15-721

DATABASE SYSTEMS

Term Project Final Presentation

~ Query Planner ~

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Goals

- 75% - Integrate with Postgres and execute simple queries ✓

  Implement base table sampling ✓

- 100% - Dynamic programming approach

  Tuple-based cost model

- 125% - Use sampling and static/dynamic replanning to select query plans

Goals

- 75% - Integrate with Postgres and execute simple queries ✓

  Implement base table sampling ✓

- 100% - Cost-guided Dynamic Programming Framework ✓

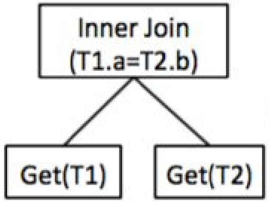
- 125% - Use sampling and static/dynamic replanning to select query plans

Cost-guided Dynamic Programming Framework

- Cascades-style incremental plan space exploration
  - Space of plans is explored on demand and only as needed
  - Both Logical and Physical transformations are applied at the same time
  - Alternative is a two-phase optimization
    - Generate entire plan space
    - Cost and choose most optimal physical plan
- Optimizer components
  - Plan Representation
  - Memo Table
    - Equivalence classes
  - Rule Interface
  - Pattern Matching
    - Binding traversal
  - Plan Exploration

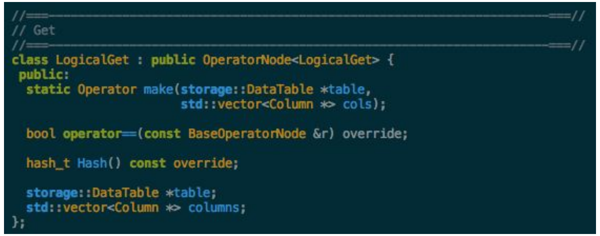
Plan Representation

- Logical, Physical, and Expression operators
- Composed to create an operator tree
    - OpExpression represents a concrete plan
- Easily extensible with new types
    - Required input & output physical properties
    - Hash function
    - Equality



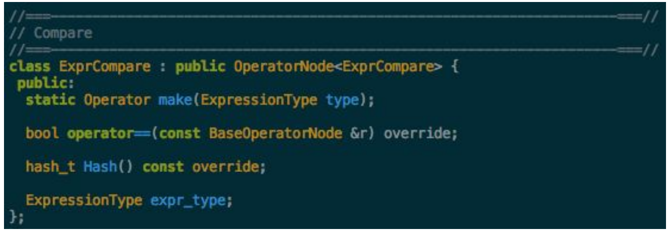
OpExpression

Credit: Orca Paper



```
//===----------------------------------------------------------------------===//
// Get
//===----------------------------------------------------------------------===//
class LogicalGet : public OperatorNode<LogicalGet> {
 public:
  static Operator make(storage::DataTable *table,
                       std::vector<Column *> cols);

  bool operator==(const BaseOperatorNode &r) override;

  hash_t Hash() const override;

  storage::DataTable *table;
  std::vector<Column *> columns;
};
```

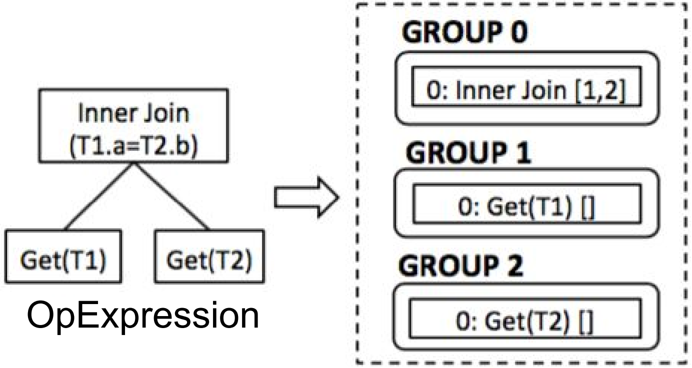
```
//===----------------------------------------------------------------------===//
// Scan
//===----------------------------------------------------------------------===//
class PhysicalScan : public OperatorNode<PhysicalScan> {
 public:
  static Operator make(storage::DataTable *table, std::vector<Column *> cols);

  bool operator==(const BaseOperatorNode &r) override;

  hash_t Hash() const override;

  storage::DataTable *table;
  std::vector<Column *> columns;
};
```



```
//===----------------------------------------------------------------------===//
// Compare
//===----------------------------------------------------------------------===//
class ExprCompare : public OperatorNode<ExprCompare> {
 public:
  static Operator make(ExpressionType type);

  bool operator==(const BaseOperatorNode &r) override;

  hash_t Hash() const override;

  ExpressionType expr_type;
};
```

