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IT314 Software Engineering

MUTATION TESTING - BACKEND GROUP 28 - Coincious Prof. Saurabh Tiwari

Mutation testing is a quality assurance technique that evaluates the effectiveness of your test suite by introducing small, intentional mutations (bugs) into the code and checking if the tests catch them. This guide explains how to perform mutation testing on the backend services. For this backend part we focused on doing mutation testing for the services file because it had the most mutations and bugs affecting core functionality and high complexity.

I have performed mutation testing for the backed folder for the following services file:

1. Expense_service
2. Categorizer_service
3. Group_service
4. Invitation_service
5. Notification_service
6. Ai_service

To find the mutation score after running the mutation test , I have created a file to calculate the score .

Mutation Score = (Killed Mutants / (Killed + Survived)) * 100 This

helps evaluate test quality:

- 90-100%: Excellent test coverage
- 80-89%: Good test coverage
- 70-79%: Acceptable test coverage
- 60-69%: Needs improvement
- <60%: Poor test coverage

Score Progression

Phase	Tests	Killed	Survived	Score	Grade	Key Action
Initial	4	159	2,695	5.57%	F	Baseline
Phase 1	10	329	2,033	13.93%	F	Added expense_service tests
Phase 2	49	455	1,493	23.36%	F	Added categorizer, invitation, notification tests
Phase 3	71	579	773	42.83%	F	Added group_service additional tests
Phase 4	91	605	773	43.90%	F	Added create_group & expense edge cases
Phase 5	305	1230	276	81.67%	B	Comprehensive testing + test consolidation
Phase 6	324	1320	98	93.09	A	AI service testing + final optimization

```
karthikraman@Balamurugans-MacBook-Pro backend % python -m pytest tests/ -q --tb=no
..... [ 44%]
..... [ 88%]
..... [100%]
324 passed in 2.17s
```

In total i have made 324 tests

I have also made a setup.cfg file which is a configuration file used by Python tools and packages. The setup.cfg file is a standard Python configuration file that various tools read to understand how to work with your project. It's part of Python's packaging ecosystem and provides configuration for multiple tools in one place. It targets the right code (app/services), Uses efficient test execution (pytest -q), Prevents problems (excludes test files) and Follows standards (standard INI format)

```
Coincious-Smart-Expense-Tracker > backend > setup.cfg
1  [mutmut]
2  paths_to_mutate = app/services
3  tests_cmd = .venv/bin/pytest -q
4  exclude = tests
```

For each of the services files I have created the test file for each of them to perform mutation testing and find mutation score.

1. test_group_all_comprehensive_merged.py :

