SWE 261P Software Testing and Analysis - Part 2 Report

PDFsam Basic: Finite State Machine Testing

JAVA 21

JUNIT 5

MAVEN

Course SWE 261P
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Team Kingson & Zian & Zhenyu

Repo Github Link:
https://github.com/eric-song-dev/pdfsam

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This report documents the systematic Finite State Machine (FSM) testing process of **PDFsam Basic**, covering three distinct features modeled as FSMs.

📂 Quick Navigation

🎯 1. Finite Models in Testing

1.1 What Are Finite Models?

Finite models are abstract representations of software behavior using a finite number of states and transitions. They allow testers to:

1. **Model complex behavior simply**: Reduce infinite input spaces to manageable state spaces
2. **Visualize system behavior**: Communicate expected behavior through diagrams
3. **Derive test cases systematically**: Generate tests that cover all states and transitions

1.2 Why Finite Models Are Useful for Testing

Finite models, particularly **Finite State Machines (FSMs)**, provide several key benefits:

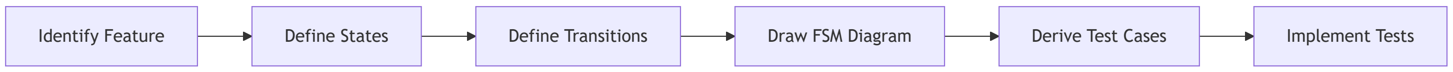
Benefit	Description
Systematic Coverage	Ensure all states and transitions are tested
Defect Detection	Identify missing transitions and invalid state combinations
Documentation	Serve as executable specifications
Regression Testing	Provide baseline for detecting behavioral changes

1.3 FSM Testing Coverage Criteria

Common FSM coverage criteria include:

- **State Coverage**: Visit every state at least once
- **Transition Coverage**: Execute every transition at least once
- **Path Coverage**: Test all possible paths (often impractical)
- **Transition Pair Coverage**: Cover all pairs of adjacent transitions

1.4 FSM Testing Process



2. Kingson's FSM: PDF Document Loading Status

2.1 Feature Description

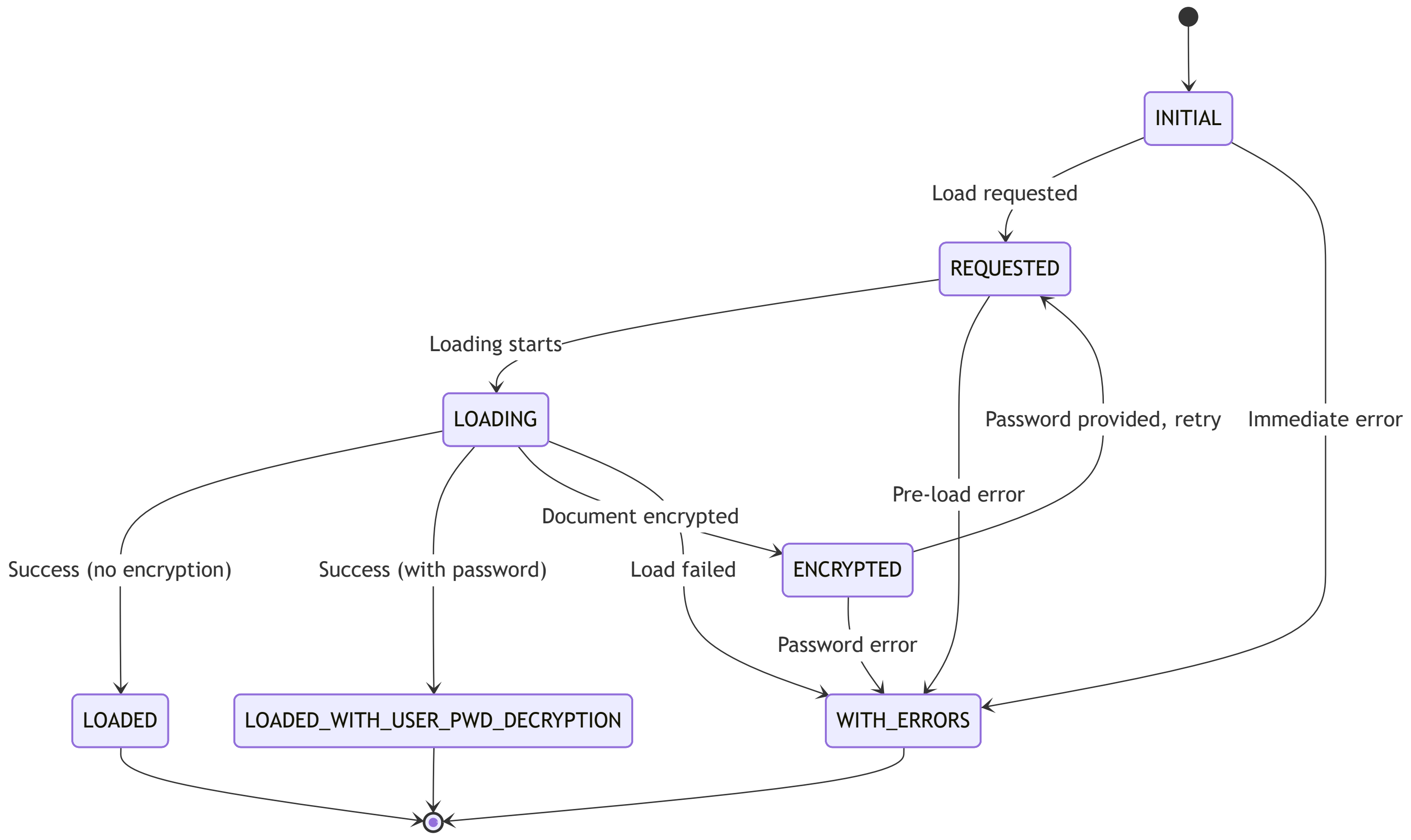
We selected the `PdfDescriptorLoadingStatus` enum, which models the lifecycle of PDF document loading in PDFsam.

