SQL EXECUTOR

1. 实验概述

Executor（执行器）的主要功能是根据解释器（Parser）生成的语法树，通过Catalog Manager 提供的信息生成执行计划，并调用 Record Manager、Index Manager 和 Catalog Manager 提供的相应接口进行执行，最后通过执行上下文`ExecuteContext`将执行结果返回给上层模块。

在本实验中，助教已经在框架中设计好MiniSQL中的Parser模块，与Parser模块的相关代码如下：（具体代码可以在工程中查看修改，此处不做说明）

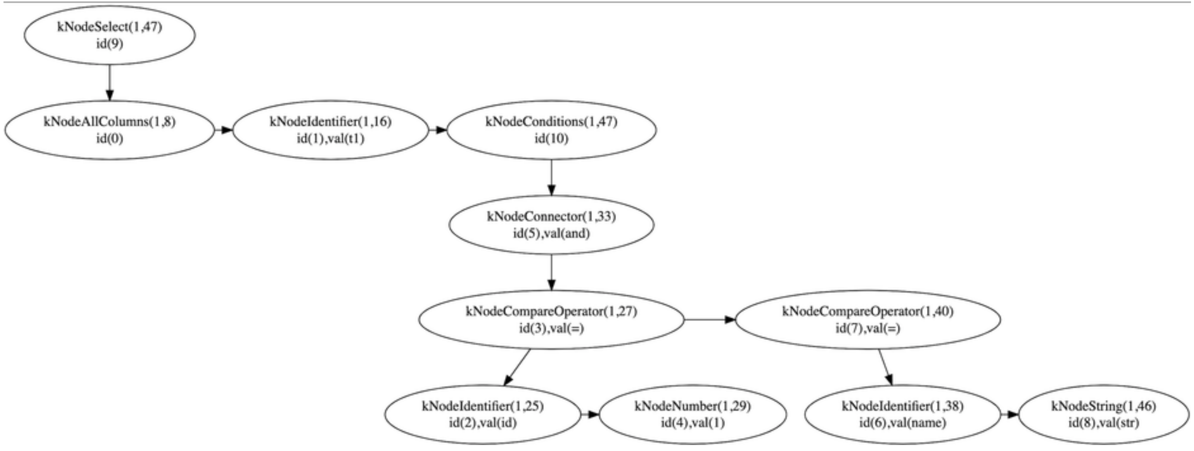
- `src/include/parser/minisql.l`：SQL的词法分析规则；
- `src/include/parser/minisql.y`：SQL的文法分析规则；
- `src/include/parser/minisql_lex.h`：`flex(lex)`根据词法规则自动生成的代码；
- `src/include/parser/minisql_yacc.h`：`bison(yacc)`根据文法规则自动生成的代码；
- `src/include/parser/parser.h`：Parser模块相关的函数定义，供词法分析器和语法分析器调用存储分析结果，同时可供执行器调用获取语法树根结点；
- `src/include/parser/syntax_tree.h`：语法树相关定义，语法树各个结点的类型同样在`SyntaxNodeType`中被定义。

1.1 语法树数据结构

以下是语法树（结点）的数据结构定义，每个结点都包含了一个唯一标识符`id_`，唯一标识符在调用`CreateSyntaxNode`函数时生成（框架中已经给出实现）。`type_`表示语法树结点的类型，`line_no_`和`col_no_`表示该语法树结点对应的是SQL语句的第几行第几列，`child_`和`next_`分别表示该结点的子结点和兄弟结点，`val_`用作一些额外信息的存储（如在`kNodeString`类型的结点中，`val_`将用于存储该字符串的字面量）。
架构说明：此语法树节点需要注意，所有的查询语句中出现的信息都会出现在`val_`域中，包括表名，属性名，或者属性值等多种信息

```
/**
 * Syntax node definition used in abstract syntax tree.
 */
struct SyntaxNode {
  int id_;    /** node id for allocated syntax node, used for debug */
  SyntaxNodeType type_; /** syntax node type */
  int line_no_; /** line number of this syntax node appears in sql */
  int col_no_;  /** column number of this syntax node appears in sql */
  struct SyntaxNode *child_;  /** children of this syntax node */
  struct SyntaxNode *next_;   /** siblings of this syntax node, linked by a single linked list */
  char *val_; /** attribute value of this syntax node, use deep copy */
};
typedef struct SyntaxNode *pSyntaxNode;
```

举一个简单的例子，`select * from t1 where id = 1 and name = "str";`这一条SQL语句生成的语法树如下。以根结点为例说明，`kNodeSelect`为结点的类型，`(1,47)`表示该结点在规约（*reduce*，编译原理中的术语）后位于行的第1行第47列（语句末），`id(9)`表示该结点的`id_`为`9`。


kNodeSelect(1,47) id(9)
kNodeAllColumns(1,8) id(0)
kNodeIdentifier(1,16) id(1),val(t1)
kNodeConditions(1,47) id(10)
kNodeConnector(1,33) id(5),val(and)
kNodeCompareOperator(1,27) id(3),val(=)
kNodeCompareOperator(1,40) id(7),val(=)
kNodeIdentifier(1,25) id(2),val(id)
kNodeNumber(1,29) id(4),val(1)
kNodeIdentifier(1,38) id(6),val(name)
kNodeString(1,46) id(8),val(str)

2. 解析语法树完成命令执行

Parser模块中目前能够支持以下类型的SQL语句。其中包含了一些在语法定义上正确，但在语义上错误的SQL语句（如Line 8 ~ 10）需要我们在执行器中对这些特殊情况进行处理。此外涉及到事务开启、提交和回滚相关的`begin`、`commit`和`rollback`命令在此个版本中暂未实现。

```
1  create database db0;
2  drop database db0;
3  show databases;
4  use db0;
5  show tables;
6  create table t1(a int, b char(20) unique, c float, primary key(a, c));
7  create table t1(a int, b char(0) unique, c float, primary key(a, c));
8  create table t1(a int, b char(-5) unique, c float, primary key(a, c));
9  create table t1(a int, b char(3.69) unique, c float, primary key(a, c));
10 create table t1(a int, b char(-0.69) unique, c float, primary key(a, c));
11 create table student(
12   sno char(8),
13   sage int,
14   sab float unique,
15   primary key (sno, sab)
16 );
17 drop table t1;
18 create index idx1 on t1(a, b);
19 -- "btree" can be replaced with other index types
20 create index idx1 on t1(a, b) using btree;
21 drop index idx1;
22 show indexes;
23 select * from t1;
24 select id, name from t1;
25 select * from t1 where id = 1;
26 -- note: use left association
27 select * from t1 where id = 1 and name = "str";
28 select * from t1 where id = 1 and name = "str" or age is null and bb not
   null;
29 insert into t1 values(1, "aaa", null, 2.33);
30 delete from t1;
31 delete from t1 where id = 1 and amount = 2.33;
32 update t1 set c = 3;
```

```
update t1 set a = 1, b = "ccc" where b = 2.33;
begin;
commit;
rollback;
quit;
execfile "a.txt";
```