In this file i have created 206 tests and it handles

- Group Service Functions (47 tests): create_new_group, delete_group, get_user_groups, get_group_detail, add_group_member, get_group_members, get_group_balances, settle_group_balance
- Group Operations(49 tests): Input validation, authorization checks, cascading deletes, permission management
- Group Data Retrieval (54 tests): Balance calculations, member information, expense data, cross-service integration
- Add Group Member(26 tests): User validation, permission checks, invitation creation, notification logic
- Settle Group Balance (30 tests): Validation logic, expense creation, split creation, notification handling, rollback logic

```
karthikraman@Balamurugans-MacBook-Pro backend % python -m pytest tests/test_group_all_comprehensive_merged.py -v --tb=no
===== test session starts =====
platform darwin -- Python 3.13.5, pytest-9.0.1, pluggy-1.6.0 -- /Users/karthikraman/.pyenv/versions/3.13.5/bin/python
cachedir: .pytest_cache
rootdir: /Users/karthikraman/Documents/expense_pro_new/Coincious-Smart-Expense-Tracker/backend
plugins: anyio-4.11.0
collected 206 items

tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_create_new_group_insert_returns_empty_list PASSED [ 0%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_create_new_group_insert_returns_no_data PASSED [ 0%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_create_new_group_member_add_fails PASSED [ 1%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_create_new_group_member_insert_fails_detailed PASSED [ 1%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_create_new_group_no_name PASSED [ 2%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_create_new_group_success PASSED [ 2%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_create_new_group_very_long_name PASSED [ 3%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_create_new_group_whitespace_only_name PASSED [ 3%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_delete_group_delete_fails PASSED [ 4%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_delete_group_delete_success PASSED [ 4%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_delete_group_not_creator PASSED [ 4%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_delete_group_not_found PASSED [ 5%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_delete_group_success PASSED [ 5%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_delete_group_with_related_data PASSED [ 6%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_get_group_balances_no_members PASSED [ 6%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_get_group_balances_not_member PASSED [ 7%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_get_group_balances_success PASSED [ 7%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_get_group_detail_expenses_with_none_amounts PASSED [ 8%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_get_group_detail_group_not_found PASSED [ 8%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_get_group_detail_negative_expenses PASSED [ 9%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_get_group_detail_not_member PASSED [ 9%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_get_group_detail_success PASSED [ 10%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_get_group_members_auth_fetch_exception PASSED [ 10%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_get_group_members_fetch_fails PASSED [ 11%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_get_group_members_member_without_user_data PASSED [ 11%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_get_group_members_not_member PASSED [ 12%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_get_group_members_success PASSED [ 12%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_get_user_groups_calls_correct_rpc PASSED [ 13%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_get_user_groups_empty_list PASSED [ 13%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_get_user_groups_empty_result PASSED [ 14%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_get_user_groups_float_conversion PASSED [ 14%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_get_user_groups_large_balance_values PASSED [ 15%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_get_user_groups_multiple_groups PASSED [ 15%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_get_user_groups_none_values PASSED [ 16%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_get_user_groups_preserves_metadata PASSED [ 16%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_get_user_groups_rpc_exception PASSED [ 16%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_get_user_groups_special_characters_in_name PASSED [ 17%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_get_user_groups_success_single_group PASSED [ 17%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_get_user_groups_zero_balance PASSED [ 18%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_settle_group_balance_creates_expense PASSED [ 18%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_settle_group_balance_float_precision PASSED [ 19%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_settle_group_balance_invalid_amount PASSED [ 19%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_settle_group_balance_invalid_fields PASSED [ 20%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_settle_group_balance_missing_fields PASSED [ 20%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_settle_group_balance_not_member PASSED [ 20%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_settle_group_balance_string_amount PASSED [ 21%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_settle_group_balance_very_large_amount PASSED [ 21%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_settle_group_balance_very_small_amount PASSED [ 22%]
tests/test_group_all_comprehensive_merged.py::TestGroupServiceComprehensiveMerged::test_settle_group_balance_zero_amount PASSED [ 22%]
tests/test_group_all_comprehensive_merged.py::TestCreateNewGroupMutations::test_create_group_adds_creator_as_member PASSED [ 23%]
tests/test_group_all_comprehensive_merged.py::TestCreateNewGroupMutations::test_create_group_error_on_insert PASSED [ 23%]
tests/test_group_all_comprehensive_merged.py::TestCreateNewGroupMutations::test_create_group_error_on_member_add PASSED [ 24%]
tests/test_group_all_comprehensive_merged.py::TestCreateNewGroupMutations::test_create_group_exception_handling PASSED [ 24%]
tests/test_group_all_comprehensive_merged.py::TestCreateNewGroupMutations::test_create_group_includes_creator_id PASSED [ 25%]
```