Property	Value
Location	PdfDescriptorLoadingStatus.java
Type	Java Enum with FSM semantics
Used By	`PdfDocumentDescriptor` , `LoadingStatusIndicatorUpdater` , `SelectionTable`

This component is ideal for FSM modeling because:

1. **Explicit State Machine Implementation**: The enum defines states with a `validNext` set controlling transitions
2. **Transition Validation**: Built-in `canMoveTo()` and `moveTo()` methods enforce valid transitions
3. **Terminal State Detection**: `isFinal()` method identifies states with no outgoing transitions

2.2 FSM Diagram



2.3 State Descriptions

State	Icon	Description	Terminal?
INITIAL	-	Document just added, no load attempted	No

State	Icon	Description	Terminal?
REQUESTED	🕐	Load request submitted	No
LOADING	▶	Actively loading document	No
LOADED	-	Successfully loaded, no password needed	**Yes**
LOADED_WITH_USER_PWD_DECRYPTION	🔓	Successfully loaded with user password	**Yes**
ENCRYPTED	🔒	Document is encrypted, password required	No
WITH_ERRORS	⚠	Error occurred during loading	**Yes**

2.4 Transition Table

From \ To	INITIAL	REQUESTED	LOADING	LOADED	LOADED_PWD	ENCRYPTED	WITH_ERRORS
INITIAL	-	✓	-	-	-	-	✓
REQUESTED	-	-	✓	-	-	-	✓
LOADING	-	-	-	✓	✓	✓	✓
ENCRYPTED	-	✓	-	-	-	-	✓
LOADED	-	-	-	-	-	-	-
LOADED_PWD	-	-	-	-	-	-	-
WITH_ERRORS	-	-	-	-	-	-	-

2.5 Test Cases

Test File Location

File	Location
PdfLoadingStatusFSMTest.java	`pdfsam-model/src/test/java/org/pdfsam/model/pdf/`

