depicted (ID, run duration, circular percentage of stages with status). The visualization form remains consistent across DevOps tools.

Navigation in VR

- Two navigation modes are incorporated in our solution: default gliding controls for fly-through VR, while teleporting instantly places the camera at a selected position via a selection on the VR-Tablet. Teleporting is potentially disconcerting, but may reduce the likelihood of VR sickness.

Interaction in VR

- User-element interaction is supported primarily through VR controllers and a *VR-Tablet*. The VR-Tablet is used to provide detailed context-specific element information. It includes a virtual keyboard for text entry via laser pointer key selection. On a hyperplane corner, an anchor sphere affordance (labeled with its pipeline ID) supports moving, hiding (collapsing), or showing (expanding) hyperplanes, as shown in the bottom left of the figure.

Realization

- VR visualization aspects were implemented using Unity.
- The Data Hub is implemented in Python and integrates and stores all data in JSON.
- The MongoDB Atlas cloud is used for storage
  - Can easily be switched to a local MongoDB
- Integration via Adapters
  - All integrations with DevOps tools use their Web APIs via our tool-specific Adapters in our Data Hub.
  - To demonstrate the tool or platform independence (i.e., heterogeneity) of our solution concept, we chose to integrate with
    - Jenkins to exemplify a private (local) cloud tool
    - SemaphoreCI to exemplify a public cloud tool


```
"name": "SpringBootExample",
"runs": [
  {
    "id": "6",
    "name": "#6",
    "status": "ABORTED",
    "durationMillis": 11910,
    "stages": [
      {
        "id": "8",
        "name": "Declarative: Tool Install",
        "status": "SUCCESS",
        "durationMillis": 160,
        "steps": [
          {
            "id": "9",
            "name": "Use a tool from a predefined Tool Installation",
            "status": "SUCCESS",
            "durationMillis": 47,
            "errorMessage": "",
            "description": [
              "maven3"
```

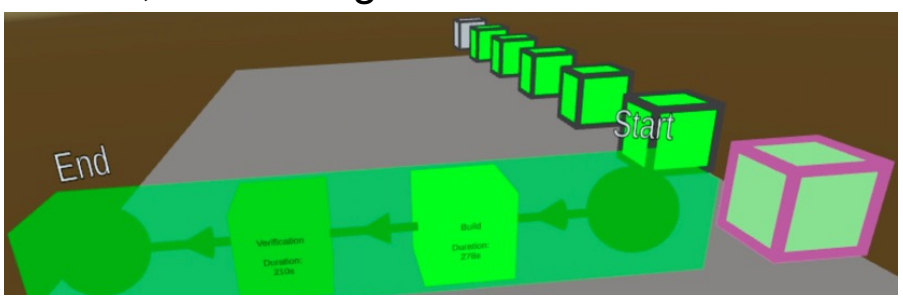

- A CD pipeline is an automated expression of the process for preparing software for delivery.
  - A Jenkins pipeline is a set of Jenkins plugins with a set of instructions specified in a text-based Jenkinsfile using Groovy syntax.
    - It can be written in a scripted or declarative syntax, and typically defines the entire build process, including building, testing, and delivery. Concepts involved can include agents (executors), nodes (machines), stages (subset of tasks), and steps (a single task).
  - A SemaphoreCI pipeline is described via YAML syntax.
- We created our own common generic JSON format to store pipeline information shown in the figure.
  - A pipeline instance refers to a run. The refresh rates can be configured for Data Hub state retrieval from Unity and for each Adapter's Web APIs calls.