在Parser模块调用`yyparse()`（一个示例在`src/main.cpp`中）完成SQL语句解析后，将会得到语法树的根结点`pSyntaxNode`，将语法树根结点传入执行器`ExecuteEngine`（定义于`src/include/executor/execute_engine.h`）后，`ExecuteEngine`将会根据语法树根结点的类型，分发到对应的执行函数中，以完成不同类型SQL语句的执行。

在本节中，我们需要实现`ExecuteEngine`中所有的执行函数，它们被声明为`private`类型的成员，即所有的执行过程对上层模块是隐藏的，上层模块只需要调用`ExecuteEngine::execute()`并传入语法树结点即可无感知地获取到执行结果。

此模块由于要实现的函数功能较多，并且代码实现较为复杂，生成的代码重复度较高，代码量较大，故具体的代码实现只给出部分较为重要精妙的设计，其他设计可以自行在工程文件中查看：

- `ExecuteEngine::ExecuteCreateDatabase(*ast, *context)`

  具体代码实现参照工程文件，实现较为简单

- `ExecuteEngine::ExecuteDropDatabase(*ast, *context)`

  具体代码实现参照工程文件，实现较为简单

- `ExecuteEngine::ExecuteShowDatabases(*ast, *context)`

  具体代码实现参照工程文件，实现较为简单

- `ExecuteEngine::ExecuteUseDatabase(*ast, *context)`

  具体代码实现参照工程文件，实现较为简单

- `ExecuteEngine::ExecuteShowTables(*ast, *context)`

  具体代码实现参照工程文件，实现较为简单

- `ExecuteEngine::ExecuteCreateTable(*ast, *context)`

  具体实现通过直接调用catalog模块提供的接口实现，参照工程文件

- `ExecuteEngine::ExecuteDropTable(*ast, *context)`

  具体实现通过直接调用catalog模块提供的接口实现，参照工程文件

- `ExecuteEngine::ExecuteShowIndexes(*ast, *context)`

  具体实现通过调用catalog模块提供的`GetIndexes`方法实现，参照工程文件

- `ExecuteEngine::ExecuteCreateIndex(*ast, *context)`

  具体实现通过取出语法树信息并调用catalog模块提供的`CreateIndex`方法进行实现，参照工程文件

- `ExecuteEngine::ExecuteDropIndex(*ast, *context)`

  具体实现通过调用catalog模块接口即可实现，参照工程文件

- `ExecuteEngine::ExecuteSelect(*ast, *context)`
  接口设计说明：此处的上层调用模块无需修改，由框架提供，其中返回值需要根据各种特殊情况进行判断，最终返回一个操作状态；`context`参数在我们的实现中属于不需要使用的多余参数，`ast`参数是语法树的根节点，需要根据`next_`找到兄弟节点，或者根据`child_`找到孩子节点的方法对语法树进行遍历，解析语法树的含义。

实现思路说明：每个executor函数的执行思路第一步首先都是找到`Executor`类中的`StorageEngine`以及`CatalogManager`，方便后续的处理和更新。第二步都是通过遍历语法树将操作的含义进行解析（因此后续可以考虑封装），并在这个过程中将语句中不符合规范或者不应该继续执行的情况进行初步判断并返回操作错误原因。第三步对于select功能来说，是找到对应的表，并查询是否可以使用index进行加速；如果可以，直接使用index加速查找，并将返回的结果构建进行展示；如果不可以使用index，则需要使用堆表遍历，直到将所有记录遍历结束，并将结果返回，构建表格并最终展示在标准输出上。

```cpp
dberr_t ExecuteEngine::ExecuteSelect(pSyntaxNode ast, ExecuteContext *context) {
#ifdef ENABLE_EXECUTE_DEBUG
  LOG(INFO) << "ExecuteSelect" << std::endl;
#endif
  dberr_t state = DB_FAILED;
  // Step0: Prepare StorageEngine and CatalogManager
  // Get the Storage of the DbstorageEngine
  auto StorageEngine_Iter = this->dbs_.find(this->current_db_);
  auto Current_Storage_Engine = StorageEngine_Iter->second;
  auto Current_Ctr = Current_Storage_Engine->catalog_mgr_;

  // Get the TableName
  pSyntaxNode ast_TableName = ast->child_->next_;
  std::string TableName(ast_TableName->val_);
  TableInfo *CurTableInfo = nullptr;
  Current_Ctr->GetTable(TableName, CurTableInfo);
  TableHeap *CurTableHeap = CurTableInfo->GetTableHeap();

  // We need to Do the Projection for the All Column
  std::vector<RowId> Result;
  std::vector<uint32_t> Map;
  if (ast->child_->type_ == kNodeColumnList) {
    // 1.Get the TableName
    TableName = ast->child_->next_->val_;
    // 2.Get the Column Will Show on the Result

    for (pSyntaxNode node = ast->child_->child_; node != nullptr; node = node->next_) {
      // Find the Column Index in the Schema
      uint32_t index = 0;
      GetColumnIndex(Current_Ctr, string(node->val_), TableName, index);
      Map.push_back(index);
    }
  }

  // We Do not Need to the Projection
  else {
    uint32_t length = CurTableInfo->GetSchema()->GetColumnCount();
    for (uint32_t i = 0; i < length; i++) {
      Map.push_back(i);
    }
  }
  // 3. Exist Condition StateMent
  clock_t out_diff;
  if (ast->child_->next_->next_ != nullptr) {
    clock_t start, end;
    start = clock();
    GetSatifedRowSet(ast, TableName, Current_Ctr, Result);
    end = clock();
    clock_t diff = end - start;
    out_diff = diff;
  }

  else {
    // 4.Not Exist the Condition StateMent- Get All Row
    for (auto iter = CurTableInfo->GetTableHeap()->Begin(nullptr); iter != CurTableInfo->GetTableHeap()->End();
         ++iter) {
      Result.push_back(iter->GetRowId());
    }
  }
  // Print the Table Name
  std::cout << "+--------------------------------------+" << endl;
  std::cout << "| " << left << setw(36) << TableName << '|' << endl;
  std::cout << "+--------------------------------------+" << endl;

  Schema *CurSchema = CurTableInfo->GetSchema();
  std::vector<Column *> CurColumns = CurSchema->GetColumns();

  for (auto i : Map) {
    std::cout << left << setw(12) << CurColumns[i]->GetName() << "\t";
  }

  std::cout << endl;
  std::vector<Field *> Fields;
  // Row Result Stored in the Vector
  for (auto iter : Result) {
    Row NewRow(iter);
    CurTableHeap->GetTuple(&NewRow, nullptr);
    Fields = NewRow.GetFields();

    for (auto i : Map) {
      string Data;
      Fields[i]->GetDataToString(Data);
      std::cout << left << setw(12) << Data << "\t";
    }
    state = DB_SUCCESS;
    std::cout << endl;
  }
  std::cout << "+--------------------------------------+" << endl;
  printf("\n\nThe total time of selection is: %ld ticks\n\n", out_diff);
  return state;
}
```

