

# System Verification and Validation Plan for TTE RecSys

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April 1, 2025

## Revision History

| Date         | Version | Notes   |
|--------------|---------|---|
| Feb 24, 2025 | 1.0     | First draft - Unit tests will be added after the MIS has been completed.. |
| Feb 25, 2025 | 1.1     | Minor update after VnV presentation                                       |

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# 1 Symbols, Abbreviations, and Acronyms

| symbol | description                         |
|--------|-------------------------------------|
| T      | Test                                |
| R      | Requirement                         |
| NFR    | Nonfunctional Requirement           |
| TTE    | Two Tower Embedding                 |
| RecSys | Recommendation System               |
| ANN    | Approximate Nearest Neighbor        |
| SRS    | Software Requirements Specification |
| FAISS  | Facebook AI Similarity Search       |
| DNN    | Deep Neural Network                 |

This document outlines the verification and validation plan for the Two-Tower Embeddings Recommendation System (TTE RecSys) to ensure compliance with the requirements and objectives specified in the [Software Requirements Specification \(SRS\)](#). It is structured to first present general information and verification strategies, followed by detailed descriptions of system and unit testing for both functional and non-functional requirements.

## 2 General Information

### 2.1 Summary

The software under test is the Two-Tower Embedding Recommendation System, which generates personalized recommendations using user and item embeddings. The system consists of two main components:

- Training Phase: Learns user and item embedding functions using a deep neural network architecture, optimized via Stochastic Gradient Descent (SGD).
- Inference Phase: Retrieves candidate items using Approximate Nearest Neighbor (ANN) search and ranks them by dot product similarity.

The system is implemented in Python, leveraging libraries such as PyTorch for model training and FAISS for ANN search.

### 2.2 Objectives

The primary objectives of this VnV plan are:

- Correctness: Verify that the system correctly implements the mathematical models for training (e.g., MSE loss) and inference (e.g., ANN search, dot product ranking).
- Accuracy: Validate that the system achieves acceptable prediction accuracy on a held-out test set.
- Scalability: Demonstrate that the system can support incremental update when new data available.

Out-of-Scope Objectives

- External Library Verification: Libraries such as PyTorch and FAISS are assumed to be correct and are not verified as part of this plan.

## 2.3 Challenge Level and Extras

This is a non-research project. The extra component of this project will be a user manual.

## 2.4 Relevant Documentation

The following documents are available for this project: [Software Requirements Specification](#), [Module Guide](#), and [Module Interface Specification](#)

# 3 Plan

The VnV plan starts with an introduction to the verification and validation team, followed by verification plans for the SRS and design. Next, it covers verification plans for the VnV Plan and implementation. Finally, it includes sections on automated testing and verification tools as well as the software validation plan .

## 3.1 Verification and Validation Team

| Name              | Document | Role                    | Description   |
|-------------------|----------|-------------------------|---|
| Yinying Huo       | All      | Author                  | Prepare all documentation, develop the software, and validate the implementation according to the VnV plan. |
| Dr. Spencer Smith | All      | Instructor/<br>Reviewer | Review all the documents.   |
| Yuanqi Xue        | All      | Domain<br>Expert        | Review all the documents.   |

Table 1: Verification and Validation Team

### 3.2 SRS Verification Plan

The Software Requirements Specification (SRS) will be reviewed by domain expert Yuanqi Xue and Dr. Smith. Feedback from reviewers will be provided on GitHub, and the author will need to address it.

There is a [SRS checklist](#) designed by Dr. Spencer Smith available to use.

### 3.3 Design Verification Plan

The design verification, including the Module Guide (MG) and Module Interface Specification (MIS), will be reviewed by domain expert Yuanqi Xue and Dr. Smith. Feedback from reviewers will be provided on GitHub, and the author will need to address it.

Dr. Spencer Smith has created a [MG checklist](#) and [MIS checklist](#), both of which are available for use.

### 3.4 Verification and Validation Plan Verification Plan

The Verification and Validation (VnV) Plan will be reviewed by domain expert Yuanqi Xue and Dr. Smith. Feedback from reviewers will be provided on GitHub, and the author will need to address it.

There is a [VnV checklist](#) designed by Dr. Spencer Smith available to use.