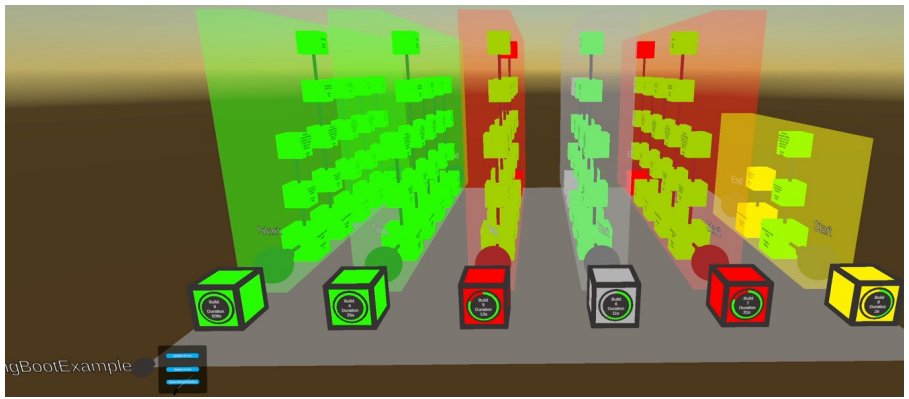
Evaluation

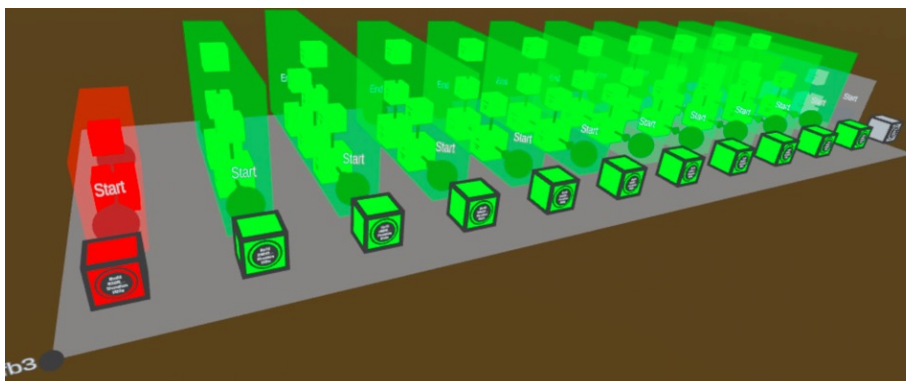
- The evaluation of our solution concept is based on the design science method and principles [22], in particular a viable artifact, problem relevance, and design evaluation (utility, quality, efficacy).
- A scenario-based case study is used (assuming the user may not be a developer):
  - The Status scenario focuses on comprehension (run state, number of runs),
  - The Analysis scenario focuses on information retrieval (towards problem identification or resolution).
- To demonstrate the heterogeneity of the solution, screenshots of runs from Jenkins or SemaphoreCI are interchangeably used.
- For Jenkins, the SpringBoot PetClinic example pipeline [23] includes 39 Java files and 1335 Lines of Code (LOC).
- For SemaphoreCI, the Android App example pipeline [24] includes 13 Kotlin files and 287 LOC.
- An additional step with an artificial error was inserted into the SpringBoot example for illustration purposes in a second version of the pipeline.

Evaluation: Status Scenario

- Analogous to a dashboard, a VR-DevOps stakeholder should be able to readily comprehend and assess the current status and state of the various pipeline runs, exemplified for Jenkins in the top right figure and SemaphoreCI in bottom right figure.
- Each run may execute different steps and stages (e.g., due to an abort or error). Fully collapsed run planes provide a purely high-level overview with relevant info on the black-lined cubes, as in the figure below.