Memo Table

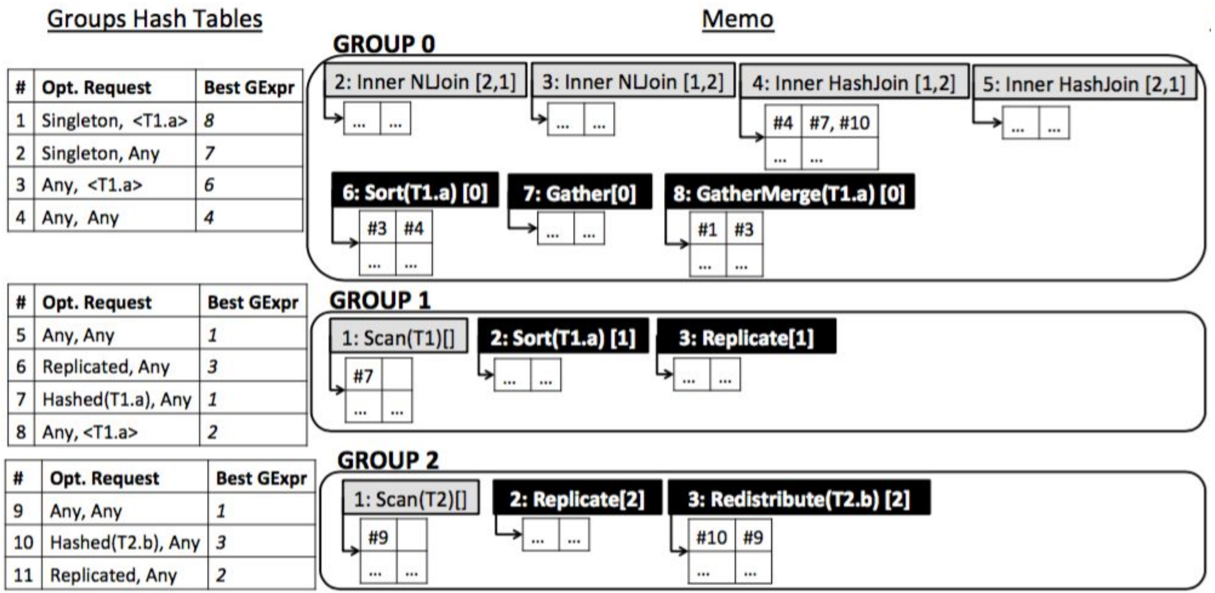
- Recursive plan space exploration has redundant sub computations
    - Memo Table enables sub problem reuse throughout optimization
- Insertion of query into Memo creates an initial set of *Groups*
    - Equivalence classes for intermediate results



Credit: Orca Paper

Memo Table

- As exploration of plan space proceeds, equivalent expressions are grouped together



Groups Hash Tables

#	Opt. Request	Best GExpr
1	Singleton, <T1.a>	8
2	Singleton, Any	7
3	Any, <T1.a>	6
4	Any, Any	4

#	Opt. Request	Best GExpr
5	Any, Any	1
6	Replicated, Any	3
7	Hashed(T1.a), Any	1
8	Any, <T1.a>	2

#	Opt. Request	Best GExpr
9	Any, Any	1
10	Hashed(T2.b), Any	3
11	Replicated, Any	2

Credit: Orca Paper

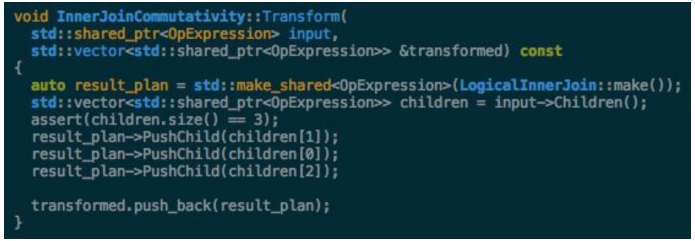
Rule Interface

- Extensible rule interface
    - Rule implementer only provides
        - Pattern to match against
        - Validation function
        - Transformation function
- Decoupled from optimizer and exploration process