- `ExecuteEngine::ExecuteInsert(*ast, *context)`

```cpp
// NOTE:: Due to Index Part Has not be Implemented , So Insert to Index not Implemented yet
dberr_t ExecuteEngine::ExecuteInsert(pSyntaxNode ast, ExecuteContext *context) {
```

```cpp
#ifdef ENABLE_EXECUTE_DEBUG
  LOG(INFO) << "ExecuteInsert" << std::endl;
#endif
  if (this->current_db_.empty()) {
    std::cerr << "Choose the DataBase First" << std::endl;
    return DB_FAILED;
  } else {
    // Step0: Prepare StorageEngine and CatalogManager
    // Get the Storage of the DbstorageEngine
    auto StorageEngine_Iter = this->dbs_.find(this->current_db_);
    auto Current_Storage_Engine = StorageEngine_Iter->second;
    auto Current_Ctr = Current_Storage_Engine->catalog_mgr_;

    // Step1: Check the Table is in the CatalogManager or not
    // Get the Table Name
    pSyntaxNode ast_TableName = ast->child_;
    std::string TableName = (ast_TableName->val_);
    TableInfo *CurTableInfo = nullptr;
    dberr_t state = Current_Ctr->GetTable(TableName, CurTableInfo);
    std::vector<Field> Fields;
    // Get the MemHeap
    MemHeap *CurMemHeap = CurTableInfo->GetMemHeap();

    // Table is not Exists in the Current Database
    if (state == DB_TABLE_NOT_EXIST) {
      std::cerr << "Choose the DataBase First" << std::endl;
      return DB_FAILED;
    } else {
      // 0. Get the Shema of the Table
      Schema *CurSchema = CurTableInfo->GetSchema();
      std::vector<Column *> Columns = CurSchema->GetColumns();
      int CurPosition = 0;
      dberr_t state;

      for (pSyntaxNode ColumnNode = ast_TableName->next_->child_; ColumnNode != nullptr;
           ColumnNode = ColumnNode->next_, CurPosition++) {
        // 1. Check Value Type
        // 2. Check Not null
        // 3. Get the Entity of the Fields
        switch (ColumnNode->type_) {
          case SyntaxNodeType::kNodeNull:
            // Current Column can not be null
            if (Columns[CurPosition]->IsNullable() == false) {
              state = DB_FAILED;
            } else {
              char *mem = (char *)CurMemHeap->Allocate(sizeof(char) * 5);
              strcpy(mem, "null");
              Fields.push_back(Field(kTypeChar, mem, 5, true));
              state = DB_SUCCESS;
            }
            break;

          case SyntaxNodeType::kNodeNumber:
```

```
          if (Columns[CurPosition]->GetType() == kTypeInt || Columns[CurPosition]->GetType() == kTypeFloat) {
            if (Columns[CurPosition]->GetType() == kTypeInt) {
              std::string str(ColumnNode->val_);
              int Number = atoi(str.c_str());
              Fields.push_back(Field(kTypeInt, Number));
            } else if (Columns[CurPosition]->GetType() == kTypeFloat) {
              std::string str(ColumnNode->val_);
              float f = atof(str.c_str());
              Fields.push_back(Field(kTypeFloat, f));
            }
            state = DB_SUCCESS;

          } else {
            state = DB_FAILED;
          }
          break;

        case SyntaxNodeType::kNodeString:
          if (Columns[CurPosition]->GetType() == kTypeChar) {
            Fields.push_back(Field(kTypeChar, ColumnNode->val_, Columns[CurPosition]->GetLength(), true));
            state = DB_SUCCESS;
          } else {
            state = DB_FAILED;
          }
          break;

        default:
          state = DB_FAILED;
          break;
      }
      if (state == DB_FAILED) {
        return state;
      }

      // 3. Check Unique
      // Traverse the TableHeap to Check the New Inserted Column is Unique or Not
      if (Columns[CurPosition]->IsUnique() == true) {
        TableHeap *CurTableHeap = CurTableInfo->GetTableHeap();
        for (TableIterator iter = CurTableHeap->Begin(nullptr); iter != CurTableHeap->End(); iter++) {
          // if there is value in the Table Heap is Equal with the NewInserted Tuple
          if (iter->GetField(CurPosition)->CompareEquals(Fields[CurPosition]) == kTrue) {
            state = DB_FAILED;
            break;
          }
        }
      }
      if (state == DB_FAILED) {
        return state;
        }
      }
      // 4. Insert Tuple
      TableHeap *CurTableHeap = CurTableInfo->GetTableHeap();
      Row NewRow(Fields);
      bool InsertState = CurTableHeap->InsertTuple(NewRow, nullptr);

      if (InsertState) {
        // 5. Update the Index to The Correspoding the Index
        // Step1- Get All Index From the Correspoding TableName
        std::vector<std::string> IndexName;
        dberr_t state = Current_Ctr->GetAllIndexNames(TableName, IndexName);
        if (state != DB_INDEX_NOT_FOUND) {
          // There are Index for the Table needed to Update
          for (std::vector<std::string>::iterator iter = IndexName.begin(); iter != IndexName.end(); iter++) {
            IndexInfo *index_info = nullptr;
            if (Current_Ctr->GetIndex(TableName, (*iter), index_info) == DB_SUCCESS) {
              // Get the KeyMap
              std::vector<uint32_t> KeyMap = index_info->GetMetaData()->GetKeyMapping();
              std::vector<Field> fields;
              // Using the KeyMap to GetField In order to Get the Key Schema
              for (std::vector<uint32_t>::iterator iter = KeyMap.begin(); iter != KeyMap.end(); iter++) {
                fields.push_back(*(NewRow.GetField(KeyMap[(*iter)])));
              }
              Row IndexRow(fields);
              RowId rid(NewRow.GetRowId());
              index_info->GetIndex()->InsertEntry(IndexRow, NewRow.GetRowId(), nullptr);
            }
          }
        }
        return DB_SUCCESS;

      } else {
        std::cout << "InsertTuple Failed" << endl;
        return DB_FAILED;
      }
    }
  }

  return DB_FAILED;
}
```