tests/test_group_all_comprehensive_merged.py::TestCreateNewGroupMutations::test_create_group_inserts_to_correct_table	PASSED	[25%]
tests/test_group_all_comprehensive_merged.py::TestCreateNewGroupMutations::test_create_group_no_name	PASSED	[26%]
tests/test_group_all_comprehensive_merged.py::TestCreateNewGroupMutations::test_create_group_none_name	PASSED	[26%]
tests/test_group_all_comprehensive_merged.py::TestCreateNewGroupMutations::test_create_group_preserves_group_name	PASSED	[27%]
tests/test_group_all_comprehensive_merged.py::TestCreateNewGroupMutations::test_create_group_returns_correct_status	PASSED	[27%]
tests/test_group_all_comprehensive_merged.py::TestCreateNewGroupMutations::test_create_group_successful_creation	PASSED	[28%]
tests/test_group_all_comprehensive_merged.py::TestCreateNewGroupMutations::test_create_group_whitespace_name	PASSED	[28%]
tests/test_group_all_comprehensive_merged.py::TestCreateNewGroupMutations::test_create_group_with_special_characters	PASSED	[29%]
tests/test_group_all_comprehensive_merged.py::TestDeleteGroupMutations::test_delete_group_created_by_empty_string	PASSED	[29%]
tests/test_group_all_comprehensive_merged.py::TestDeleteGroupMutations::test_delete_group_created_by_none	PASSED	[30%]
tests/test_group_all_comprehensive_merged.py::TestDeleteGroupMutations::test_delete_group_exception_handling	PASSED	[30%]
tests/test_group_all_comprehensive_merged.py::TestDeleteGroupMutations::test_delete_group_exception_in_cascade	PASSED	[31%]
tests/test_group_all_comprehensive_merged.py::TestDeleteGroupMutations::test_delete_group_exception_in_group_fetch	PASSED	[31%]
tests/test_group_all_comprehensive_merged.py::TestDeleteGroupMutations::test_delete_group_expense_ids_empty_list	PASSED	[32%]
tests/test_group_all_comprehensive_merged.py::TestDeleteGroupMutations::test_delete_group_expenses_delete_fails	PASSED	[32%]
tests/test_group_all_comprehensive_merged.py::TestDeleteGroupMutations::test_delete_group_expenses_deletion_fails	PASSED	[33%]
tests/test_group_all_comprehensive_merged.py::TestDeleteGroupMutations::test_delete_group_expenses_fetch_fails	PASSED	[33%]
tests/test_group_all_comprehensive_merged.py::TestDeleteGroupMutations::test_delete_group_final_delete_empty_data	PASSED	[33%]
tests/test_group_all_comprehensive_merged.py::TestDeleteGroupMutations::test_delete_group_final_delete_fails	PASSED	[34%]
tests/test_group_all_comprehensive_merged.py::TestDeleteGroupMutations::test_delete_group_final_delete_no_data	PASSED	[34%]
tests/test_group_all_comprehensive_merged.py::TestDeleteGroupMutations::test_delete_group_group_check_has_no_data_attribute	PASSED	[35%]
tests/test_group_all_comprehensive_merged.py::TestDeleteGroupMutations::test_delete_group_group_id_empty_string	PASSED	[35%]
tests/test_group_all_comprehensive_merged.py::TestDeleteGroupMutations::test_delete_group_group_id_none	PASSED	[36%]
tests/test_group_all_comprehensive_merged.py::TestDeleteGroupMutations::test_delete_group_invitations_deleted	PASSED	[36%]
tests/test_group_all_comprehensive_merged.py::TestDeleteGroupMutations::test_delete_group_invitations_deletion_fails	PASSED	[37%]
tests/test_group_all_comprehensive_merged.py::TestDeleteGroupMutations::test_delete_group_members_deleted	PASSED	[37%]
tests/test_group_all_comprehensive_merged.py::TestDeleteGroupMutations::test_delete_group_members_deletion_fails	PASSED	[38%]
tests/test_group_all_comprehensive_merged.py::TestDeleteGroupMutations::test_delete_group_mixed_type_ids	PASSED	[38%]
tests/test_group_all_comprehensive_merged.py::TestDeleteGroupMutations::test_delete_group_no_expenses_in_list	PASSED	[39%]
tests/test_group_all_comprehensive_merged.py::TestDeleteGroupMutations::test_delete_group_not_found	PASSED	[39%]
tests/test_group_all_comprehensive_merged.py::TestDeleteGroupMutations::test_delete_group_notifications_deleted	PASSED	[40%]
tests/test_group_all_comprehensive_merged.py::TestDeleteGroupMutations::test_delete_group_notifications_deletion_fails	PASSED	[40%]