Test Coverage Strategy

Test that all 7 states exist and have expected properties (icons, descriptions, styles).

```
@Test
@DisplayName("All 7 states are defined")
void allStatesExist() {
    PdfDescriptorLoadingStatus[] states = PdfDescriptorLoadingStatus.values();
    assertThat(states).hasSize(7);
    assertThat(states).contains(
        INITIAL, REQUESTED, LOADING, LOADED,
        LOADED_WITH_USER_PWD_DECRYPTION, ENCRYPTED, WITH_ERRORS
    );
}
```

Transition Coverage Tests

Test all 11 valid transitions:

Test	From	To
`testInitialToRequested`	INITIAL	REQUESTED
`testInitialToWithErrors`	INITIAL	WITH_ERRORS
`testRequestedToLoading`	REQUESTED	LOADING
`testRequestedToWithErrors`	REQUESTED	WITH_ERRORS
`testLoadingToLoaded`	LOADING	LOADED
`testLoadingToLoadedWithPwd`	LOADING	LOADED_WITH_USER_PWD_DECRYPTION
`testLoadingToEncrypted`	LOADING	ENCRYPTED
`testLoadingToWithErrors`	LOADING	WITH_ERRORS
`testEncryptedToRequested`	ENCRYPTED	REQUESTED
`testEncryptedToWithErrors`	ENCRYPTED	WITH_ERRORS

```
// From INITIAL
@Test
@DisplayName("INITIAL → REQUESTED: Load request initiated")
void initialToRequested() {
    assertThat(INITIAL.canMoveTo(REQUESTED)).isTrue();
    assertThat(INITIAL.moveTo(REQUESTED)).isEqualTo(REQUESTED);
}

// From REQUESTED
@Test
@DisplayName("REQUESTED → LOADING: Loading begins")
void requestedToLoading() {
    assertThat(REQUESTED.canMoveTo(LOADING)).isTrue();
    assertThat(REQUESTED.moveTo(LOADING)).isEqualTo(LOADING);
}

// From LOADING
@Test
@DisplayName("LOADING → LOADED: Successful load (no encryption)")
void loadingToLoaded() {
    assertThat(LOADING.canMoveTo(LOADED)).isTrue();
    assertThat(LOADING.moveTo(LOADED)).isEqualTo(LOADED);
}
```

Invalid Transition Tests

Verify `IllegalStateException` is thrown for invalid transitions.

```
@Test
@DisplayName("INITIAL cannot directly reach LOADING")
void initialCannotSkipToLoading() {
    assertThat(INITIAL.canMoveTo(LOADING)).isFalse();
    assertThatThrownBy(() -> INITIAL.moveTo(LOADING))
        .isInstanceOf(IllegalStateException.class)
        .hasMessageContaining("Cannot move status from INITIAL to LOADING");
}
```

Terminal State Tests

Verify `isFinal()` returns true only for LOADED, LOADED_WITH_USER_PWD_DECRYPTION, and WITH_ERRORS.

```
@Test
@DisplayName("LOADED is a terminal state")
void loadedIsFinal() {
    assertThat(LOADED.isFinal()).isTrue();
}
```

Running the Tests

```
# Build the project first
mvn install -DskipTests

# Run FSM tests
mvn test -pl pdfsam-model -Dtest=PdfLoadingStatusFSMTest
```

Test Results

```
Results:

Tests run: 50, Failures: 0, Errors: 0, Skipped: 0

------------------------------------------------------------------------
BUILD SUCCESS
------------------------------------------------------------------------
Total time:  4.830 s
Finished at: 2026-02-11T00:14:55-08:00
------------------------------------------------------------------------
```

3. Zian's FSM: Form Validation State

Test File: pdfsam-ui-components/src/test/java/org/pdfsam/ui/components/support/ZianValidationStateFSMTest.java

3.1 Feature Description

The **Validation State** system manages form field validation in PDFsam's UI. It tracks whether user input has been validated and the result of that validation.