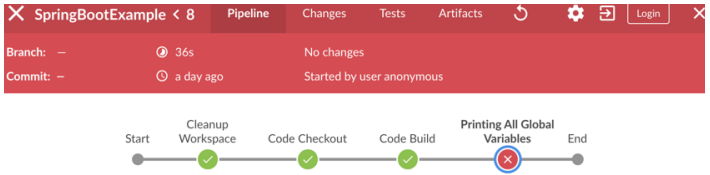


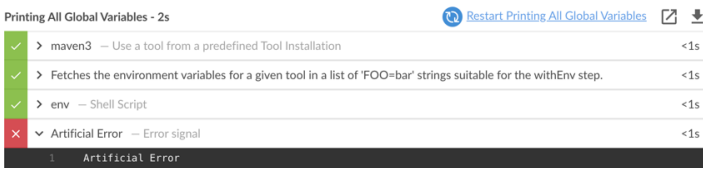


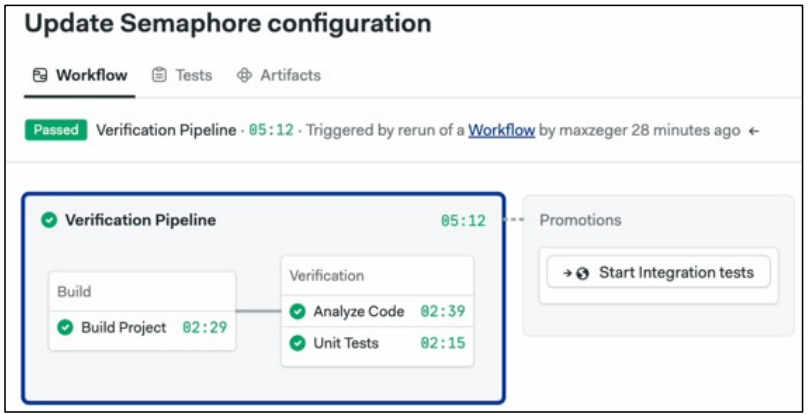


Evaluation: Status Scenario

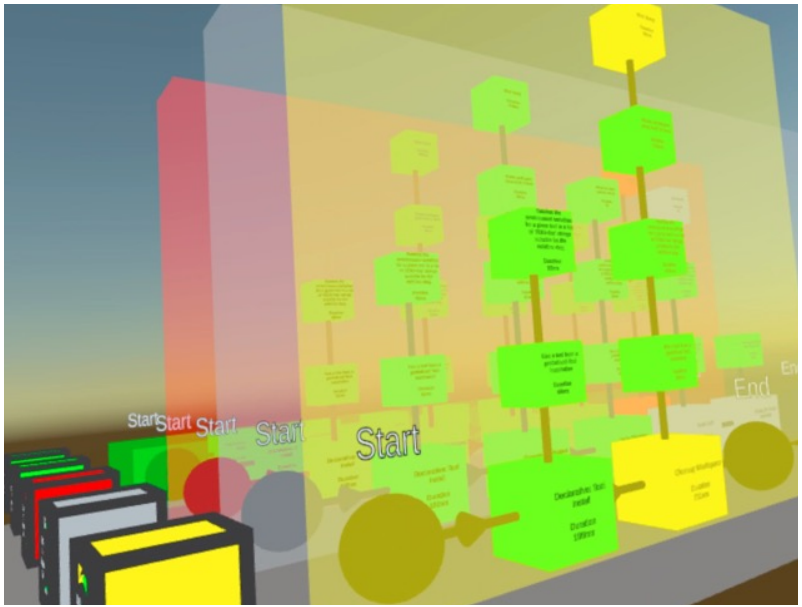
- In contrast, every DevOps tool has its own web interface and way of accessing information, illustrated via screenshots of Jenkins in the top right and SemaphoreCI in the bottom right.
- Retrieval of equivalent status and state details typically requires multiple separate web page requests, thus VR-DevOps supports utility and efficacy, especially for increasing pipeline complexity, pipeline versions, and large scale-out of runs.