tests/test_group_all_comprehensive_merged.py::TestDeleteGroupMutations::test_delete_group_numeric_user_id	PASSED	[41%]
tests/test_group_all_comprehensive_merged.py::TestDeleteGroupMutations::test_delete_group_permission_none_created_by	PASSED	[41%]
tests/test_group_all_comprehensive_merged.py::TestDeleteGroupMutations::test_delete_group_split_deletion_fails	PASSED	[42%]
tests/test_group_all_comprehensive_merged.py::TestDeleteGroupMutations::test_delete_group_split_deletion_with_multiple_expenses	PASSED	[42%]
tests/test_group_all_comprehensive_merged.py::TestDeleteGroupMutations::test_delete_group_string_created_by	PASSED	[43%]
tests/test_group_all_comprehensive_merged.py::TestDeleteGroupMutations::test_delete_group_successful	PASSED	[43%]
tests/test_group_all_comprehensive_merged.py::TestDeleteGroupMutations::test_delete_group_unauthorized	PASSED	[44%]
tests/test_group_all_comprehensive_merged.py::TestDeleteGroupMutations::test_delete_group_unauthorized_string_conversion	PASSED	[44%]
tests/test_group_all_comprehensive_merged.py::TestDeleteGroupMutations::test_delete_group_user_id_empty_string	PASSED	[45%]
tests/test_group_all_comprehensive_merged.py::TestDeleteGroupMutations::test_delete_group_user_id_none	PASSED	[45%]
tests/test_group_all_comprehensive_merged.py::TestDeleteGroupMutations::test_delete_group_with_expenses	PASSED	[46%]
tests/test_group_all_comprehensive_merged.py::TestDeleteGroupMutations::test_delete_group_with_many_expenses	PASSED	[46%]
tests/test_group_all_comprehensive_merged.py::TestGetGroupBalancesComprehensive::test_get_group_balances_large_amounts	PASSED	[47%]
tests/test_group_all_comprehensive_merged.py::TestGetGroupBalancesComprehensive::test_get_group_balances_member_check_with_data	PASSED	[47%]
tests/test_group_all_comprehensive_merged.py::TestGetGroupBalancesComprehensive::test_get_group_balances_member_without_user_data	PASSED	[48%]
tests/test_group_all_comprehensive_merged.py::TestGetGroupBalancesComprehensive::test_get_group_balances_multiple_expenses	PASSED	[48%]
tests/test_group_all_comprehensive_merged.py::TestGetGroupBalancesComprehensive::test_get_group_balances_multiple_members	PASSED	[49%]
tests/test_group_all_comprehensive_merged.py::TestGetGroupBalancesComprehensive::test_get_group_balances_negative_amounts	PASSED	[49%]
tests/test_group_all_comprehensive_merged.py::TestGetGroupBalancesComprehensive::test_get_group_balances_no_expenses	PASSED	[50%]
tests/test_group_all_comprehensive_merged.py::TestGetGroupBalancesComprehensive::test_get_group_balances_no_members	PASSED	[50%]
tests/test_group_all_comprehensive_merged.py::TestGetGroupBalancesComprehensive::test_get_group_balances_not_member	PASSED	[50%]
tests/test_group_all_comprehensive_merged.py::TestGetGroupBalancesComprehensive::test_get_group_balances_settlements_multiple	PASSED	[51%]
tests/test_group_all_comprehensive_merged.py::TestGetGroupBalancesComprehensive::test_get_group_balances_settlements_simple	PASSED	[51%]
tests/test_group_all_comprehensive_merged.py::TestGetGroupBalancesComprehensive::test_get_group_balances_settlements_zero_balance	PASSED	[52%]
tests/test_group_all_comprehensive_merged.py::TestGetGroupBalancesComprehensive::test_get_group_balances_single_expense_single_payer	PASSED	[52%]
tests/test_group_all_comprehensive_merged.py::TestGetGroupBalancesComprehensive::test_get_group_balances_single_member	PASSED	[53%]
tests/test_group_all_comprehensive_merged.py::TestGetGroupMembersMutations::test_get_group_members_balance_field_exists	PASSED	[53%]
tests/test_group_all_comprehensive_merged.py::TestGetGroupMembersMutations::test_get_group_members_exception_handling	PASSED	[54%]
tests/test_group_all_comprehensive_merged.py::TestGetGroupMembersMutations::test_get_group_members_fetch_error_no_data	PASSED	[54%]
tests/test_group_all_comprehensive_merged.py::TestGetGroupMembersMutations::test_get_group_members_member_check_no_hasattr	PASSED	[55%]