Location: pdfsam-ui-components/src/test/java/org/pdfsam/ui/components/support/FXValidationSupportTest.java

3.2 FSM Model Design

```java
public enum ValidationState {
NOT_VALIDATED(false),
VALID(false),
INVALID(false);

    private Set<ValidationState> validDestinations;

    static {
        NOT_VALIDATED.validDestinations = Set.of(NOT_VALIDATED, VALID, INVALID);

        VALID.validDestinations = Set.of(VALID, INVALID, NOT_VALIDATED);

        INVALID.validDestinations = Set.of(INVALID, VALID, NOT_VALIDATED);
    }

    public boolean canMoveTo(ValidationState dest) {
        return validDestinations.contains(dest);
    }
}
```

Note: All states in this model are non-terminal (isFinal = false) because the UI validation process is inherently cyclic—users can continuously modify inputs and reset the state.

3.3 FSM Diagram

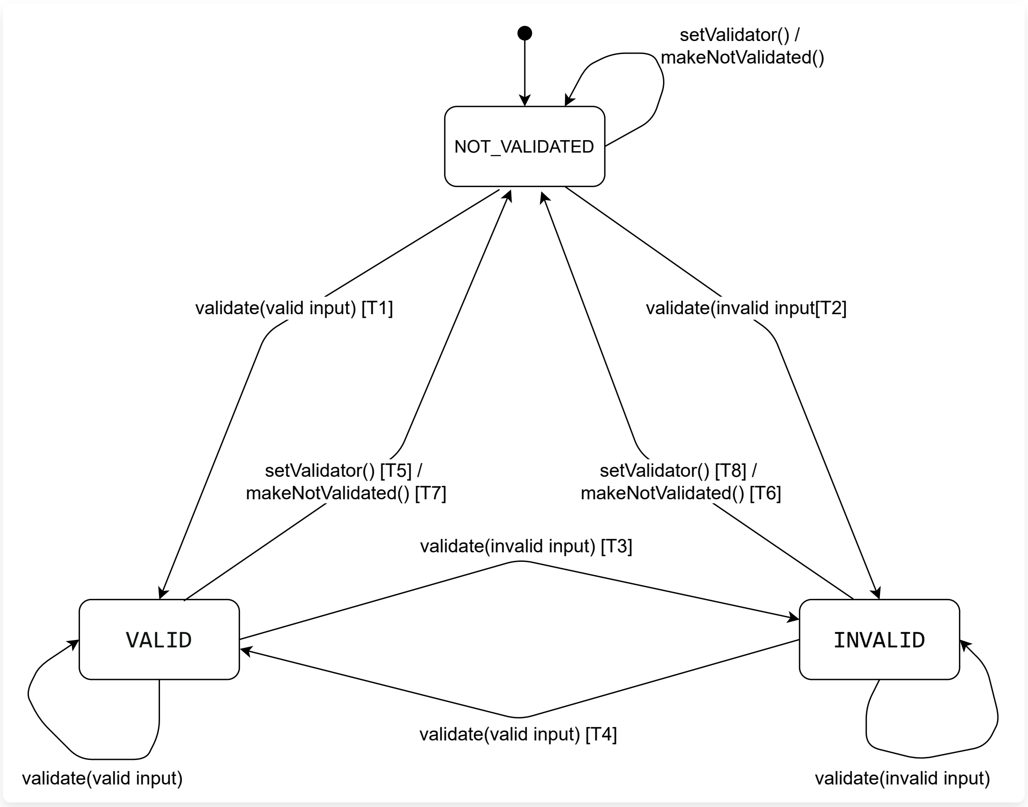

setValidator() / makeNotValidated()
NOT_VALIDATED
validate(valid input) [T1]
validate(invalid input[T2]
setValidator() [T5] / makeNotValidated() [T7]
setValidator() [T8] / makeNotValidated() [T6]
validate(invalid input) [T3]
VALID
INVALID
validate(valid input) [T4]
validate(valid input)
validate(invalid input)

Figure 1: Hand-tuned State Transition Diagram for FXValidationSupport

3.4 State Descriptions

State	Description
`NOT_VALIDATED`	Initial state, no validation performed yet
`VALID`	Input passed the current validator
`INVALID`	Input failed the current validator

