Group No : 15
Ameya Hujare (A20545367)
Deep Pawar (A20545137)
Canyu Chen (A20479758)
Professor: Gerald Balekaki
Institute: Illinois Institute of Technology

CS 525: Advanced Database Organization

Spring 2025 - Assignment 3 - Record Manager

1. INTRODUCTION

This assignment aims to develop a Record Manager that handles tables with a fixed schema. The Record Manager supports inserting, deleting, updating, and scanning records based on search conditions. The tables are stored in separate page files, accessed via a Buffer Manager developed in Assignment 2.

2. RECORD MANAGER OVERVIEW

The Record Manager provides essential functionalities for managing records in a structured manner. It supports:

- **Schema Management:** Defines table attributes and constraints.
- **Record Storage and Access:** Uses a page-file-based approach for storing records efficiently.
- **Free Space Management:** Maintains an optimized allocation strategy for record storage.
- **Scanning:** Retrieves records matching specific conditions using expressions.

3. FUNCTIONALITIES AND CONCEPTS

3.1 Record Representation

Each record follows a fixed-length schema, making storage efficient. The system assigns unique Record IDs (RIDs), consisting of page number and slot number.

3.2 Page Layout

Records are stored within fixed-size pages, which also contain metadata for slot management and free space tracking. The first few pages store table schema and indexing information.

3.3 Free Space Management

Deleted records create free slots, tracked using either a linked list approach or a bitmap-based directory. The system optimally allocates new records to free slots before extending the storage.

3.4 Scan Operations

Scanning retrieves records based on a search condition represented by an expression tree. It supports both full table scans and conditional scans using comparison operators such as Equal, Less Than, AND, OR, and NOT.

4. INTERFACE AND IMPLEMENTATION

4.1 Data Structures

- **Schema**:
  Defines table structure, attribute names, and data types.
- **Record**:
  Represents a data entry with a unique RID.
- **RM_TableData**:
  Encapsulates table metadata and management data.
- **RM_ScanHandle**:
  Tracks active scan operations.

4.2 Table Management Functions

- **initRecordManager()**:
  Initializes the Record Manager.
- **createTable()**:
  Creates a table and initializes schema storage.
- **openTable() / closeTable()**:
  Manages access to table files.
- **deleteTable()**:
  Deletes an existing table.
- **getNumTuples()**:
  Returns the count of stored records.

4.3 Record Management Functions

- **insertRecord()**:
  Adds a new record and assigns an RID.
- **deleteRecord()**:
  Marks a record as deleted and updates free space.
- **updateRecord()**:
  Modifies an existing record.
- **getRecord()**:
  Retrieves a record using its RID.

4.4 Scan Functions

- **startScan()**:
  Initializes a scan operation.
- **next()**:
  Retrieves the next matching record.
- **closeScan()**:
  Cleans up scan resources.

4.5 Schema and Attribute Functions

- **getRecordSize()**:
  Returns the size of records for a given schema.

- **createSchema()**:
  Constructs a schema definition.
- **createRecord() / freeRecord()**:
  Manages memory allocation for records.
- **getAttr() / setAttr()**:
  Retrieves or updates specific attribute values.

5. ERROR HANDLING AND DEBUGGING

- **Error Codes:**
  Defined in dberror.h for consistency.

- **Debugging Methods:**
  Included print functions for schema, records, and page contents.

6. SOURCE CODE STRUCTURE

The project directory follows this structure:

```
assign3/
│── buffer_mgr_stat.c
│── buffer_mgr_stat.h
│── buffer_mgr.c
│── buffer_mgr.h
│── dberror.c
│── dberror.h
│── dt.h
│── expr.c
│── expr.h
│── makefile
│── README.md
│── record_mgr.c
│── record_mgr.h
│── rm_serializer.c
│── storage_mgr_backup.c
│── storage_mgr.c
│── storage_mgr.h
│── tables.h
│── test_assign3_1.c
│── test_expr.c
│── test_helper.h
```

7. TESTING AND VALIDATION

Test cases ensure the correctness of:

- **Basic record operations** (Insert, Delete, Update, Retrieve)
- **Scan functionalities** (Full scan, Conditional scan)
- **Schema and attribute management**