2. test_categorizer_service_comprehensive.py (47 tests)

- User rule retrieval and management
- Category learning algorithms
- Keyword management and matching
- Image parsing and categorization
- Edge cases and error handling

```
karthikraman@Balamurugans-MacBook-Pro backend % python -m pytest tests/test_categorizer_service_comprehensive.py -v --tb=no
===== test session starts =====
platform darwin -- Python 3.13.5, pytest-9.0.1, pluggy-1.6.0 -- /Users/karthikraman/.pyenv/versions/3.13.5/bin/python
cachedir: .pytest_cache
rootdir: /Users/karthikraman/Documents/expense_pro_new/Coincious-Smart-Expense-Tracker/backend
plugins: anyio-4.11.0
collected 47 items

tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_find_category_ai_invalid_json PASSED [ 2%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_find_category_ai_returns_none PASSED [ 4%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_find_category_ai_returns_other PASSED [ 6%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_find_category_case_insensitive_matching PASSED [ 8%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_find_category_empty_description PASSED [ 10%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_find_category_empty_user_id PASSED [ 12%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_find_category_gemini_error PASSED [ 14%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_find_category_multiple_matches PASSED [ 17%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_find_category_no_matches PASSED [ 19%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_find_category_no_model PASSED [ 21%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_find_category_no_user_rules PASSED [ 23%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_find_category_none_description PASSED [ 25%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_find_category_none_user_id PASSED [ 27%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_find_category_partial_word_matching PASSED [ 29%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_find_category_with_user_rules PASSED [ 31%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_get_user_rules_database_error PASSED [ 34%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_get_user_rules_empty_user_id PASSED [ 36%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_get_user_rules_handles_empty_response PASSED [ 38%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_get_user_rules_no_data PASSED [ 40%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_get_user_rules_no_data_attribute PASSED [ 42%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_get_user_rules_none_data PASSED [ 44%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_get_user_rules_none_user_id PASSED [ 46%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_get_user_rules_returns_dict PASSED [ 48%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_get_user_rules_success PASSED [ 51%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_learn_new_rule_adds_keyword_to_existing PASSED [ 53%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_learn_new_rule_avoids_duplicate_keywords PASSED [ 55%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_learn_new_rule_converts_description_to_lowercase PASSED [ 57%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_learn_new_rule_creates_new_category PASSED [ 59%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_learn_new_rule_database_error_on_check PASSED [ 61%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_learn_new_rule_database_error_on_insert PASSED [ 63%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_learn_new_rule_database_error_on_update PASSED [ 65%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_learn_new_rule_empty_description PASSED [ 68%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_learn_new_rule_empty_user_id PASSED [ 70%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_learn_new_rule_existing_category PASSED [ 72%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_learn_new_rule_existing_keyword PASSED [ 74%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_learn_new_rule_new_category PASSED [ 76%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_learn_new_rule_none_description PASSED [ 78%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_learn_new_rule_none_user_id PASSED [ 80%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_parse_bill_image_empty_image_bytes PASSED [ 82%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_parse_bill_image_empty_mime_type PASSED [ 85%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_parse_bill_image_gemini_error PASSED [ 87%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_parse_bill_image_handles_bytes PASSED [ 89%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_parse_bill_image_json_parse_error PASSED [ 91%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_parse_bill_image_no_model PASSED [ 93%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_parse_bill_image_none_image_bytes PASSED [ 95%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_parse_bill_image_none_mime_type PASSED [ 97%]
tests/test_categorizer_service_comprehensive.py::TestCategoryrizerServiceComprehensive::test_parse_bill_image_success PASSED [100%]

===== 47 passed in 0.47s =====
```

3. test_expense_service_comprehensive_merged.py (20 tests)