Abstract Rule Class

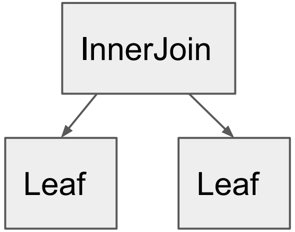
```
class Rule {
 public:
  virtual ~Rule() {};

  std::shared_ptr<Pattern> GetMatchPattern() const { return match_pattern; }

  bool IsPhysical() const { return physical; }

  bool IsLogical() const { return logical; }

  virtual bool Check(std::shared_ptr<OpExpression> expr) const = 0;

  virtual void Transform(
    std::shared_ptr<OpExpression> input,
    std::vector<std::shared_ptr<OpExpression>> &transformed) const = 0;

 protected:
  std::shared_ptr<Pattern> match_pattern;
  bool physical = false;
  bool logical = false;
};
```

Inner Join Commutativity Rule



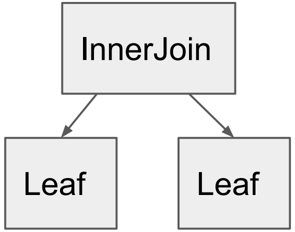
```
void InnerJoinCommutativity::Transform(
  std::shared_ptr<OpExpression> input,
  std::vector<std::shared_ptr<OpExpression>> &transformed) const
{
  auto result_plan = std::make_shared<OpExpression>(LogicalInnerJoin::make());
  std::vector<std::shared_ptr<OpExpression>> children = input->Children();
  assert(children.size() == 3);
  result_plan->PushChild(children[1]);
  result_plan->PushChild(children[0]);
  result_plan->PushChild(children[2]);

  transformed.push_back(result_plan);
}
```

Pattern Matching



Binding

Pattern Matching



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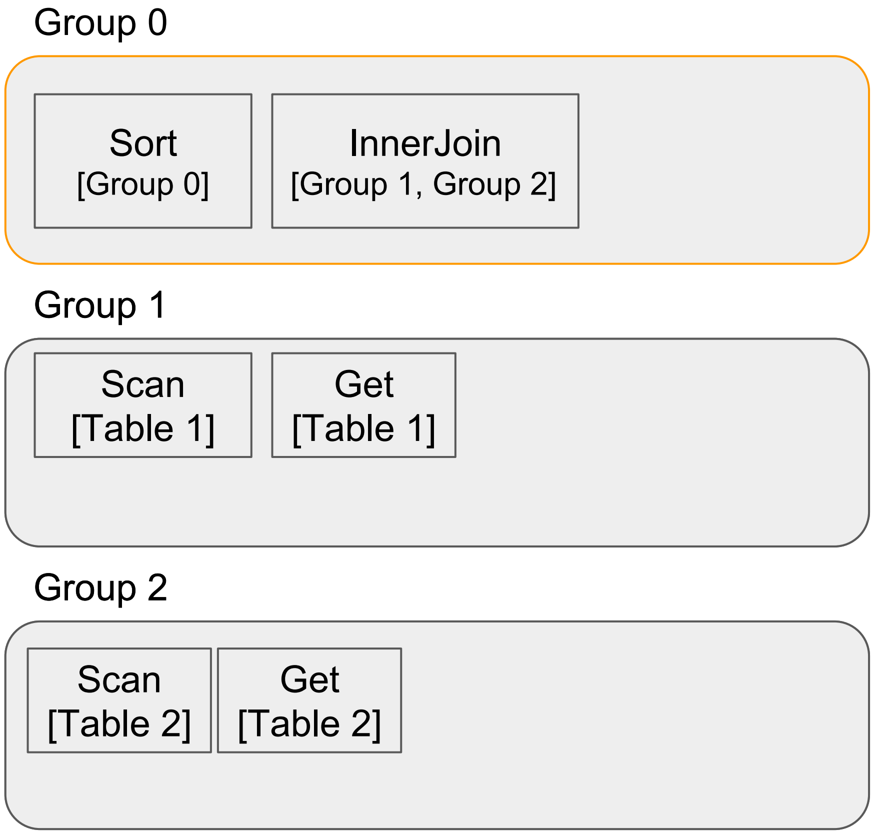