8. OPTIONAL EXTENSIONS ADDED

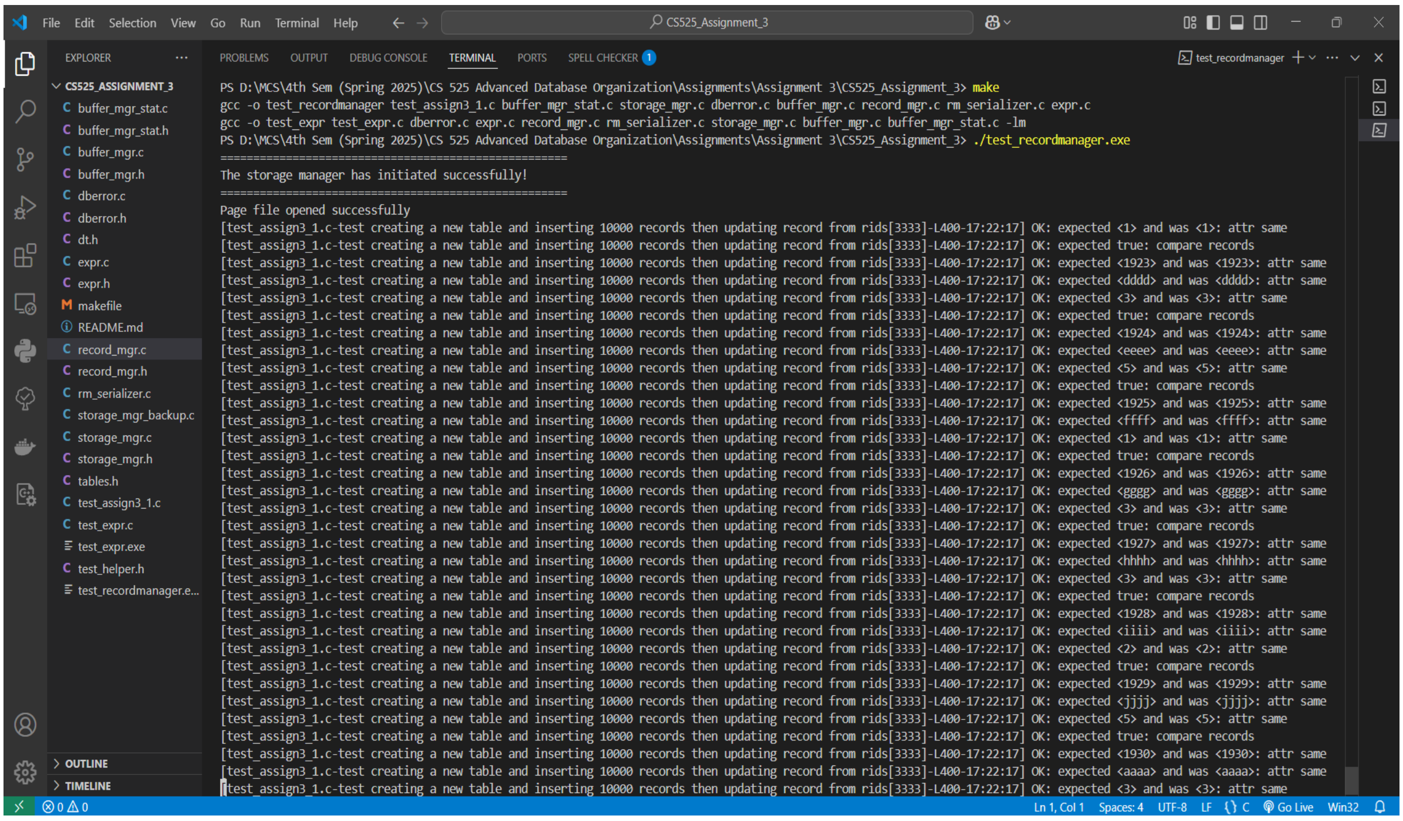
- **TIDs and Tombstones:** Implement a system for tracking record deletions (tombstones) and record locations (TIDs).
- **Null Values:** Added support for SQL-style NULL values in records and expressions.
- **Primary Key Constraint Checking:** Ensure that primary keys remain unique when inserting or updating records.
- **Ordered Scans:** Allow scans to return records in a specified sort order.

9. CONCLUSION

This assignment is focused on the development and implementation of a Record Manager that facilitates structured storage, efficient data retrieval, and versatile scanning capabilities. By integrating it with a Buffer Manager, memory access is optimized for enhanced performance. Additional features such as primary key constraints and NULL value support further strengthen its functionality, making it more aligned with real-world database management systems.