- Expense creation and validation
- Amount processing and conversion
- Split handling and calculations
- Category assignment
- Receipt and metadata handling

```
karthikraman@Balamurugans-MacBook-Pro backend % python -m pytest tests/test_expense_service_comprehensive_merged.py -v --tb=no
===== test session starts =====
platform darwin -- Python 3.13.5, pytest-9.0.1, pluggy-1.6.0 -- /Users/karthikraman/.pyenv/versions/3.13.5/bin/python
cachedir: .pytest_cache
rootdir: /Users/karthikraman/Documents/expense_pro_new/Coincious-Smart-Expense-Tracker/backend
plugins: anyio-4.11.0
collected 20 items

tests/test_expense_service_comprehensive_merged.py::TestExpenseServiceComprehensiveMerged::test_donut_data_current_month PASSED [ 5%]
tests/test_expense_service_comprehensive_merged.py::TestExpenseServiceComprehensiveMerged::test_donut_data_default_period PASSED [ 10%]
tests/test_expense_service_comprehensive_merged.py::TestExpenseServiceComprehensiveMerged::test_donut_data_exception PASSED [ 15%]
tests/test_expense_service_comprehensive_merged.py::TestExpenseServiceComprehensiveMerged::test_donut_data_many_categories PASSED [ 20%]
tests/test_expense_service_comprehensive_merged.py::TestExpenseServiceComprehensiveMerged::test_donut_data_previous_month PASSED [ 25%]
tests/test_expense_service_comprehensive_merged.py::TestExpenseServiceComprehensiveMerged::test_donut_data_single_category PASSED [ 30%]
tests/test_expense_service_comprehensive_merged.py::TestExpenseServiceComprehensiveMerged::test_donut_data_sorted_by_value_descending PASSED [ 35%]
%]
tests/test_expense_service_comprehensive_merged.py::TestExpenseServiceComprehensiveMerged::test_donut_data_sums_correctly PASSED [ 40%]
tests/test_expense_service_comprehensive_merged.py::TestExpenseServiceComprehensiveMerged::test_get_group_expenses_amount_conversion PASSED [ 45%]
]
tests/test_expense_service_comprehensive_merged.py::TestExpenseServiceComprehensiveMerged::test_get_group_expenses_db_error PASSED [ 50%]
tests/test_expense_service_comprehensive_merged.py::TestExpenseServiceComprehensiveMerged::test_get_group_expenses_empty_split PASSED [ 55%]
tests/test_expense_service_comprehensive_merged.py::TestExpenseServiceComprehensiveMerged::test_get_group_expenses_large_amount PASSED [ 60%]
tests/test_expense_service_comprehensive_merged.py::TestExpenseServiceComprehensiveMerged::test_get_group_expenses_many_splits PASSED [ 65%]
tests/test_expense_service_comprehensive_merged.py::TestExpenseServiceComprehensiveMerged::test_get_group_expenses_multiple_payer_fields PASSED [ 70%]
tests/test_expense_service_comprehensive_merged.py::TestExpenseServiceComprehensiveMerged::test_get_group_expenses_negative_amount PASSED [ 75%]
tests/test_expense_service_comprehensive_merged.py::TestExpenseServiceComprehensiveMerged::test_get_group_expenses_not_member PASSED [ 80%]
tests/test_expense_service_comprehensive_merged.py::TestExpenseServiceComprehensiveMerged::test_get_group_expenses_success_flow PASSED [ 85%]
tests/test_expense_service_comprehensive_merged.py::TestExpenseServiceComprehensiveMerged::test_get_group_expenses_uses_total_amount_not_amount PASSED [ 90%]
tests/test_expense_service_comprehensive_merged.py::TestExpenseServiceComprehensiveMerged::test_get_group_expenses_with_payer_metadata PASSED [ 95%]
tests/test_expense_service_comprehensive_merged.py::TestExpenseServiceComprehensiveMerged::test_get_group_expenses_zero_amount PASSED [100%]

===== 20 passed in 0.38s =====
```

4. Test_invitation_service_comprehensive_merged.py (19 tests)

- Invitation accept/decline flows
- Authorization and permission checks
- Notification creation and management
- Name fallback logic
- Error handling scenarios

```
karthikraman@Balamurugans-MacBook-Pro backend % python -m pytest tests/test_invitation_service_comprehensive_merged.py -v --tb=no
===== test session starts =====
platform darwin -- Python 3.13.5, pytest-9.0.1, pluggy-1.6.0 -- /Users/karthikraman/.pyenv/versions/3.13.5/bin/python
cachedir: .pytest_cache
rootdir: /Users/karthikraman/Documents/expense_pro_new/Coincious-Smart-Expense-Tracker/backend
plugins: anyio-4.11.0
collected 19 items

tests/test_invitation_service_comprehensive_merged.py::TestInvitationServiceComprehensiveMerged::test_respond_to_invitation_accept_adds_member_mu
tation PASSED [ 5%]
tests/test_invitation_service_comprehensive_merged.py::TestInvitationServiceComprehensiveMerged::test_respond_to_invitation_accept_creates_member
PASSED [ 10%]
tests/test_invitation_service_comprehensive_merged.py::TestInvitationServiceComprehensiveMerged::test_respond_to_invitation_accept_success PASSED [ 15%]
tests/test_invitation_service_comprehensive_merged.py::TestInvitationServiceComprehensiveMerged::test_respond_to_invitation_accept_success_mutati
on PASSED [ 21%]
tests/test_invitation_service_comprehensive_merged.py::TestInvitationServiceComprehensiveMerged::test_respond_to_invitation_accept_updates_status
PASSED [ 26%]
tests/test_invitation_service_comprehensive_merged.py::TestInvitationServiceComprehensiveMerged::test_respond_to_invitation_creates_notification_
mutation PASSED [ 31%]
tests/test_invitation_service_comprehensive_merged.py::TestInvitationServiceComprehensiveMerged::test_respond_to_invitation_creates_notification_
on_accept PASSED [ 36%]
tests/test_invitation_service_comprehensive_merged.py::TestInvitationServiceComprehensiveMerged::test_respond_to_invitation_decline_success PASSE
D [ 42%]
tests/test_invitation_service_comprehensive_merged.py::TestInvitationServiceComprehensiveMerged::test_respond_to_invitation_decline_success_mutati
on PASSED [ 47%]
tests/test_invitation_service_comprehensive_merged.py::TestInvitationServiceComprehensiveMerged::test_respond_to_invitation_decline_updates_statu
s PASSED [ 52%]
tests/test_invitation_service_comprehensive_merged.py::TestInvitationServiceComprehensiveMerged::test_respond_to_invitation_deletes_original_noti
fication PASSED [ 57%]
tests/test_invitation_service_comprehensive_merged.py::TestInvitationServiceComprehensiveMerged::test_respond_to_invitation_empty_action PASSED [ 63%]
tests/test_invitation_service_comprehensive_merged.py::TestInvitationServiceComprehensiveMerged::test_respond_to_invitation_invalid_action PASSED [ 68%]
tests/test_invitation_service_comprehensive_merged.py::TestInvitationServiceComprehensiveMerged::test_respond_to_invitation_invalid_action_mutati
on PASSED [ 73%]
tests/test_invitation_service_comprehensive_merged.py::TestInvitationServiceComprehensiveMerged::test_respond_to_invitation_not_found PASSED [ 78%]
tests/test_invitation_service_comprehensive_merged.py::TestInvitationServiceComprehensiveMerged::test_respond_to_invitation_not_found_mutation PA
SSED [ 84%]
tests/test_invitation_service_comprehensive_merged.py::TestInvitationServiceComprehensiveMerged::test_respond_to_invitation_uses_fallback_name PA
SSED [ 89%]
tests/test_invitation_service_comprehensive_merged.py::TestInvitationServiceComprehensiveMerged::test_respond_to_invitation_wrong_user PASSED [ 94%]
tests/test_invitation_service_comprehensive_merged.py::TestInvitationServiceComprehensiveMerged::test_respond_to_invitation_wrong_user_mutation P
ASSED [100%]

===== 19 passed in 0.37s =====
```