### 3.5 Implementation Verification Plan

The implementation will be verified by testing both the functional and non-functional requirements outlined in section 4. Unit tests, as described in section 5, will also be performed. Additionally, a code walkthrough will be conducted with the class during the final presentation.

### 3.6 Automated Testing and Verification Tools

All system tests and unit tests will be performed using Python scripts. GitHub Actions is used for continuous integration, and the workflow will run all unit tests.



### 3.7 Software Validation Plan

The software validation plan is beyond the scope of TTE RecSys, as it requires additional time and data that are not available within the scope of the project.

## 4 System Tests

This section covers the system tests that will be applied to both the functional and non-functional requirements.

### 4.1 Tests for Functional Requirements

The functional requirements are tested in the following areas: input validation, ranking consistency, and output correctness. These tests ensure the system behaves as expected under various conditions.

#### 4.1.1 Area of Testing 1: Dataset

1. test-id1

Control: Automatic

Initial State: Before training the DNN.

Input: Dataset

Output: A verified training dataset where each user-item pair has an associated reward.

Test Case Derivation: Ensures that the system receives a valid dataset for training, as specified in the [SRS](#).

How test will be performed: This test will be performed automatically using GitHub Actions every time before training the DNN.

#### 4.1.2 Area of Testing 2: Model Training Convergence

1. test-id2

Control: Automatic

Initial State: After training of the DNN

Input: The loss record during training

Output: A boolean value, “True” if the loss of the DNN decreases over

iterations, and “False” otherwise.

Test Case Derivation: Ensures the correctness of the output as specified in [SRS](#).

How the test will be performed: This test will be performed automatically using GitHub Actions once training is complete.

### 4.1.3 Area of Testing 3: Model Storage

1. test-id3:

Control: Automatic

Initial State: After model training is complete

Input: Path to the model and pre-computed item embeddings

Output: bA boolean variable – “True” iff the model and pre-computed item embeddings are stored in the specified location, and “False” otherwise

Test Case Derivation: Ensures R3 (model storage) is properly implemented

How test will be performed: The test will be performed automatically using GitHub Actions once model training convergence is complete.

## 4.2 Tests for Nonfunctional Requirements

### 4.2.1 Reliability

The reliability of the software is tested through the tests for functional requirements in section 4.1 and 5.2 .

### 4.2.2 Portability

1. test-id4

Type: Automatic and manual

Initial State: None

Input/Condition: None

Output/Result: The results of all automatic tests and feedback from users.

How test will be performed: All automatic tests will be conducted during the continuous integration workflow. Potential users will install the project on their computers (Windows, macOS, or Linux) and follow the instructions in [README.md](#) to run the software.

#### 4.2.3 Usability

1. test-id5

Type: Manual

Initial State: The software is setup and ready to use.

Input/Condition: None

Output/Result: Survey result from the user

How test will be performed: The user will be ask to filfled the servey after using this software. The survey can be find at appendix [6.1](#).

### 4.3 Traceability Between Test Cases and Requirements

The table [4.3](#) shows the traceability between test cases and requirements

|      | test-id1 | test-id2 | test-id3 | test-id4 | test-id5 |
|------|----------|----------|----------|----------|----------|
| R1   | X        |          |          |          |          |
| R2   |          | X        |          |          |          |
| R3   |          |          | X        |          |          |
| R4   |          | X        |          |          |          |
| R5   |          | X        |          |          |          |
| R6   |          | X        |          |          | X        |
| NFR1 |          |          |          |          | X        |
| NFR2 | X        | X        | X        |          |          |
| NFR3 |          |          |          | X        |          |

Table 2: Traceability Matrix Showing the Connections Between Test Cases and Requirements

## 5 Unit Test Description

The unit tests for this system will follow a hierarchical approach based on the module decomposition in the Module Guide. The testing philosophy focuses on:

1. Black-box testing of module interfaces according to their specifications
2. White-box testing for complex algorithms and edge cases
3. Mock objects for isolating modules from their dependencies

### 5.1 Unit Testing Scope

The unit testing will focus on the four core modules of the system: Data Processing, Vector Operations, Neural Network Architecture, and Recommendation. Other modules will be tested indirectly through system tests or as part of the testing of these core modules. External libraries (PyTorch, FAISS) are considered outside the scope of unit testing.