3.5 Transition Table

ID	From	To	Trigger
T1	NOT_VALIDATED	VALID	`validate()` with valid input
T2	NOT_VALIDATED	INVALID	`validate()` with invalid input
T3	VALID	INVALID	`validate()` with invalid input
T5,T7	VALID	NOT_VALIDATED	`setValidator()` or `makeNotValidated()`
T4	INVALID	VALID	`validate()` with valid input
T6,T8	INVALID	NOT_VALIDATED	`setValidator()` or `makeNotValidated()`

3.6 Test Cases

Test File: pdfsam-ui-components/src/test/java/org/pdfsam/ui/components/support/ZianValidationStateFSMTest.java

Test Coverage Summary

CATEGORY	IDS	SCOPE
State Coverage	S1-S3	Initial, Valid, and Invalid states
Transitions	T1-T8	All valid FSM edges including Reset
Self-Loops	L1-L4	Event suppression (e.g., VALID -> VALID)
Workflows	W1-W4	Full cycles and Validator changes
Edge Cases	E1-E3	Null inputs and idempotent reset checks

Example Test Cases

State Coverage Test:

```java
@Test
@DisplayName("S1: NOT_VALIDATED state - initial state")
void testNotValidatedState() {
    assertEquals(ValidationState.NOT_VALIDATED,
            validator.validationStateProperty().get());
}
```

Valid Transition Test:

```java
@Test
@DisplayName("T1: NOT_VALIDATED -> VALID")
void testNotValidatedToValid() {
    ChangeListener<ValidationState> listener = mock(ChangeListener.class);
    validator.validationStateProperty().addListener(listener);
    validator.setValidator(Validators.nonBlank());

    validator.validate("valid input");

    verify(listener).changed(any(ObservableValue.class),
            eq(ValidationState.NOT_VALIDATED), eq(ValidationState.VALID));
    assertEquals(ValidationState.VALID,
            validator.validationStateProperty().get());
}
```

Self-Loop Test:

```java
@Test
@DisplayName("L1: VALID -> VALID (re-validate with valid input)")
void testValidToValid() {
    validator.setValidator(Validators.nonBlank());
    validator.validate("valid1");
    assertEquals(ValidationState.VALID, validator.validationStateProperty().get());

    ChangeListener<ValidationState> listener = mock(ChangeListener.class);
    validator.validationStateProperty().addListener(listener);

    validator.validate("valid2");

    // No state change should occur for self-loop
    verify(listener, never()).changed(any(), any(), any());
    assertEquals(ValidationState.VALID, validator.validationStateProperty().get());
}
```

Complete Workflow Test:

```java
@Test
@DisplayName("W1: Full validation cycle: NOT_VALIDATED -> VALID -> INVALID -> VALID")
void testFullValidationCycle() {
    validator.setValidator(Validators.nonBlank());

    // Initial state
    assertEquals(ValidationState.NOT_VALIDATED,
            validator.validationStateProperty().get());

    // First validation - valid
    validator.validate("valid");
    assertEquals(ValidationState.VALID,
            validator.validationStateProperty().get());

    // Re-validate - invalid
    validator.validate("");
    assertEquals(ValidationState.INVALID,
            validator.validationStateProperty().get());

    // Re-validate - valid again
    validator.validate("valid again");
    assertEquals(ValidationState.VALID,
            validator.validationStateProperty().get());
}
```

Test Results

```
$ mvn test -pl pdfsam-ui-components -Dtest=ZianValidationStateFSMTest
...
[INFO] Results:
[INFO]
[INFO] Tests run: 23, Failures: 0, Errors: 0, Skipped: 0
[INFO]
[INFO] ------------------------------------------------------------------------
[INFO] BUILD SUCCESS
[INFO] ------------------------------------------------------------------------
[INFO] Total time:  9.638 s
[INFO] Finished at: 2026-02-09T12:03:50-08:00
[INFO] ------------------------------------------------------------------------```
```

4. Zhenyu's FSM: Footer Task Execution UI

Test File: pdfsam-ui-components/src/test/java/org/pdfsam/ui/components/tool/ZhenyuFooterFSMTest.java

4.1 Feature Description

The **Footer Task Execution UI** manages the visual state of task execution in PDFsam's footer component. It tracks task progress from request to completion/failure through event-driven state transitions.