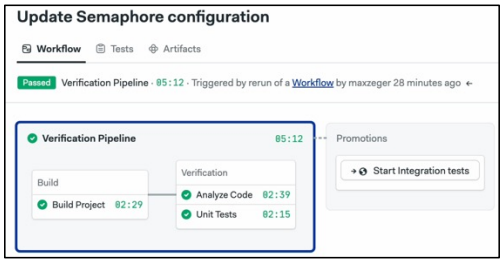






Evaluation: Analysis Scenario

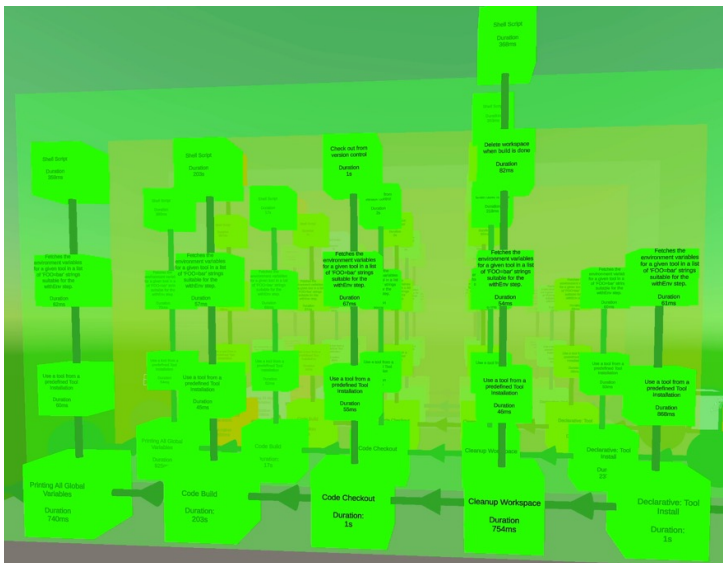


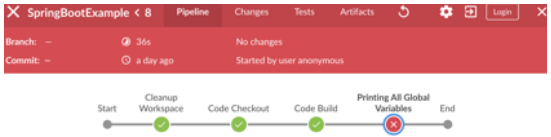


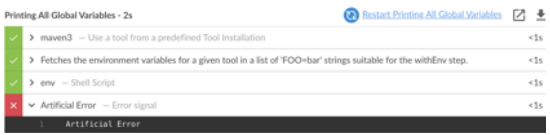

```yaml
version: v1.0
name: Verification Pipeline
agent:
  machine:
    type: e1-standard-2
    os_image: ubuntu2004
  containers:
    - name: main
      image: 'registry.semaphoreci.com/android:29'
global_job_config:
  env_vars:
    - name: ADB_INSTALL_TIMEOUT
      value: '10'
  prologue:
    commands:
      - checkout
      - cache restore gradle-wrapper
      - cache restore gradle-cache
      - cache restore android-build
blocks:
  - name: Build
    task:
      jobs:
        - name: Build Project
          commands:
            - ./gradlew bundleDebug
      epilogue:
        on_pass:
          commands:
            - cache clear
            - cache store gradle-wrapper ~/.gradle/wrapper
            - cache store gradle-cache ~/.gradle/caches
            - cache store android-build ~/.android/build-cache
  - name: Verification
    task:
      jobs:
        - name: Analyze Code
          commands:
            - ./gradlew lint
        - name: Unit Tests
          commands:
            - ./gradlew testDebugUnitTest
      epilogue:
        always:
          commands:
            - artifact push job --expire-in 2w --destination reports/ app/build/reports/
promotions:
  - name: Start Integration tests
    pipeline_file: integration-tests.yml
```

- VR-DevOps supports issue analysis via immersive visual patterns and contrasts, visually revealing differences in pipeline versions and the detailed steps executed shown for the Android App (see figure below).
- The contrasts with its
  - YAML (YAML Ain't Markup Language) pipeline definition in bottom right figure, which contains many details (difficult for all stakeholders to grasp) but lacks status info,
  - Or webpage UI (top right), which provides simplified status but lacks sufficient overall details.