### 5.2 Tests for Functional Requirements

#### 5.2.1 Data Processing Module (M2)

1. test-M2-1: Dataset Validation Test

Type: Automatic, Functional

Initial State: None

Input: Path to test dataset

Output: Boolean value 'True' if the dataset meets all validation criteria

Test Case Derivation: R1 requires the system to accept valid input data.

How test will be performed:

- Load the dataset
- Run validation with the module's `validate_data` method

#### 5.2.2 Model Training Module (M3)

1. test-M3-1

Type: Automatic, Functional

Initial State: Uninitialized ModelTrainer

Input: Valid training configuration

Output: ModelTrainer with initialized state (IsInitialized=True)

Test Case Derivation: R2 requires the system to train embedding functions.

How test will be performed: Initialize the ModelTrainer with the configuration and verify the state variables are set correctly.

### 5.2.3 Embedding Generation Module (M4)

1. test-M4-1

Type: Automatic, Functional

Initial State: Initialized EmbeddingGenerator

Input: A random user data from the dataset

Output: User embedding vector of the expected dimension.

Test Case Derivation: R4 requires the system to generate embeddings based on user features.

How test will be performed: Generate an embedding for an user from the dataset and verify its dimension matches the expected value.

### 5.2.4 Recommendation Module (M5)

1. test-M5-1

Type: Automatic, Functional

Initial State: Initialized Recommender

Input: Processed user data and number of results (10)

Output: Array of recommendation objects with length 10, each containing an item ID and similarity score

Test Case Derivation: R6 requires the system to return ranked recommendations with similarity scores.

How test will be performed: Generate recommendations for an user from the dataset and verify the output has the correct format and length.

### 5.2.5 Neural Network Architecture Module (M6)

1. test-M6-1

Type: Automatic, Functional

Initial State: None

Input: Configuration parameters for input dimension, hidden layers, and embedding dimension

Output: Neural network model with the specified architecture

Test Case Derivation: R2 requires the system to create models for embedding generation.

How test will be performed: Create a model with the architecture and verify the layer structure matches the specification.

### 5.2.6 ANN Search Module (M7)

1. test-M7-1

Type: Automatic, Functional

Initial State: None

Input: Array of item embeddings from the production model and a query embedding

Output: Array of (item\_id, similarity\_score) tuples with the expected length

Test Case Derivation: R6 requires efficient retrieval of nearest items.

How test will be performed: Build an index with item embeddings, search with an user embedding, and verify the results structure. The correctness will not be verified, as the external library (FAISS) is assumed to be correct.

### 5.2.7 Vector Operations Module (M8)

1. test-M8-1

Type: Automatic, Functional

Initial State: None

Input: Two embedding vectors

Output: Scalar dot product value

Test Case Derivation: The system relies on dot product for similarity calculation.

How test will be performed: Calculate the dot product of two vectors and compare it with the expected value.

### 5.3 Tests for Nonfunctional Requirements

Unit testing the nonfunctional requirements is beyond the scope.

### 5.4 Traceability Between Test Cases and Modules

The table 5.4 shows the traceability between test cases and modules.

| Test ID   | M1 | M2 | M3 | M4 | M5 | M6 | M7 | M8 |
|-----------|----|----|----|----|----|----|----|----|
| test-M2-1 |    | X  |    |    |    |    |    |    |
| test-M3-1 |    |    | X  |    |    |    |    |    |
| test-M4-1 |    |    |    | X  |    |    |    |    |
| test-M5-1 |    |    |    |    | X  |    |    |    |
| test-M6-1 |    |    |    |    |    | X  |    |    |
| test-M7-1 |    |    |    |    |    |    | X  |    |
| test-M8-1 |    |    |    |    |    |    |    | X  |

Table 3: Traceability Matrix Between Test Cases and Modules

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## 6 Appendix

### 6.1 Usability Survey

- On a scale from 1 to 5, with 5 being the most satisfied, how would you rate your overall experience using the software?
- Were the installation and setup process straightforward? If not, what difficulties did you encounter?
- Did you find the user interface intuitive and easy to navigate? If not, what improvements would you suggest?
- Did the software meet your expectations? If not, what features or improvements would you like to see?