Feature File: pdfsam-ui-components/src/main/java/org/pdfsam/ui/components/tool/Footer.java

4.2 FSM Model Design

This FSM is **explicitly modeled** using a custom enum with transition validation:

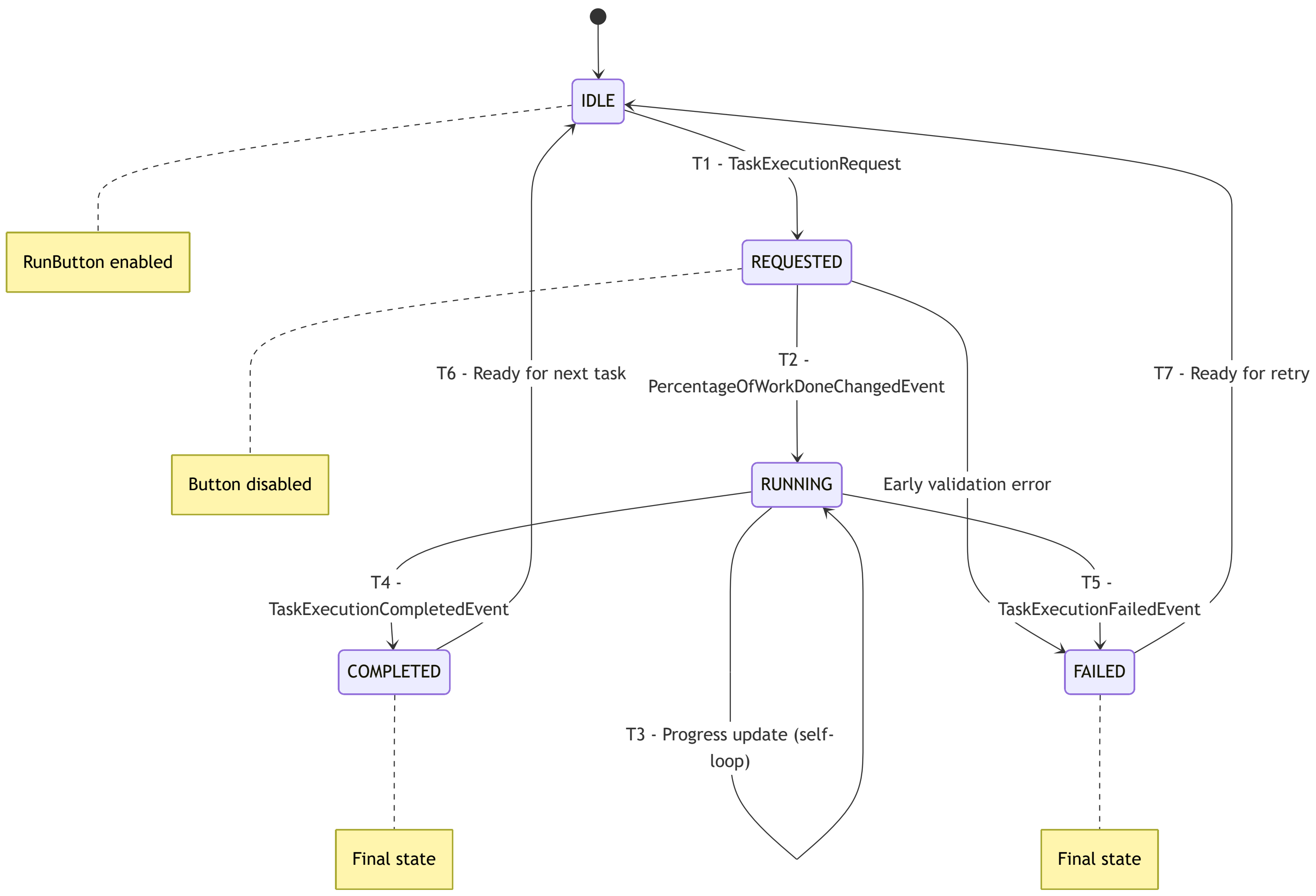
```
public enum TaskExecutionState {
    IDLE(false),
    REQUESTED(false),
    RUNNING(false),
    COMPLETED(true),  // final state
    FAILED(true);     // final state

    static {
        IDLE.validDestinations = Set.of(REQUESTED);
        REQUESTED.validDestinations = Set.of(RUNNING, FAILED);
        RUNNING.validDestinations = Set.of(RUNNING, COMPLETED, FAILED);
        COMPLETED.validDestinations = Set.of(IDLE);
        FAILED.validDestinations = Set.of(IDLE);
    }

    public boolean canMoveTo(TaskExecutionState dest) {
        return validDestinations.contains(dest);
    }
}
```