5. Test_notification_service.py (13 tests)

- Notification logging and retrieval
- Read status updates
- User filtering and ordering
- Exception handling

```
karthikraman@Balamurugans-MacBook-Pro backend % python -m pytest tests/test_notification_service.py -v --tb=no
===== test session starts =====
platform darwin -- Python 3.13.5, pytest-9.0.1, pluggy-1.6.0 -- /Users/karthikraman/.pyenv/versions/3.13.5/bin/python
cachedir: .pytest_cache
rootdir: /Users/karthikraman/Documents/expense_pro_new/Coincious-Smart-Expense-Tracker/backend
plugins: anyio-4.11.0
collected 13 items

tests/test_notification_service.py::TestNotificationService::test_create_notification_includes_link PASSED [ 7%]
tests/test_notification_service.py::TestNotificationService::test_create_notification_success PASSED [ 15%]
tests/test_notification_service.py::TestNotificationService::test_create_raw_notification_success PASSED [ 23%]
tests/test_notification_service.py::TestNotificationService::test_delete_invitation_notification_filters_correctly PASSED [ 30%]
tests/test_notification_service.py::TestNotificationService::test_delete_invitation_notification_success PASSED [ 38%]
tests/test_notification_service.py::TestNotificationService::test_get_notifications_ordered_by_date PASSED [ 46%]
tests/test_notification_service.py::TestNotificationService::test_get_notifications_returns_list PASSED [ 53%]
tests/test_notification_service.py::TestNotificationService::test_log_notification_handles_exception PASSED [ 61%]
tests/test_notification_service.py::TestNotificationService::test_log_notification_success PASSED [ 69%]
tests/test_notification_service.py::TestNotificationService::test_log_notification_with_related_expense PASSED [ 76%]
tests/test_notification_service.py::TestNotificationService::test_mark_as_read_filters_by_user PASSED [ 84%]
tests/test_notification_service.py::TestNotificationService::test_mark_as_read_not_found PASSED [ 92%]
tests/test_notification_service.py::TestNotificationService::test_mark_as_read_success PASSED [100%]

===== 13 passed in 0.32s =====
karthikraman@Balamurugans-MacBook-Pro backend %
```

6. Test_ai_service_mutations.py (19 tests)

get_financial_context (12 tests):

- Cache management, budget fetching, group balance calculations, date logic, exception handling

chat_with_groq (7 tests):