- `ExecuteEngine::ExecuteDelete(*ast, *context)`

  和select实现逻辑类似，通过多种情况判断即可实现，参照工程文件

- `ExecuteEngine::ExecuteExecfile(*ast, *context)`

```cpp
dberr_t ExecuteEngine::ExecuteExecfile(pSyntaxNode ast, ExecuteContext *context) {
#ifdef ENABLE_EXECUTE_DEBUG
  LOG(INFO) << "ExecuteExecfile" << std::endl;
#endif
  string FileName(ast->child_->val_);
  std::ifstream fin;
  fin.open(FileName, std::ios::in);
  if (!fin) {
    cout << "Open Failed" << endl;
    return DB_FAILED;
  }
  char line[1024] = {0};
  // int buf_size = 1024;
  string tmp;

  while (fin.getline(line, sizeof(line))) {
    std::stringstream word(line);
    string result;
    int flag = 0;
    while (word) {
      word >> tmp;
      if (flag != 0) result += " ";
      result += tmp;
      flag++;
    }
    cout << result << endl;
    YY_BUFFER_STATE bp = yy_scan_string(line);
    if (bp == nullptr) {
      LOG(ERROR) << "Failed to create yy buffer state." << std::endl;
      exit(1);
    }
    yy_switch_to_buffer(bp);

    // init parser module
    MinisqlParserInit();

    // parse
    yyparse();

    // parse result handle
    if (MinisqlParserGetError()) {
      // error
      printf("%s\n", MinisqlParserGetErrorMessage());
    } else {
      printf("[INFO] Sql syntax parse ok!\n");
    }

    ExecuteContext context;
    dberr_t exe_rst = Execute(MinisqlGetParserRootNode(), &context);
    if (exe_rst == DB_SUCCESS) {
      printf("EXECUTE SUCCESS\n");
    } else if (exe_rst == DB_FAILED) {
      printf("EXECUTE FAILED\n");
    }

    // clean memory after parse
    MinisqlParserFinish();
    yy_delete_buffer(bp);
    yylex_destroy();

    // quit condition
    if (context.flag_quit_) {
      printf("bye!\n");
      break;
    }
  }

  return DB_SUCCESS;
}
```

- `ExecuteEngine::ExecuteQuit(*ast, *context)`

  框架已经实现，参照工程文件

- 辅助函数
  这些辅助函数由select调用，可以在多种情况判断的时候减少冗余代码，直接调用即可实现相关功能。

```
void GetFieldFromString(TypeId KeyTypeId, string StringValue, uint32_t length, std::vector<Field> &fields) {
  if (KeyTypeId == TypeId::kTypeChar) {
    fields.push_back(Field(KeyTypeId, const_cast<char *>(StringValue.c_str()), length, true));
  } else if (KeyTypeId == TypeId::kTypeInt) {
    int value = atoi(StringValue.c_str());
    fields.push_back(Field(KeyTypeId, value));
  } else if (KeyTypeId == TypeId::kTypeFloat) {
    float value = atof(StringValue.c_str());
    fields.push_back(Field(KeyTypeId, value));
  }
}
void GetColumnIndex(CatalogManager *Curr_Ctr, string ColumnName, string TableName, uint32_t &ColumnIndex) {
  Schema *TableSchema = nullptr;
  TableInfo *table_info = nullptr;
  if (Curr_Ctr->GetTable(TableName, table_info) == DB_SUCCESS) {
    TableSchema = table_info->GetSchema();
    if (TableSchema->GetColumnIndex(ColumnName, ColumnIndex) != DB_SUCCESS) {
      // Current Column is not Exist in the Table
      std::cerr << "Current Column is  not Exist in the Table" << std::endl;
    }
  }
}
// Note: We only can use one connector
void GetSatisfiedRow(pSyntaxNode Curr_Node, CatalogManager *Curr_Ctr, string TableName, std::vector<RowId> &Result) {
  bool state = false;