Group 0

Sort [Group 0]

InnerJoin [Group 1, Group 2]

Group 1

Scan [Table 1]

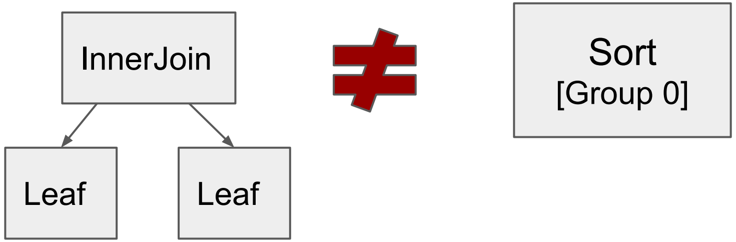
Get [Table 1]

Group 2

Scan [Table 2]

Get [Table 2]

Pattern Matching



Binding

Group 0

- Sort [Group 0]
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- Scan [Table 1]
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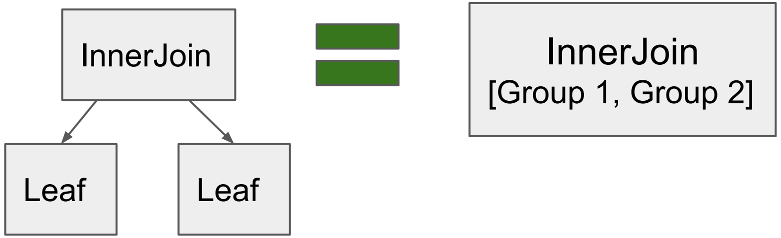
Group 2

- Scan [Table 2]
- Get [Table 2]

Pattern Matching



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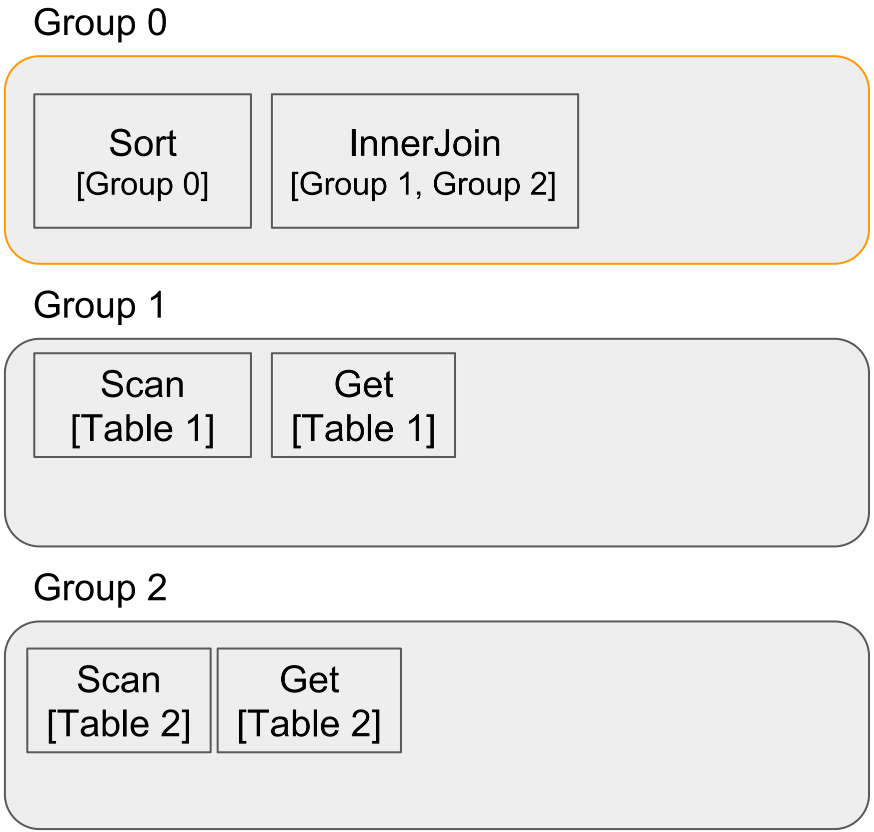