API integration, history management, financial data integration, error handling, parameter validation

```
karthikraman@Balamurugans-MacBook-Pro backend % python -m pytest tests/test_ai_service_mutations.py -v --tb=no
===== test session starts =====
platform darwin -- Python 3.13.5, pytest-9.0.1, pluggy-1.6.0 -- /Users/karthikraman/.pyenv/versions/3.13.5/bin/python
cachedir: .pytest_cache
rootdir: /Users/karthikraman/Documents/expense_pro_new/Coincious-Smart-Expense-Tracker/backend
plugins: anyio-4.11.0
collected 19 items

tests/test_ai_service_mutations.py::TestAIServiceMutations::test_budget_fetch_exception PASSED [ 5%]
tests/test_ai_service_mutations.py::TestAIServiceMutations::test_budget_set PASSED [ 10%]
tests/test_ai_service_mutations.py::TestAIServiceMutations::test_cache_hit PASSED [ 15%]
tests/test_ai_service_mutations.py::TestAIServiceMutations::test_chat_api_error PASSED [ 21%]
tests/test_ai_service_mutations.py::TestAIServiceMutations::test_chat_empty_history PASSED [ 26%]
tests/test_ai_service_mutations.py::TestAIServiceMutations::test_chat_includes_financial_data PASSED [ 31%]
tests/test_ai_service_mutations.py::TestAIServiceMutations::test_chat_limits_history_to_5 PASSED [ 36%]
tests/test_ai_service_mutations.py::TestAIServiceMutations::test_chat_simple_message PASSED [ 42%]
tests/test_ai_service_mutations.py::TestAIServiceMutations::test_chat_temperature_and_tokens PASSED [ 47%]
tests/test_ai_service_mutations.py::TestAIServiceMutations::test_chat_with_history PASSED [ 52%]
tests/test_ai_service_mutations.py::TestAIServiceMutations::test_date_range_ninety_days PASSED [ 57%]
tests/test_ai_service_mutations.py::TestAIServiceMutations::test_exception_on_expenses_fetch PASSED [ 63%]
tests/test_ai_service_mutations.py::TestAIServiceMutations::test_group_with_negative_balance PASSED [ 68%]
tests/test_ai_service_mutations.py::TestAIServiceMutations::test_group_with_positive_balance PASSED [ 73%]
tests/test_ai_service_mutations.py::TestAIServiceMutations::test_group_with_zero_balance PASSED [ 78%]
tests/test_ai_service_mutations.py::TestAIServiceMutations::test_group_without_name PASSED [ 84%]
tests/test_ai_service_mutations.py::TestAIServiceMutations::test_multiple_groups PASSED [ 89%]
tests/test_ai_service_mutations.py::TestAIServiceMutations::test_no_expenses PASSED [ 94%]
tests/test_ai_service_mutations.py::TestAIServiceMutations::test_no_groups PASSED [100%]

===== 19 passed in 0.39s =====
karthikraman@Balamurugans-MacBook-Pro backend %
```

Final Mutation Test results :

```
karthikraman@Balamurugans-MacBook-Pro expense_pro_new % cd /Users/karthikraman/Documents
karthikraman@Balamurugans-MacBook-Pro backend % python calculate_mutation_score.py
Calculating mutation score...

=====
                        MUTATION TESTING REPORT
=====

Mutation Score: 93.09% 🟢 [Grade: A]
=====

Detailed Results:
✅ Killed (Good):      1320 mutants
❌ Survived (Bad):     98 mutants
👁️ No Tests:          0 mutants
⌚ Timeout:           0 mutants
😟 Suspicious:         0 mutants
🔥 Incompetent:       1694 mutants
-----
📊 Total Mutants:     1418 mutants

Calculation:
Killed / (Killed + Survived) = 1320 / (1320 + 98) = 93.09%

Grade: A
Status: ✅ Excellent – Test suite is very effective
```

```
karthikraman@Balamurugans-MacBook-Pro backend % mutmut run 2>&1 | tail -10
: Generating mutants
  done in 44776ms
.: Listing all tests
.: Running clean tests
  done
.: Running forced fail test
  done
Running mutation testing
.: 3112/3112 🐛 1320 😟 98 ⌚ 0 😟 0 😟 1694 🚫 0
13.88 mutations/second
```

Conclusion & challenges faced during mutation testing:

1. While performing mutation testing we thought of generating the html report for the results but we realised we need a python version less than 3.8.
2. When we tried using an older version of python it was not able to detect mutants properly and had issues with requirements in installing the package.
3. We decided to use the python 3.13 version and found results accordingly. At first we got a mutation score of 5% only and later we improved the test cases phase by phase and then we reached 93% score . we took help from ai for generation of test cases .