10. OUTPUT

a. Executing test cases for the Record Manager functions.



```
PS D:\MCS\4th Sem (Spring 2025)\CS 525 Advanced Database Organization\Assignments\Assignment 3\CS525_Assignment_3> make
gcc -o test_recordmanager test_assign3_1.c buffer_mgr_stat.c storage_mgr.c dberror.c buffer_mgr.c record_mgr.c rm_serializer.c expr.c
gcc -o test_expr test_expr.c dberror.c expr.c record_mgr.c rm_serializer.c storage_mgr.c buffer_mgr.c buffer_mgr_stat.c -lm
PS D:\MCS\4th Sem (Spring 2025)\CS 525 Advanced Database Organization\Assignments\Assignment 3\CS525_Assignment_3> ./test_recordmanager.exe
==================================================
The storage manager has initiated successfully!
==================================================
Page file opened successfully
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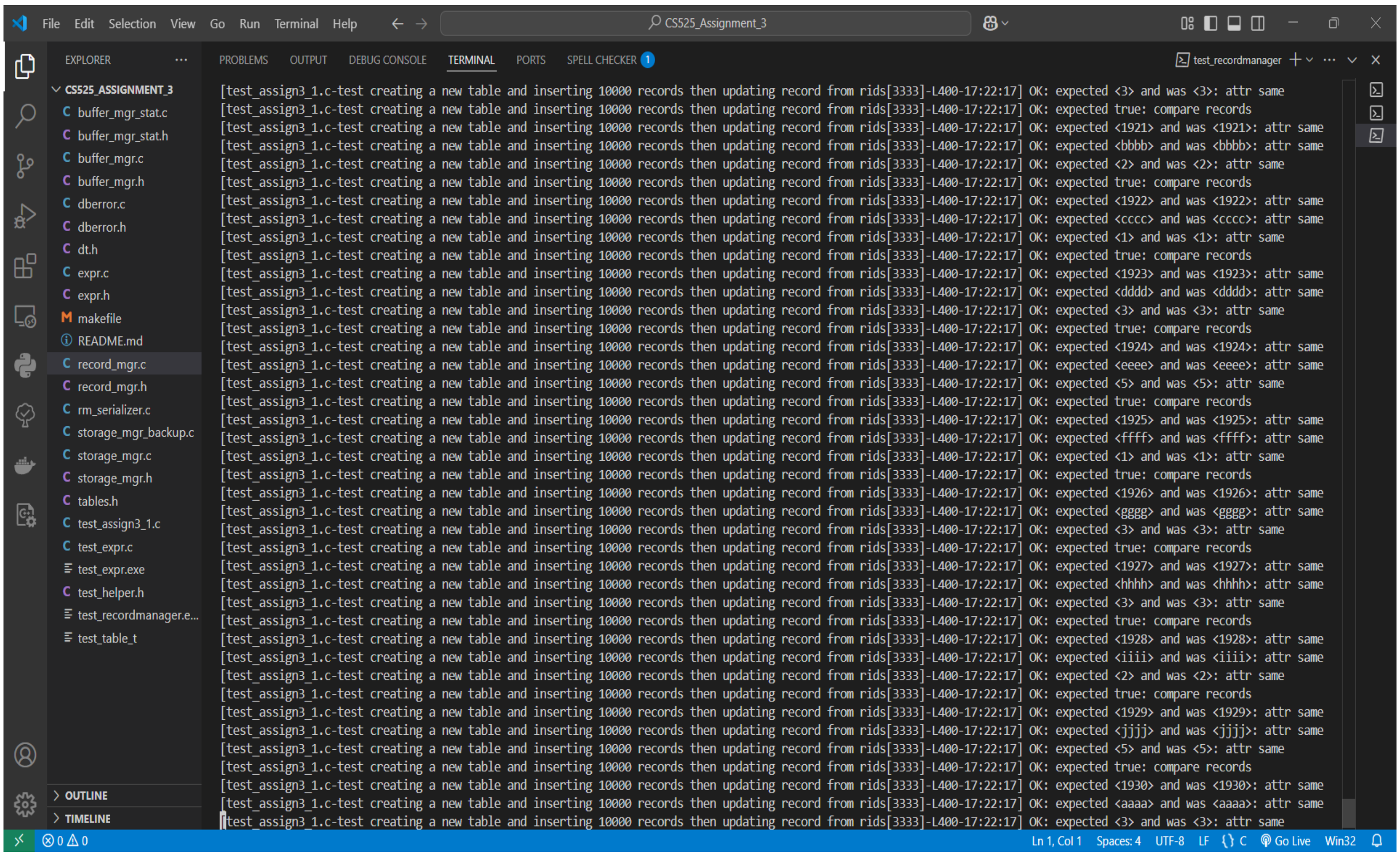

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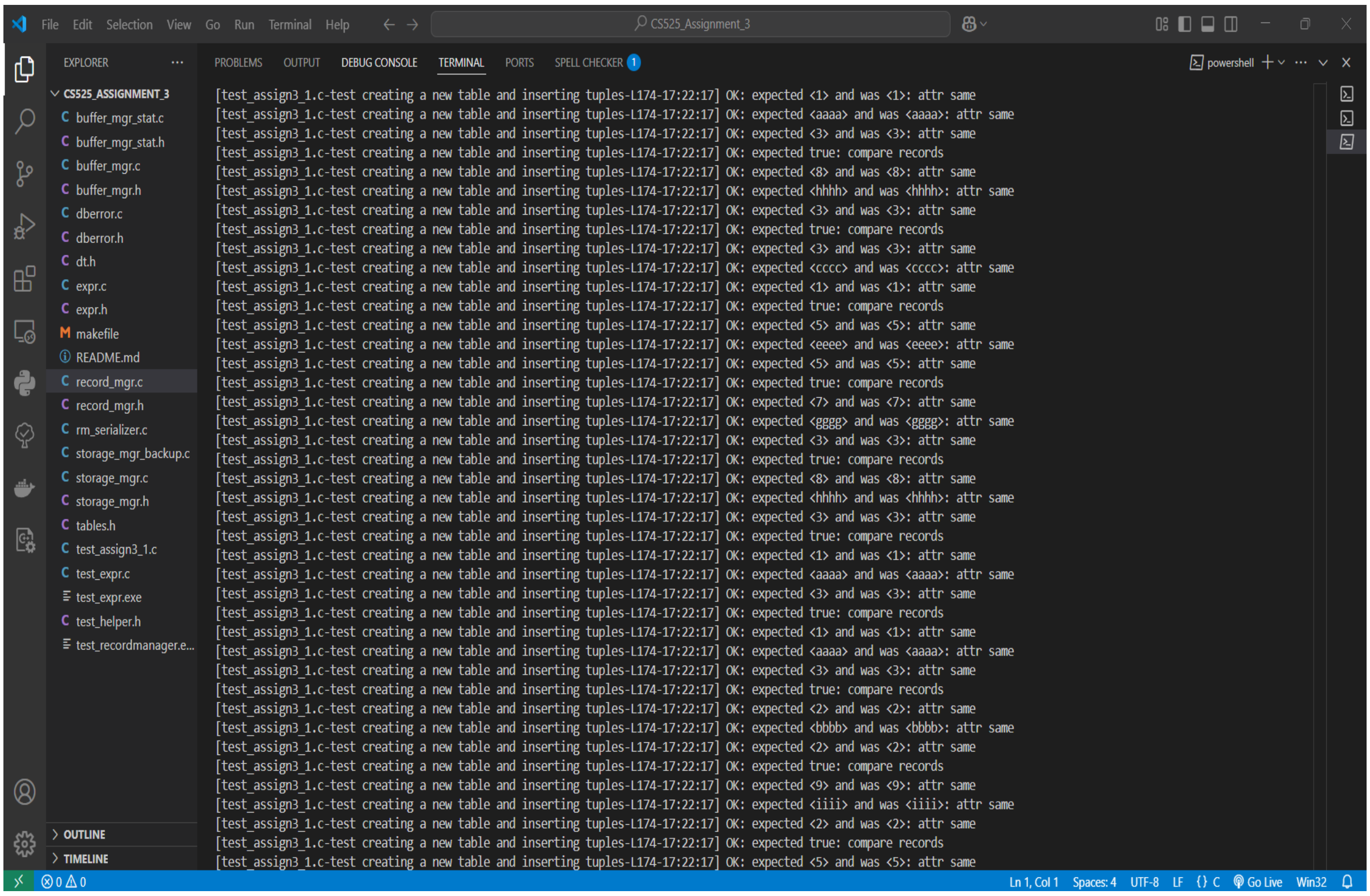

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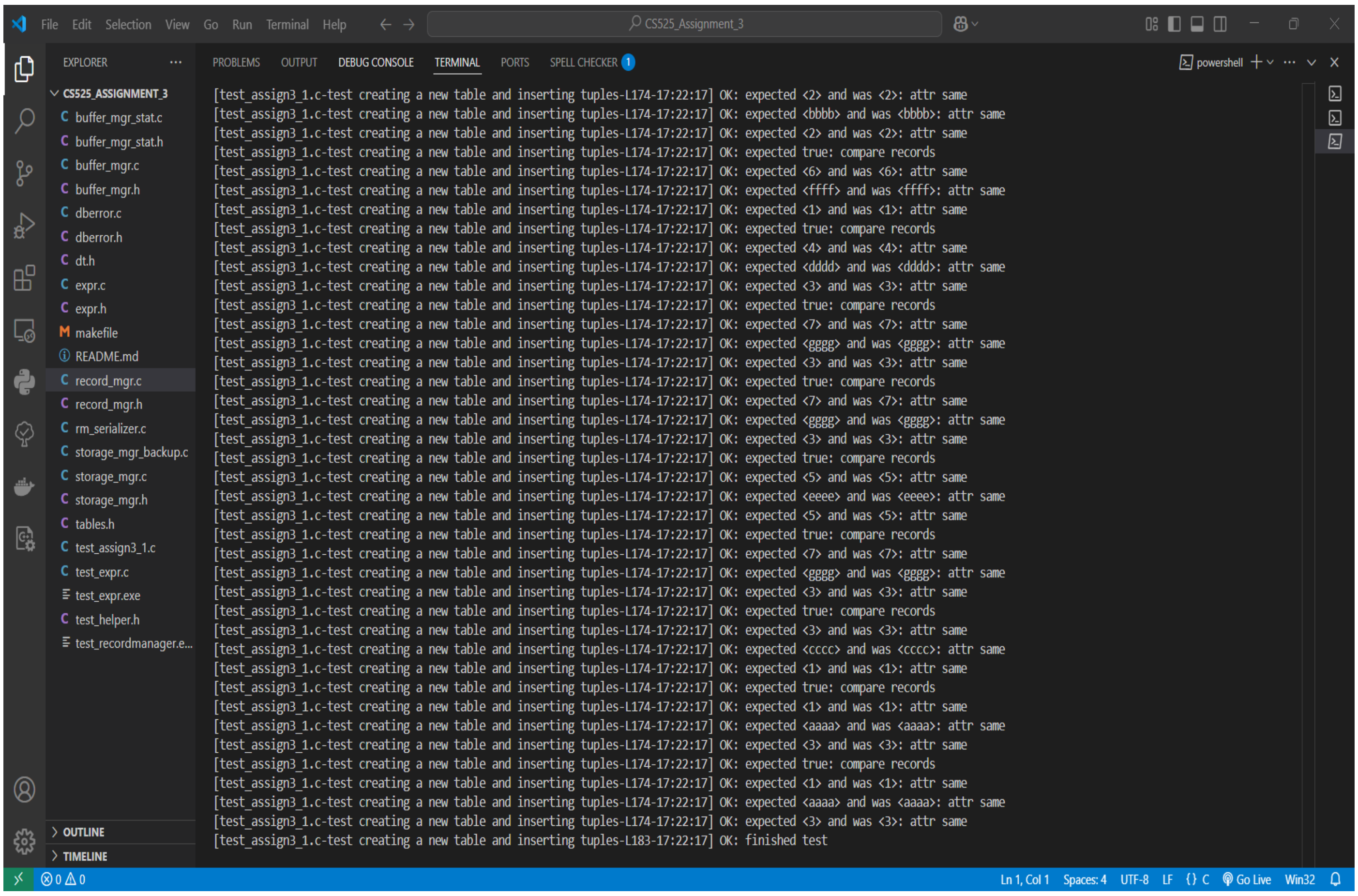

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[test_assign3_1.c-test creating a new table and inserting tuples-L174-17:22:17] OK: expected <3> and was <3>: attr same
[test_assign3_1.c-test creating a new table and inserting tuples-L174-17:22:17] OK: expected true: compare records
[test_assign3_1.c-test creating a new table and inserting tuples-L174-17:22:17] OK: expected <7> and was <7>: attr same
[test_assign3_1.c-test creating a new table and inserting tuples-L174-17:22:17] OK: expected <gggg> and was <gggg>: attr same
[test_assign3_1.c-test creating a new table and inserting tuples-L174-17:22:17] OK: expected <3> and was <3>: attr same
[test_assign3_1.c-test creating a new table and inserting tuples-L174-17:22:17] OK: expected true: compare records