This design allows the FSM to validate transitions programmatically and throw exceptions for invalid state changes.

4.3 FSM Diagram


IDLE
RunButton enabled
T1 - TaskExecutionRequest
REQUESTED
Button disabled
T6 - Ready for next task
T2 - PercentageOfWorkDoneChangedEvent
T7 - Ready for retry
RUNNING
Early validation error
T4 - TaskExecutionCompletedEvent
T5 - TaskExecutionFailedEvent
COMPLETED
FAILED
T3 - Progress update (self-loop)
Final state
Final state

4.4 State Descriptions

State	Run Button	Final?	Description
`IDLE`	✅ Enabled	No	Initial state, ready for new task
`REQUESTED`	❌ Disabled	No	Task requested, waiting to start
`RUNNING`	❌ Disabled	No	Task executing, progress updating
`COMPLETED`	✅ Enabled	**Yes**	Task finished successfully
`FAILED`	✅ Enabled	**Yes**	Task failed with error

4.5 Transition Table

ID	From	To	Trigger Event
T1	IDLE	REQUESTED	`TaskExecutionRequest`
T2	REQUESTED	RUNNING	`PercentageOfWorkDoneChangedEvent`
T3	RUNNING	RUNNING	`PercentageOfWorkDoneChangedEvent` (self-loop)
T4	RUNNING	COMPLETED	`TaskExecutionCompletedEvent`
T5	RUNNING	FAILED	`TaskExecutionFailedEvent`
T6	COMPLETED	IDLE	Ready for next task
T7	FAILED	IDLE	Ready for retry

4.6 Test Implementation

Test File: pdfsam-ui-components/src/test/java/org/pdfsam/ui/components/tool/ZhenyuFooterFSMTest.java

Test Coverage Summary

Category	Tests	Description
State Coverage	5	IDLE, REQUESTED, RUNNING, COMPLETED, FAILED: Each state's properties and button behavior
Transition Coverage	7	T1-T7: All valid transitions including self-loop
Invalid Transitions	7	Verify invalid paths throw `IllegalStateException`
Complete Paths	4	Happy Path, Error Path, Early Error Path, Retry Path
FSM Model Validation	2	Verify model metadata (final states, transition counts)

Example Test Cases

State Coverage Test:

```
@Test
@DisplayName("COMPLETED: final, button re-enabled")
void completed() {
    fsm.moveTo(TaskExecutionState.REQUESTED);
    fsm.moveTo(TaskExecutionState.RUNNING);
    fsm.moveTo(TaskExecutionState.COMPLETED);
    eventStudio().broadcast(request("test"));
    eventStudio().broadcast(new TaskExecutionCompletedEvent(1000L, mockMetadata));

    assertEquals(TaskExecutionState.COMPLETED, fsm.getState());
    assertTrue(TaskExecutionState.COMPLETED.isFinal());
    assertFalse(runButton.isDisabled());
}
```

Invalid Transition Test:

```
@Test
@DisplayName("IDLE → RUNNING (must go through REQUESTED)")
void idleToRunningInvalid() {
    assertFalse(TaskExecutionState.IDLE.canMoveTo(TaskExecutionState.RUNNING));
    assertThrows(IllegalStateException.class, () -> fsm.moveTo(TaskExecutionState.RUNNING));
}
```