```

```cpp
  // 1.Get the KeyIndex From the Node
  string ColumnName = (Curr_Node->child_->val_);
  // 2.Get the Key From the Next Node
  string StringValue = (Curr_Node->child_->next_->val_);
  uint32_t ColumnIndex = 0;

  // 3. Get the Column Index in the Schema
  Schema *TableSchema = nullptr;
  TableInfo *table_info = nullptr;
  if (Curr_Ctr->GetTable(TableName, table_info) == DB_SUCCESS) {
    TableSchema = table_info->GetSchema();
    if (TableSchema->GetColumnIndex(ColumnName, ColumnIndex) != DB_SUCCESS) {
      // Current Column is not Exist in the Table
      std::cerr << "Current Column is  not Exist in the Table" << std::endl;
    }
  }

  // 4.Using Column Index to Judge Exist the Index Or not
  std::vector<IndexInfo *> indexes;
  // Get All Indexes For the Correspoding TableName
  dberr_t GetIndexState = Curr_Ctr->GetTableIndexes(TableName, indexes);
  IndexInfo *ExistIndexInfo = nullptr;
  int flag = 0;
  if (GetIndexState == DB_SUCCESS) {
    // Find All index For the Table
    for (auto iter : indexes) {
      std::vector<uint32_t> KeyMap = iter->GetMetaData()->GetKeyMapping();
      // Judge Exist Index Or not
      for (auto i : KeyMap) {
        if (i == ColumnIndex) {
          // Exist Index
          flag = 1;
          break;
        }
      }
      if (flag) {
        // Get IndexInfo for the Existing Index
        ExistIndexInfo = iter;
        state = true;
        break;
      }
    }
  }

  string Connector = string(Curr_Node->val_);
  TypeId KeyTypeId = TableSchema->GetColumn(ColumnIndex)->GetType();
  uint32_t length = TableSchema->GetColumn(ColumnIndex)->GetLength();

  std::vector<Field> fields;
  GetFieldFromString(KeyTypeId, StringValue, length, fields);
  if (Connector == "=") {
    if (state) {
      // Exist the Index

      Row row(fields);
      ExistIndexInfo->GetIndex()->ScanKey(row, Result, nullptr);

    } else {
      // Using Table Heap
      for (auto iter = table_info->GetTableHeap()->Begin(nullptr); iter != table_info->GetTableHeap()->End(); ++iter) {
        if (iter->GetField(ColumnIndex)->CompareEquals(fields.front()) == CmpBool::kTrue) {
          Result.push_back(iter->GetRowId());
        }
      }
    }
  } else if (Connector == "<>") {
    // Using Table Heap
    for (auto iter = table_info->GetTableHeap()->Begin(nullptr); iter != table_info->GetTableHeap()->End(); ++iter) {
      if (iter->GetField(ColumnIndex)->CompareNotEquals(fields.front()) == CmpBool::kTrue) {
        Result.push_back(iter->GetRowId());
      }
    }

  } else if (Connector == ">=") {
    // Using Table Heap
    for (auto iter = table_info->GetTableHeap()->Begin(nullptr); iter != table_info->GetTableHeap()->End(); ++iter) {
      if (iter->GetField(ColumnIndex)->CompareGreaterThanEquals(fields.front()) == CmpBool::kTrue) {
        Result.push_back(iter->GetRowId());
      }
    }

  } else if (Connector == "<=") {
    // Using Table Heap
    for (auto iter = table_info->GetTableHeap()->Begin(nullptr); iter != table_info->GetTableHeap()->End(); ++iter) {
      if (iter->GetField(ColumnIndex)->CompareLessThanEquals(fields.front()) == CmpBool::kTrue) {
        Result.push_back(iter->GetRowId());
      }
    }

  } else if (Connector == "<") {
    // Using Table Heap
    for (auto iter = table_info->GetTableHeap()->Begin(nullptr); iter != table_info->GetTableHeap()->End(); ++iter) {
      if (iter->GetField(ColumnIndex)->CompareLessThan(fields.front()) == CmpBool::kTrue) {
        Result.push_back(iter->GetRowId());
      }
    }

  } else if (Connector == ">") {
    // Using Table Heap
    for (auto iter = table_info->GetTableHeap()->Begin(nullptr); iter != table_info->GetTableHeap()->End(); ++iter) {
      if (iter->GetField(ColumnIndex)->CompareGreaterThan(fields.front()) == CmpBool::kTrue) {
        Result.push_back(iter->GetRowId());
      }
    }
  }
}
void AndRow(const std::vector<RowId> &Result1, const std::vector<RowId> &Result2, std::vector<RowId> &Result) {
  for (auto i : Result1) {
    for (auto j : Result2) {
      if (i == j) {
        Result.push_back(i);
        break;
      }
    }
  }
}
void UnionRow(std::vector<RowId> &Result1, std::vector<RowId> &Result2, std::vector<RowId> &Result) {
  for (auto i : Result1) {
    Result.push_back(i);
  }
  for (auto i : Result2) {
    int flag = 0;
    for (auto j : Result) {
      if (i == j) {
        flag = 1;
        break;
      }
    }
    // it means The Elements in the Result1 Does not Overlap With the Result2
    if (flag == 0) {
      Result.push_back(i);
    }
  }
}
void GetSatifedRowSet(pSyntaxNode ast, string TableName, CatalogManager *Current_Ctr, std::vector<RowId> &Result) {
  pSyntaxNode Curr_Node = ast->child_->next_->next_->child_;

  // Condition StateMent Exists
  // Connector Exists
  if (Curr_Node->type_ == kNodeConnector) {
    std::vector<RowId> Result1;
    GetSatisfiedRow(Curr_Node->child_, Current_Ctr, TableName, Result1);
    std::vector<RowId> Result2;
    GetSatisfiedRow(Curr_Node->child_->next_, Current_Ctr, TableName, Result2);

    if (string(Curr_Node->val_) == "and") {
      AndRow(Result1, Result2, Result);
    } else if (string(Curr_Node->val_) == "or") {
      UnionRow(Result1, Result2, Result);
    }
  } else if (Curr_Node->type_ == kNodeCompareOperator) {
    // If it exists Index-index_info

    GetSatisfiedRow(Curr_Node, Current_Ctr, TableName, Result);
  }
}
```

- `ExecuteEngine::ExecuteTrxBegin(*ast, *context)`：事务相关，暂未实现
- `ExecuteEngine::ExecuteTrxCommit(*ast, *context)`：事务相关，暂未实现
- `ExecuteEngine::ExecuteTrxRollback(*ast, *context)`：事务相关，暂未实现

Note: 执行结果上下文`ExecuteContext`中提供了部分可能需要用到的数据，在后续拓展的时候根据需要自行定义`ExecuteContext`即可。

```
/**
 * ExecuteContext stores all the context necessary to run in the execute engine
 * This struct is implemented by student self for necessary.
 *
 * eg: transaction info, execute result...
 */
struct ExecuteContext {
  bool flag_quit_{false};
  Transaction *txn_{nullptr};
};
```

通过添加构造函数和析构函数中对于记录数据库文件的文件信息，可以实现简单的多数据库文件管理，但是这样的管理必须通过quit语句才能够及时更新，如果需要每次操作都进行更新，对于IO负担又会急剧增加，故后续可以考虑其他的catalog模式从而让catalog成为单独管理的单元，独立于其他模块页即可，此处给出实现的方法，即构造与析构函数，具体代码实现如下所示：

- `ExecuteEngine::ExecuteEngine();`

```
ExecuteEngine::ExecuteEngine() {
  // find the file in the bin file folder, and fill the contents in the object
  // all the private value can be initialized by using the disk manager when used.
  // add the txt file implementation, format -> every line contains a database storage file's name (of course no spaces
  // and other white space)
  std::fstream db_contents;
  const std::string contents_name("content.txt");
  // read, do not need refreshing
  db_contents.open(contents_name, std::ios::in | std::ios::out);
```

```cpp
  if (!db_contents.is_open()) {
    db_contents.clear();
    db_contents.open(contents_name, std::ios::trunc | std::ios::out);
    db_contents.close();
    db_contents.open(contents_name, std::ios::in | std::ios::out);
    if (!db_contents.is_open()) {
      std::cerr << "Can not open the content file!" << std::endl;
    }
  }
  // if the program keeps running to here, then the file has been opened successfully
  // the current_db_ needs to be initialized after usedatabase is executed.
  std::string db_file_names;
  while (db_contents >> db_file_names) {
    if (!db_file_names.empty()) {
      DBStorageEngine *store_eng = new DBStorageEngine(db_file_names, false);
      this->dbs_.emplace(db_file_names, store_eng);
    }
  }
  db_contents.close();
}
```