[test_assign3_1.c-test creating a new table and inserting tuples-L174-17:22:17] OK: expected <7> and was <7>: attr same
[test_assign3_1.c-test creating a new table and inserting tuples-L174-17:22:17] OK: expected <gggg> and was <gggg>: attr same
[test_assign3_1.c-test creating a new table and inserting tuples-L174-17:22:17] OK: expected <3> and was <3>: attr same
[test_assign3_1.c-test creating a new table and inserting tuples-L174-17:22:17] OK: expected true: compare records
[test_assign3_1.c-test creating a new table and inserting tuples-L174-17:22:17] OK: expected <5> and was <5>: attr same
[test_assign3_1.c-test creating a new table and inserting tuples-L174-17:22:17] OK: expected <eeee> and was <eeee>: attr same
[test_assign3_1.c-test creating a new table and inserting tuples-L174-17:22:17] OK: expected <5> and was <5>: attr same
[test_assign3_1.c-test creating a new table and inserting tuples-L174-17:22:17] OK: expected true: compare records
[test_assign3_1.c-test creating a new table and inserting tuples-L174-17:22:17] OK: expected <7> and was <7>: attr same
[test_assign3_1.c-test creating a new table and inserting tuples-L174-17:22:17] OK: expected <gggg> and was <gggg>: attr same
[test_assign3_1.c-test creating a new table and inserting tuples-L174-17:22:17] OK: expected <3> and was <3>: attr same
[test_assign3_1.c-test creating a new table and inserting tuples-L174-17:22:17] OK: expected true: compare records
[test_assign3_1.c-test creating a new table and inserting tuples-L174-17:22:17] OK: expected <3> and was <3>: attr same
[test_assign3_1.c-test creating a new table and inserting tuples-L174-17:22:17] OK: expected <cccc> and was <cccc>: attr same
[test_assign3_1.c-test creating a new table and inserting tuples-L174-17:22:17] OK: expected <1> and was <1>: attr same