Self-Loop Test:

```java
@Test
@DisplayName("RUNNING → RUNNING (self-loop)")
void runningToRunning() {
    fsm.moveTo(TaskExecutionState.REQUESTED);
    fsm.moveTo(TaskExecutionState.RUNNING);

    // Multiple progress updates - stays in RUNNING
    for (int pct : new int[] { 25, 50, 75, 100 }) {
        assertTrue(fsm.getState().canMoveTo(TaskExecutionState.RUNNING));
        fsm.moveTo(TaskExecutionState.RUNNING);
        assertEquals(TaskExecutionState.RUNNING, fsm.getState());

        var event = new PercentageOfWorkDoneChangedEvent(new BigDecimal(pct), mockMetadata);
        assertEquals(pct, event.getPercentage().intValue());
    }
}
```

Complete Path Test:

```java
@Test
@DisplayName("Happy Path: IDLE → REQUESTED → RUNNING → COMPLETED → IDLE")
void happyPath() {
    assertEquals(TaskExecutionState.IDLE, fsm.getState());

    fsm.moveTo(TaskExecutionState.REQUESTED);
    eventStudio().broadcast(request("merge"));
    assertTrue(runButton.isDisabled());

    fsm.moveTo(TaskExecutionState.RUNNING);
    fsm.moveTo(TaskExecutionState.COMPLETED);
    eventStudio().broadcast(new TaskExecutionCompletedEvent(2000L, mockMetadata));
    assertFalse(runButton.isDisabled());
    assertTrue(TaskExecutionState.COMPLETED.isFinal());

    fsm.moveTo(TaskExecutionState.IDLE);
    assertEquals(TaskExecutionState.IDLE, fsm.getState());
}
```

Test Results

```
$ mvn test -pl pdfsam-ui-components -Dtest=ZhenyuFooterFSMTest
...
[INFO] Results:
[INFO]
[INFO] Tests run: 25, Failures: 0, Errors: 0, Skipped: 0
[INFO]
[INFO] ------------------------------------------------------------------------
[INFO] BUILD SUCCESS
[INFO] ------------------------------------------------------------------------
[INFO] Total time:  2.227 s
[INFO] Finished at: 2026-02-08T23:29:13-08:00
[INFO] ------------------------------------------------------------------------
```

📋 5. Test Implementation Summary

5.1 New Test Files

File	Location	Author
	`pdfsam-model/src/test/java/org/pdfsam/model/pdf/`	Kingson Zhang
ZianValidationStateFSMTest.java	`pdfsam-ui-components/src/test/java/org/pdfsam/ui/components/support/`	Zian Xu
ZhenyuFooterFSMTest.java	`pdfsam-ui-components/src/test/java/org/pdfsam/ui/components/tool/`	Zhenyu Song

5.2 Running the FSM Tests

```
# Run Kingson's PDF Loading Status FSM tests
mvn test -pl pdfsam-model -Dtest=KingsonPdfLoadingStatusFSMTest

# Run Zian's Validation State FSM tests
mvn test -pl pdfsam-ui-components -Dtest=ZianValidationStateFSMTest

# Run Zhenyu's Footer FSM tests
mvn test -pl pdfsam-ui-components -Dtest=ZhenyuFooterFSMTest

# Run all FSM tests together
mvn test -pl pdfsam-model,pdfsam-ui-components -Dtest="*FSMTest"
```

🎯 6. Conclusion

This report demonstrates the application of **Finite State Machine (FSM) testing** to PDFsam Basic through three distinct features:

1. **PDF Document Loading Status (Kingson):** A 7-state FSM modeling the document loading lifecycle with explicit valid-invalid transitions
2. **Form Validation State (Zian):** A 3-state FSM modeling input validation with self-loops and reset transitions
3. **Notificaiton Type System (Zhenyu):** A multi-state FSM modeling noficiation display workflows

Key Takeaways

- FSM testing provides **systematic coverage** that random testing cannot guarantee
- State and transition coverage help identify **missing error handling** and **invalid state combinations**
- FSM diagrams serve as both **documentation** and **test case derivation source**

The FSM tests complement the **partition testing** from Part 1, providing a different perspective on the same codebase.