- `ExecuteEngine::~ExecuteEngine();`

```cpp
~ExecuteEngine() {
    // add write back to file content.txt
    std::fstream db_contents;
    const std::string contents_name("content.txt");
    remove(contents_name.c_str()); // write, need refreshing
    db_contents.open(contents_name, std::ios::in | std::ios::out);
    if (!db_contents.is_open()) {
      db_contents.clear();
      db_contents.open(contents_name, std::ios::trunc | std::ios::out); // do the creation of file if the file does not exist.
      db_contents.close();
      db_contents.open(contents_name, std::ios::in | std::ios::out);
      if (!db_contents.is_open()) {
        std::cerr << "Can not open the content file!" << std::endl;
      }
    }
    for (auto it : dbs_) {
      db_contents << it.first << std::endl;
      delete it.second;
    }
    db_contents.close();
  }
```

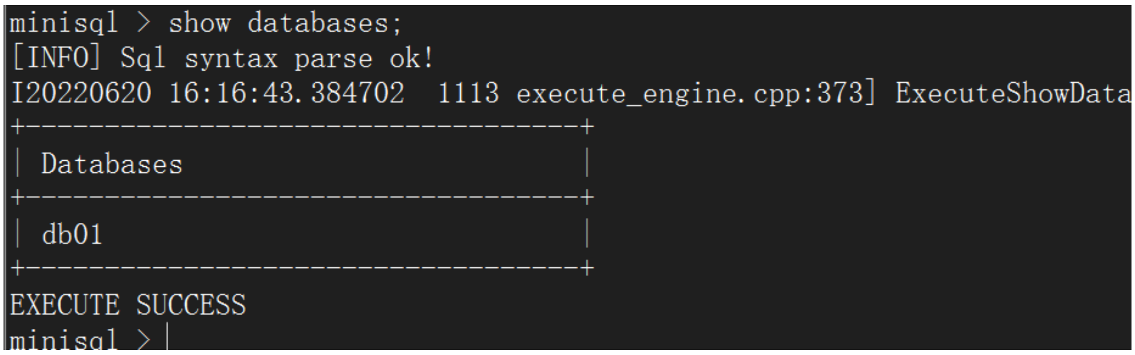
3. 模块相关代码

- `src/main.cpp`
- `src/include/executor/execute_engine.h`
- `src/executor/execute_engine.cpp`

4. 整体模块测试效果

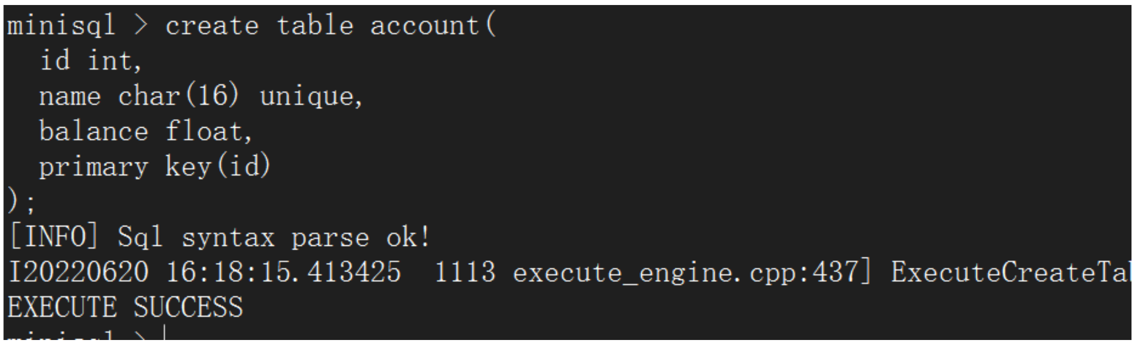
- ShowDataBases

- Create Database



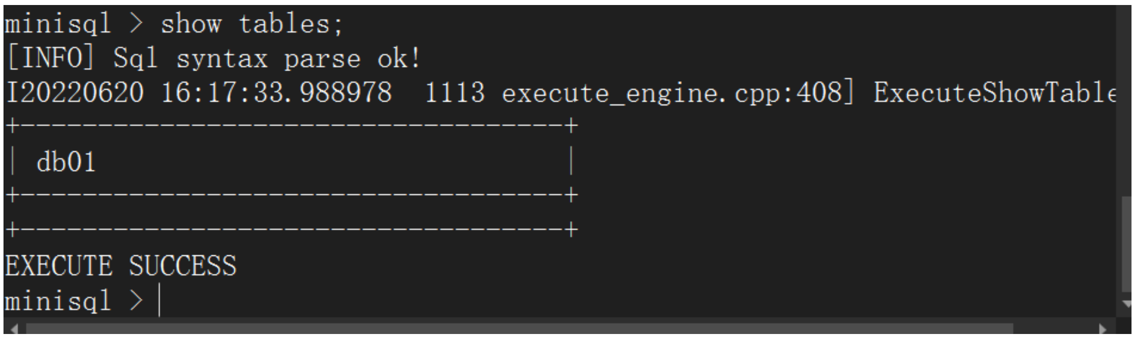
```
minisql > show databases;
[INFO] Sql syntax parse ok!
I20220620 16:16:43.384702  1113 execute_engine.cpp:373] ExecuteShowData
+-----------------------------------+
| Databases                         |
+-----------------------------------+
| db01                              |
+-----------------------------------+
EXECUTE SUCCESS
minisql > |
```