[test_assign3_1.c-test creating a new table and inserting tuples-L174-17:22:17] OK: expected true: compare records
[test_assign3_1.c-test creating a new table and inserting tuples-L174-17:22:17] OK: expected <1> and was <1>: attr same
[test_assign3_1.c-test creating a new table and inserting tuples-L174-17:22:17] OK: expected <aaaa> and was <aaaa>: attr same
[test_assign3_1.c-test creating a new table and inserting tuples-L174-17:22:17] OK: expected <3> and was <3>: attr same
[test_assign3_1.c-test creating a new table and inserting tuples-L174-17:22:17] OK: expected true: compare records
[test_assign3_1.c-test creating a new table and inserting tuples-L174-17:22:17] OK: expected <1> and was <1>: attr same
[test_assign3_1.c-test creating a new table and inserting tuples-L174-17:22:17] OK: expected <aaaa> and was <aaaa>: attr same
[test_assign3_1.c-test creating a new table and inserting tuples-L174-17:22:17] OK: expected <3> and was <3>: attr same
[test_assign3_1.c-test creating a new table and inserting tuples-L183-17:22:17] OK: finished test
```
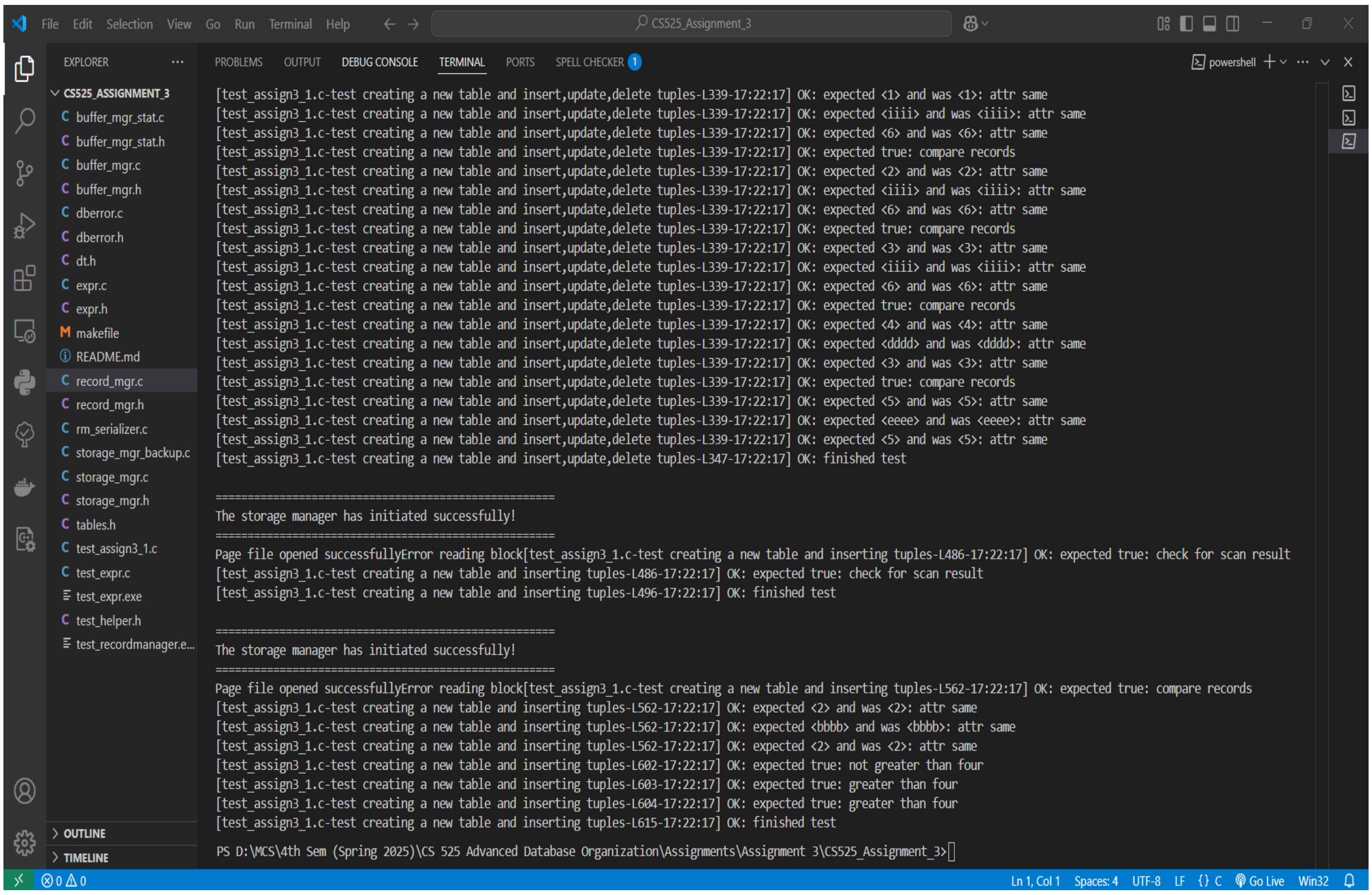
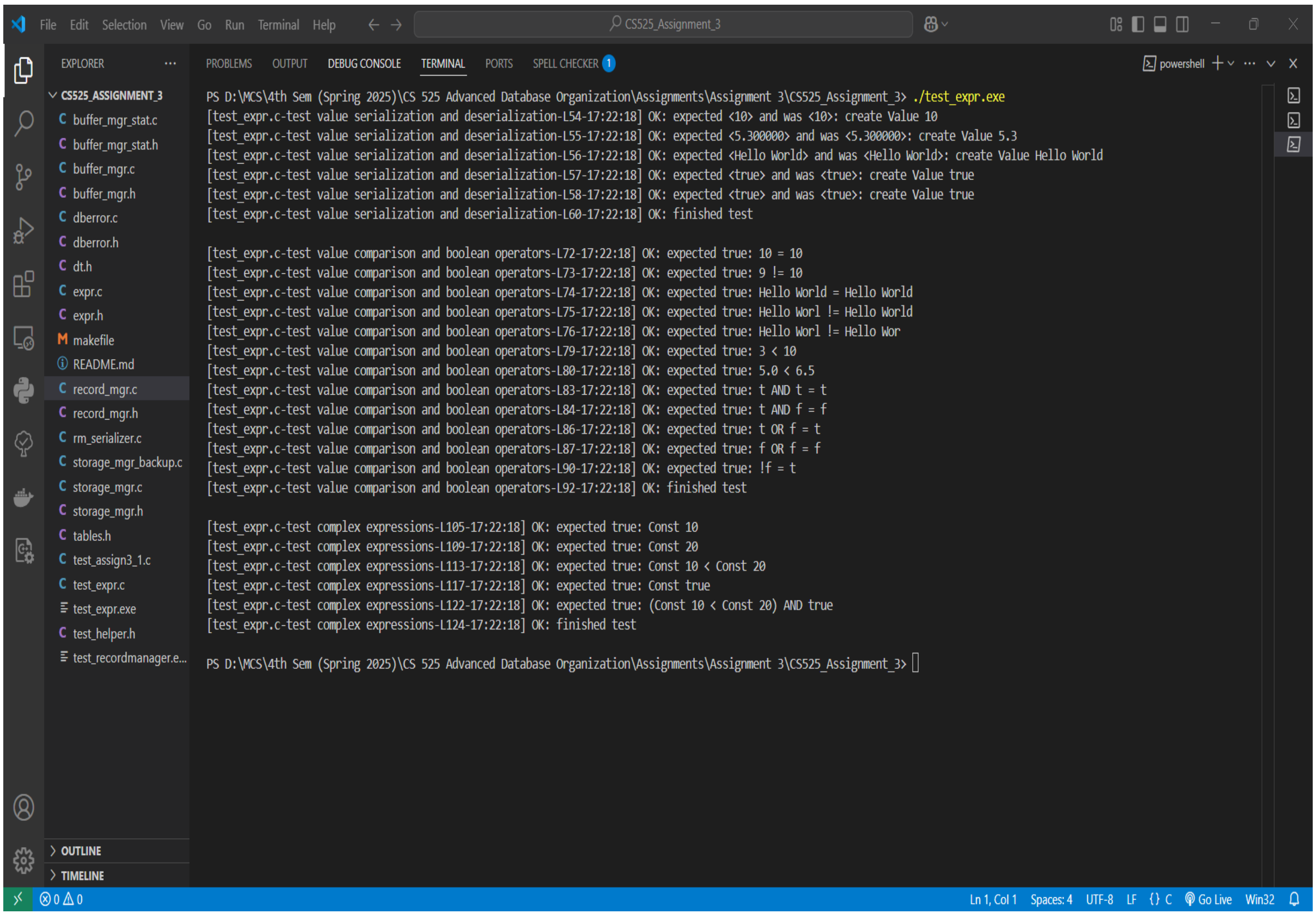



```
[test_assign3_1.c-test creating a new table and insert,update,delete tuples-L339-17:22:17] OK: expected <1> and was <1>: attr same
[test_assign3_1.c-test creating a new table and insert,update,delete tuples-L339-17:22:17] OK: expected <iiii> and was <iiii>: attr same
[test_assign3_1.c-test creating a new table and insert,update,delete tuples-L339-17:22:17] OK: expected <6> and was <6>: attr same
[test_assign3_1.c-test creating a new table and insert,update,delete tuples-L339-17:22:17] OK: expected true: compare records
[test_assign3_1.c-test creating a new table and insert,update,delete tuples-L339-17:22:17] OK: expected <2> and was <2>: attr same
[test_assign3_1.c-test creating a new table and insert,update,delete tuples-L339-17:22:17] OK: expected <iiii> and was <iiii>: attr same