Evaluation: Analysis Scenario





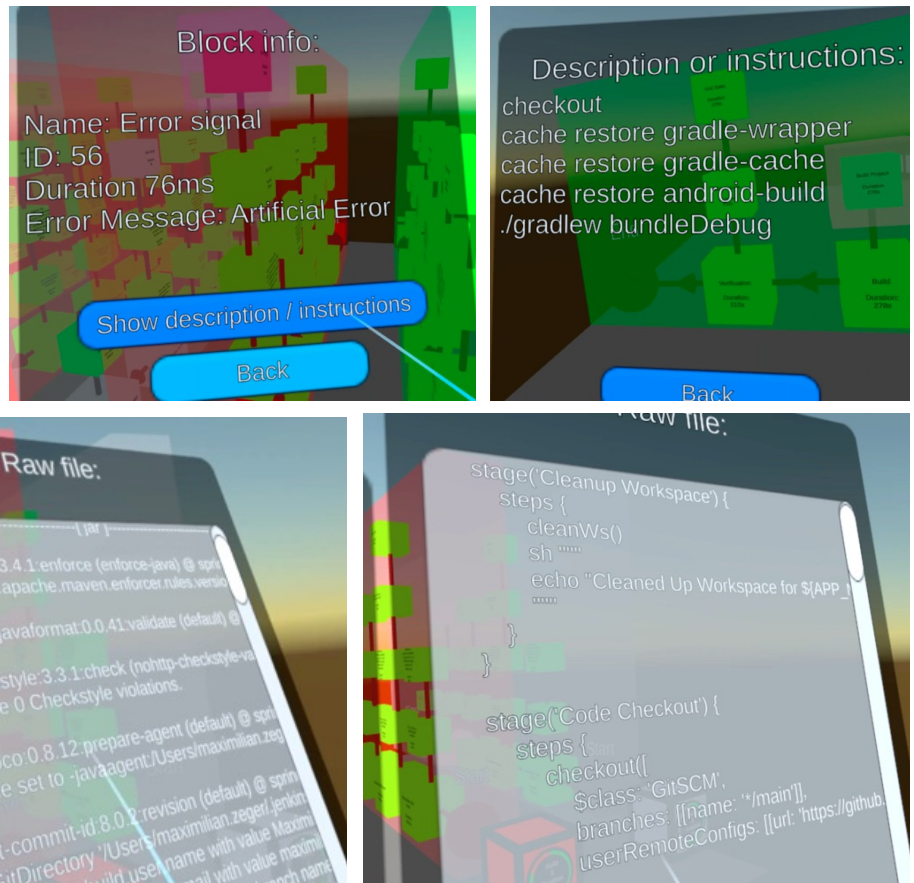



```
pipeline {
    agent any
    tools {
        maven 'maven3'
    }
    options {
        buildDiscarder logRotator(
                    daysToKeepStr: '15',
                    numToKeepStr: '10'
                )
    }
    environment {
        APP_NAME = "DCUBE_APP"
        APP_ENV  = "DEV"
    }
    stages {
        stage('Cleanup Workspace') {
            steps {
                cleanWs()
                sh """
                echo "Cleaned Up Workspace for ${APP_NAME}"
                """
            }
        }
        stage('Code Checkout') {
            steps {
                checkout([
                    $class: 'GitSCM',
                    branches: [[name: '*/main']],
                    userRemoteConfigs: [[url: 'https://github.com/spring-projects/spring-petclinic.git']]
                ])
            }
        }
        stage('Code Build') {
            steps {
                sh 'mvn install -Dmaven.test.skip=true'
            }
        }
        stage('Printing All Global Variables') {
            steps {
                sh """
                env
                """
                error "Artificial Error"
```

- Immersive visual differentiation of runs via perspective and alignment is shown for the PetClinic below
- Grasping its pipeline structure from its Groovy file (bottom right) would be more difficult for non-developers.
- Visual depiction and differentiation can help support the inclusion of non-tech-savvy stakeholders, improving the speed of assessments and the quality of analysis tasks by including more stakeholders.

Evaluation: Analysis Scenario

- The VR-Tablet provides additional context-specific metadata and error messages about a block (top left), step or stage task instructions (top right), or its raw log (bottom left) or pipeline info (bottom right) for developers.
- This consolidation, in conjunction with visual differentiation, could improve the utility and efficacy of analysis tasks, especially when considering increasing pipeline complexity, pipeline versions, and large scale-out of runs.



Conclusion

- VR-DevOps provides an immersive solution concept for visualizing, analyzing, and interacting with DevOps pipeline runs in VR.
- The realization prototype showed its feasibility, and the case-based evaluation showed its potential to support typical scenarios such as status and analysis.
- The solution concept is DevOps tool-independent, hiding the differences that the fragmented DevOps tool landscape might present to non-tech-savvy stakeholders.
- It thus provides a way towards broader inclusion of various DevOps stakeholders, and can thus support greater collaboration and communication to address one of the top challenges facing DevOps.
- Combining VR-DevOps with our other VR solutions, such as VR-Git, VR-GitCity, VR-SDLC, VR-EA, VR-V&V, VR-TestCoverage, etc., can support more holistic DevOps insights.
- Future work includes: a VR-native collaboration and annotation capability, additional DevOps tool integrations, and a comprehensive industrial empirical study.

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