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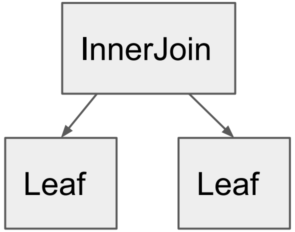

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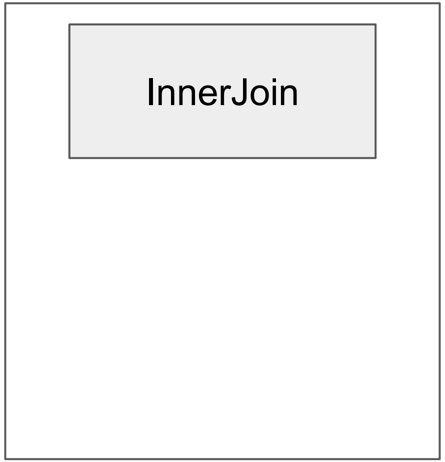
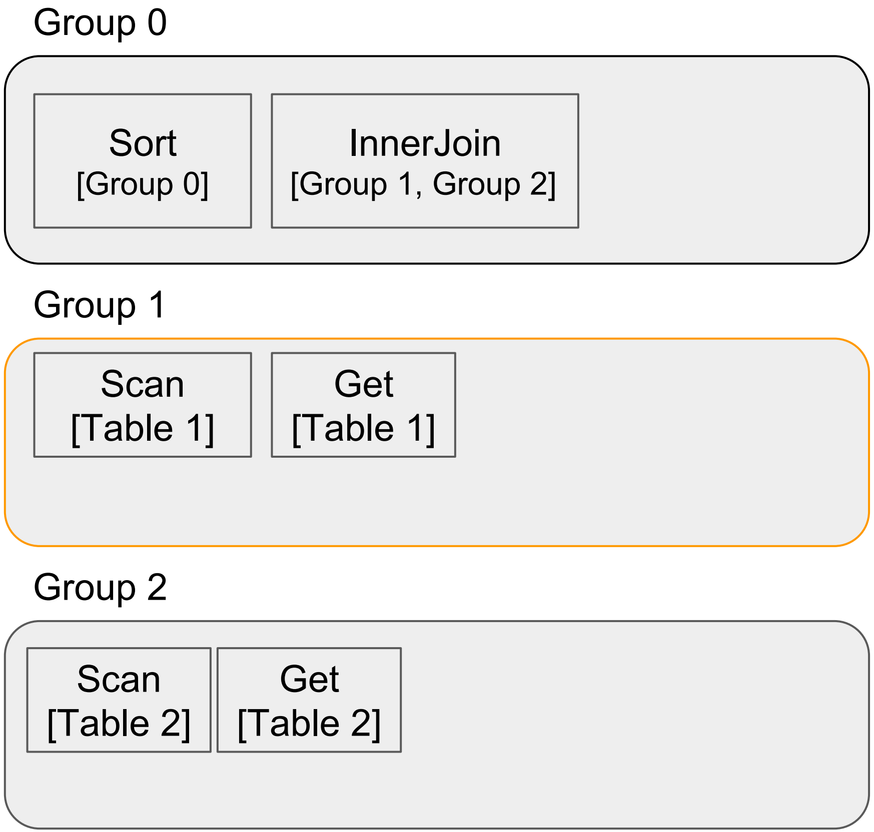
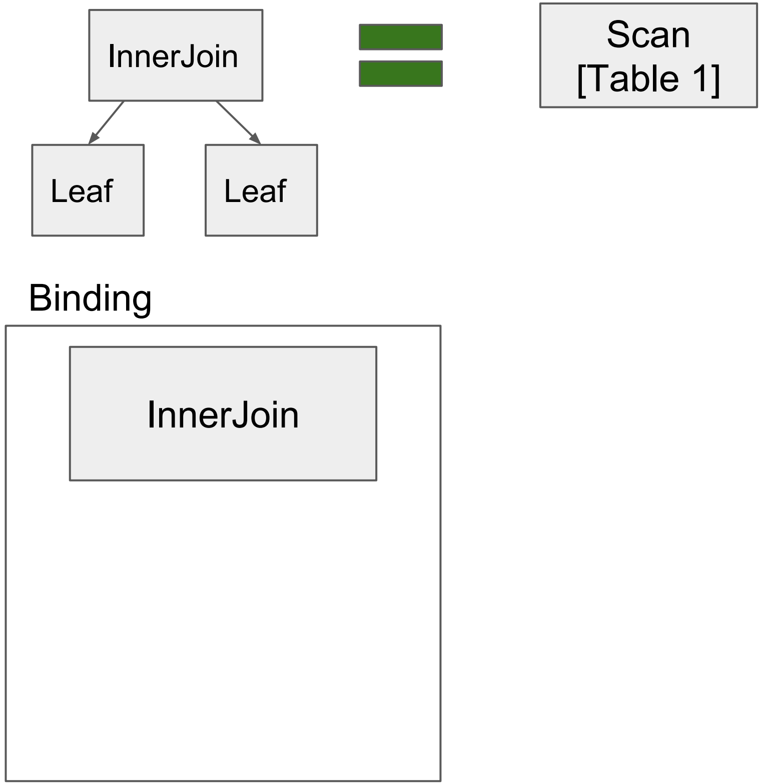