[test_assign3_1.c-test creating a new table and insert,update,delete tuples-L339-17:22:17] OK: expected <6> and was <6>: attr same
[test_assign3_1.c-test creating a new table and insert,update,delete tuples-L339-17:22:17] OK: expected true: compare records
[test_assign3_1.c-test creating a new table and insert,update,delete tuples-L339-17:22:17] OK: expected <3> and was <3>: attr same
[test_assign3_1.c-test creating a new table and insert,update,delete tuples-L339-17:22:17] OK: expected <iiii> and was <iiii>: attr same
[test_assign3_1.c-test creating a new table and insert,update,delete tuples-L339-17:22:17] OK: expected <6> and was <6>: attr same
[test_assign3_1.c-test creating a new table and insert,update,delete tuples-L339-17:22:17] OK: expected true: compare records
[test_assign3_1.c-test creating a new table and insert,update,delete tuples-L339-17:22:17] OK: expected <4> and was <4>: attr same
[test_assign3_1.c-test creating a new table and insert,update,delete tuples-L339-17:22:17] OK: expected <dddd> and was <dddd>: attr same
[test_assign3_1.c-test creating a new table and insert,update,delete tuples-L339-17:22:17] OK: expected <3> and was <3>: attr same
[test_assign3_1.c-test creating a new table and insert,update,delete tuples-L339-17:22:17] OK: expected true: compare records
[test_assign3_1.c-test creating a new table and insert,update,delete tuples-L339-17:22:17] OK: expected <5> and was <5>: attr same
[test_assign3_1.c-test creating a new table and insert,update,delete tuples-L339-17:22:17] OK: expected <eeee> and was <eeee>: attr same
[test_assign3_1.c-test creating a new table and insert,update,delete tuples-L339-17:22:17] OK: expected <5> and was <5>: attr same
[test_assign3_1.c-test creating a new table and insert,update,delete tuples-L347-17:22:17] OK: finished test