- Create Tables



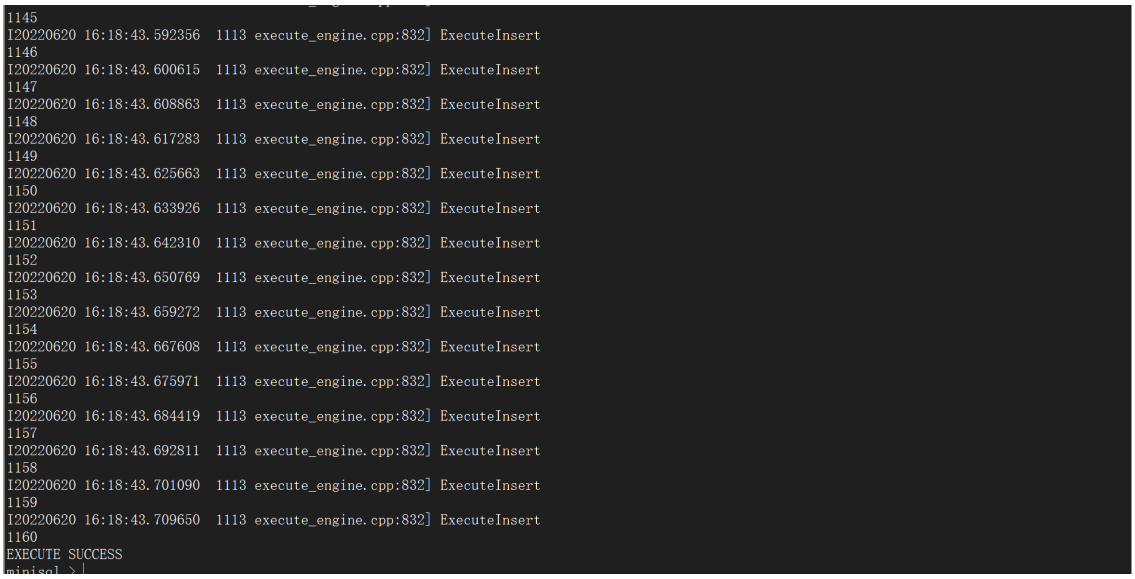
```
minisql > create table account(
  id int,
  name char(16) unique,
  balance float,
  primary key(id)
);
[INFO] Sql syntax parse ok!
I20220620 16:18:15.413425  1113 execute_engine.cpp:437] ExecuteCreateTa
EXECUTE SUCCESS
minisql > |
```

- Show Tables



```
minisql > show tables;
[INFO] Sql syntax parse ok!
I20220620 16:17:33.988978  1113 execute_engine.cpp:408] ExecuteShowTable
+-----------------------------------+
| db01                              |
+-----------------------------------+
+-----------------------------------+
EXECUTE SUCCESS
minisql > |
```

- 批量导入

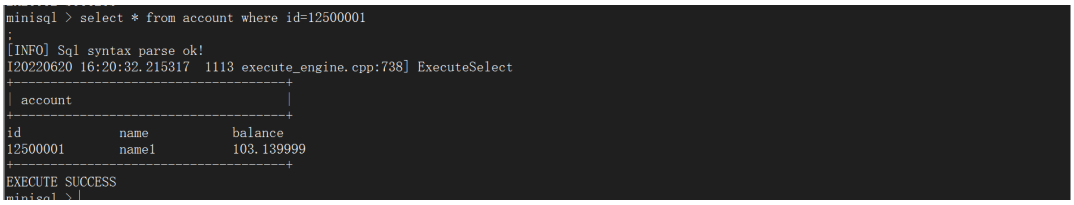


```
1145
I20220620 16:18:43.592356  1113 execute_engine.cpp:832] ExecuteInsert
1146
I20220620 16:18:43.600615  1113 execute_engine.cpp:832] ExecuteInsert
1147
I20220620 16:18:43.608863  1113 execute_engine.cpp:832] ExecuteInsert
1148
I20220620 16:18:43.617283  1113 execute_engine.cpp:832] ExecuteInsert
1149
I20220620 16:18:43.625663  1113 execute_engine.cpp:832] ExecuteInsert
1150
I20220620 16:18:43.633926  1113 execute_engine.cpp:832] ExecuteInsert
1151
I20220620 16:18:43.642310  1113 execute_engine.cpp:832] ExecuteInsert
1152
I20220620 16:18:43.650769  1113 execute_engine.cpp:832] ExecuteInsert
1153
I20220620 16:18:43.659272  1113 execute_engine.cpp:832] ExecuteInsert
1154
I20220620 16:18:43.667608  1113 execute_engine.cpp:832] ExecuteInsert
1155
I20220620 16:18:43.675971  1113 execute_engine.cpp:832] ExecuteInsert
1156
I20220620 16:18:43.684419  1113 execute_engine.cpp:832] ExecuteInsert
1157
I20220620 16:18:43.692811  1113 execute_engine.cpp:832] ExecuteInsert
1158
I20220620 16:18:43.701090  1113 execute_engine.cpp:832] ExecuteInsert
1159
I20220620 16:18:43.709650  1113 execute_engine.cpp:832] ExecuteInsert
1160
EXECUTE SUCCESS
minisql > |
```