====================================================
The storage manager has initiated successfully!
====================================================
Page file opened successfullyError reading block[test_assign3_1.c-test creating a new table and inserting tuples-L486-17:22:17] OK: expected true: check for scan result
[test_assign3_1.c-test creating a new table and inserting tuples-L486-17:22:17] OK: expected true: check for scan result
[test_assign3_1.c-test creating a new table and inserting tuples-L496-17:22:17] OK: finished test

====================================================
The storage manager has initiated successfully!
====================================================
Page file opened successfullyError reading block[test_assign3_1.c-test creating a new table and inserting tuples-L562-17:22:17] OK: expected true: compare records
[test_assign3_1.c-test creating a new table and inserting tuples-L562-17:22:17] OK: expected <2> and was <2>: attr same
[test_assign3_1.c-test creating a new table and inserting tuples-L562-17:22:17] OK: expected <bbbb> and was <bbbb>: attr same
[test_assign3_1.c-test creating a new table and inserting tuples-L562-17:22:17] OK: expected <2> and was <2>: attr same
[test_assign3_1.c-test creating a new table and inserting tuples-L602-17:22:17] OK: expected true: not greater than four
[test_assign3_1.c-test creating a new table and inserting tuples-L603-17:22:17] OK: expected true: greater than four
[test_assign3_1.c-test creating a new table and inserting tuples-L604-17:22:17] OK: expected true: greater than four
[test_assign3_1.c-test creating a new table and inserting tuples-L615-17:22:17] OK: finished test

PS D:\MCS\4th Sem (Spring 2025)\CS 525 Advanced Database Organization\Assignments\Assignment 3\CS525_Assignment_3>
```