- Select

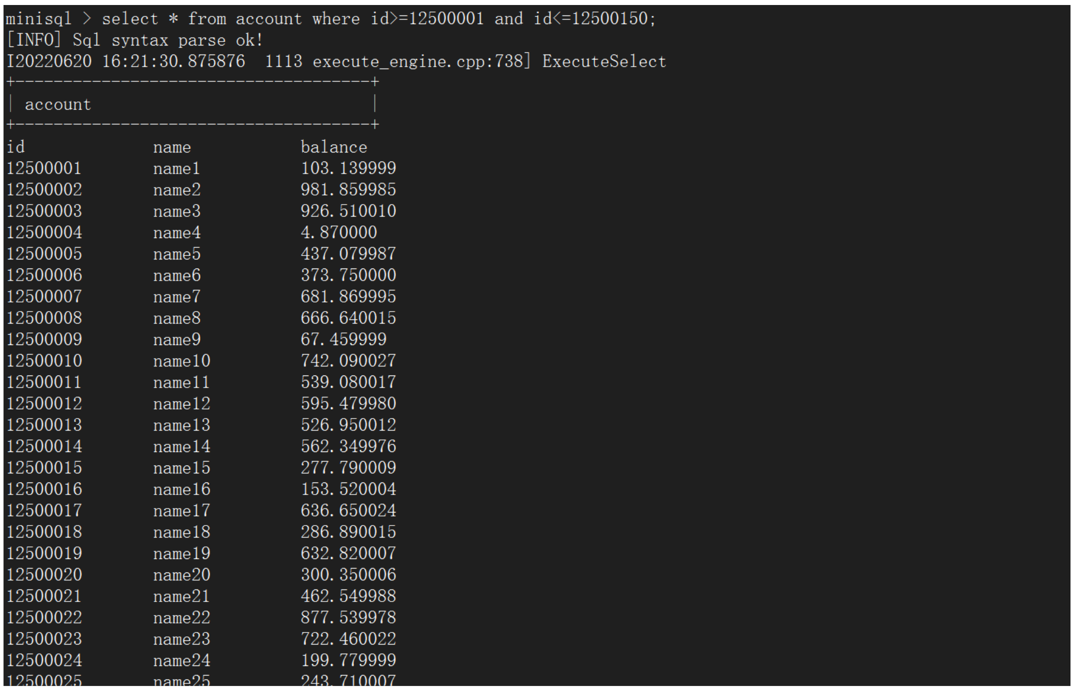
- Select * from account

- Select * from account where （条件1）

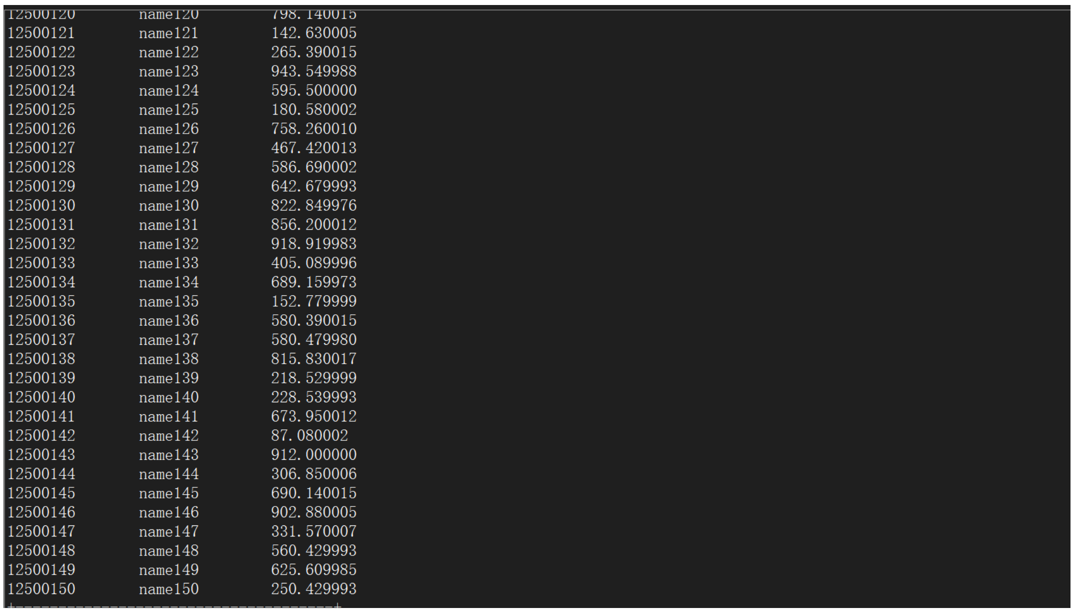


```
minisql > select * from account where id=12500001
;
[INFO] Sql syntax parse ok!
I20220620 16:20:32.215317  1113 execute_engine.cpp:738] ExecuteSelect
+-------------------------------------+
| account                             |
+-------------------------------------+
id              name            balance
12500001        name1           103.139999
+-------------------------------------+
EXECUTE SUCCESS
minisql > |
```

- Select * from account where （条件1）operator(条件2)



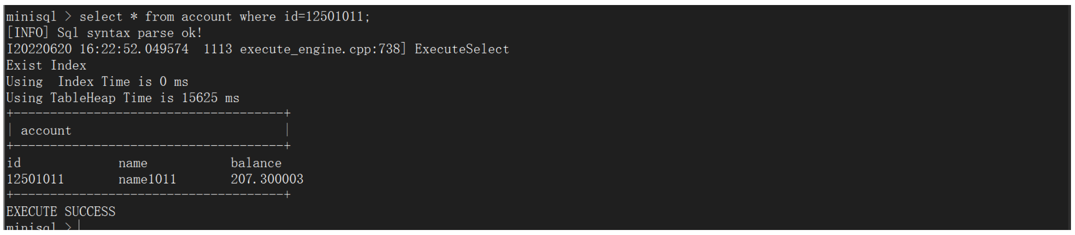
```
minisql > select * from account where id>=12500001 and id<=12500150;
[INFO] Sql syntax parse ok!
I20220620 16:21:30.875876  1113 execute_engine.cpp:738] ExecuteSelect
+-------------------------------------+
| account                             |
+-------------------------------------+
id              name            balance
12500001        name1           103.139999
12500002        name2           981.859985
12500003        name3           926.510010
12500004        name4           4.870000
12500005        name5           437.079987
12500006        name6           373.750000
12500007        name7           681.869995
12500008        name8           666.640015
12500009        name9           67.459999
12500010        name10          742.090027
12500011        name11          539.080017
12500012        name12          595.479980
12500013        name13          526.950012
12500014        name14          562.349976
12500015        name15          277.790009
12500016        name16          153.520004
12500017        name17          636.650024
12500018        name18          286.890015
12500019        name19          632.820007
12500020        name20          300.350006
12500021        name21          462.549988
12500022        name22          877.539978
12500023        name23          722.460022
12500024        name24          199.779999
12500025        name25          243.710007
```



```
12500120        name120         798.140015
12500121        name121         142.630005
12500122        name122         265.390015
12500123        name123         943.549988
12500124        name124         595.500000
12500125        name125         180.580002
12500126        name126         758.260010
12500127        name127         467.420013
12500128        name128         586.690002
12500129        name129         642.679993
12500130        name130         822.849976
12500131        name131         856.200012
12500132        name132         918.919983
12500133        name133         405.089996
12500134        name134         689.159973
12500135        name135         152.779999
12500136        name136         580.390015
12500137        name137         580.479980
12500138        name138         815.830017
12500139        name139         218.529999
12500140        name140         228.539993
12500141        name141         673.950012
12500142        name142         87.080002
12500143        name143         912.000000
12500144        name144         306.850006
12500145        name145         690.140015
12500146        name146         902.880005
12500147        name147         331.570007
12500148        name148         560.429993
12500149        name149         625.609985
12500150        name150         250.429993
+-------------------------------------+
```

- Index
  - Create Index

  - Select * from account where (condition 1) and (Condition 2)



```
minisql > select * from account where id=12501011;
[INFO] Sql syntax parse ok!
I20220620 16:22:52.049574  1113 execute_engine.cpp:738] ExecuteSelect
Exist Index
Using  Index Time is 0 ms
Using TableHeap Time is 15625 ms
+-------------------------------------+
| account                             |
+-------------------------------------+
id              name            balance
12501011        name1011        207.300003
+-------------------------------------+
EXECUTE SUCCESS
minisql > |
```

- Delete
    - Delete from account where (condition)