b. Executing test cases for the expression evaluation part of the Record Manager



```
PS D:\MCS\4th Sem (Spring 2025)\CS 525 Advanced Database Organization\Assignments\Assignment 3\CS525_Assignment_3> ./test_expr.exe
[test_expr.c-test value serialization and deserialization-L54-17:22:18] OK: expected <10> and was <10>: create Value 10
[test_expr.c-test value serialization and deserialization-L55-17:22:18] OK: expected <5.300000> and was <5.300000>: create Value 5.3
[test_expr.c-test value serialization and deserialization-L56-17:22:18] OK: expected <Hello World> and was <Hello World>: create Value Hello World
[test_expr.c-test value serialization and deserialization-L57-17:22:18] OK: expected <true> and was <true>: create Value true
[test_expr.c-test value serialization and deserialization-L58-17:22:18] OK: expected <true> and was <true>: create Value true
[test_expr.c-test value serialization and deserialization-L60-17:22:18] OK: finished test

[test_expr.c-test value comparison and boolean operators-L72-17:22:18] OK: expected true: 10 = 10
[test_expr.c-test value comparison and boolean operators-L73-17:22:18] OK: expected true: 9 != 10
[test_expr.c-test value comparison and boolean operators-L74-17:22:18] OK: expected true: Hello World = Hello World
[test_expr.c-test value comparison and boolean operators-L75-17:22:18] OK: expected true: Hello Worl != Hello World
[test_expr.c-test value comparison and boolean operators-L76-17:22:18] OK: expected true: Hello Worl != Hello Wor
[test_expr.c-test value comparison and boolean operators-L79-17:22:18] OK: expected true: 3 < 10
[test_expr.c-test value comparison and boolean operators-L80-17:22:18] OK: expected true: 5.0 < 6.5
[test_expr.c-test value comparison and boolean operators-L83-17:22:18] OK: expected true: t AND t = t
[test_expr.c-test value comparison and boolean operators-L84-17:22:18] OK: expected true: t AND f = f
[test_expr.c-test value comparison and boolean operators-L86-17:22:18] OK: expected true: t OR f = t
[test_expr.c-test value comparison and boolean operators-L87-17:22:18] OK: expected true: f OR f = f
[test_expr.c-test value comparison and boolean operators-L90-17:22:18] OK: expected true: !f = t
[test_expr.c-test value comparison and boolean operators-L92-17:22:18] OK: finished test

[test_expr.c-test complex expressions-L105-17:22:18] OK: expected true: Const 10
[test_expr.c-test complex expressions-L109-17:22:18] OK: expected true: Const 20
[test_expr.c-test complex expressions-L113-17:22:18] OK: expected true: Const 10 < Const 20
[test_expr.c-test complex expressions-L117-17:22:18] OK: expected true: Const true
[test_expr.c-test complex expressions-L122-17:22:18] OK: expected true: (Const 10 < Const 20) AND true
[test_expr.c-test complex expressions-L124-17:22:18] OK: finished test

PS D:\MCS\4th Sem (Spring 2025)\CS 525 Advanced Database Organization\Assignments\Assignment 3\CS525_Assignment_3> 
```