Pattern Matching



InnerJoin

Leaf

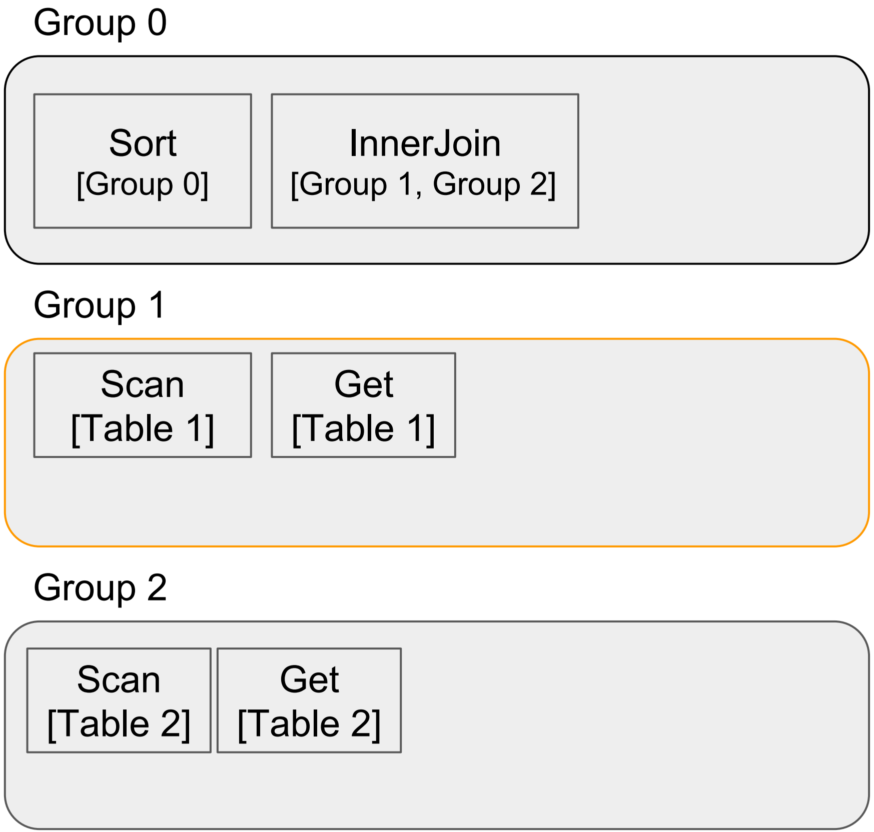
Leaf

=

Scan
[Table 1]

Binding

InnerJoin



Group 0

Sort
[Group 0]

InnerJoin
[Group 1, Group 2]

Group 1

Scan
[Table 1]

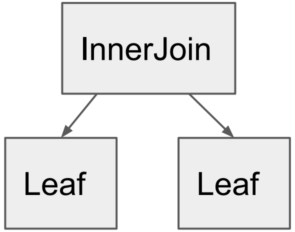
Get
[Table 1]

Group 2

Scan
[Table 2]

Get
[Table 2]

Pattern Matching



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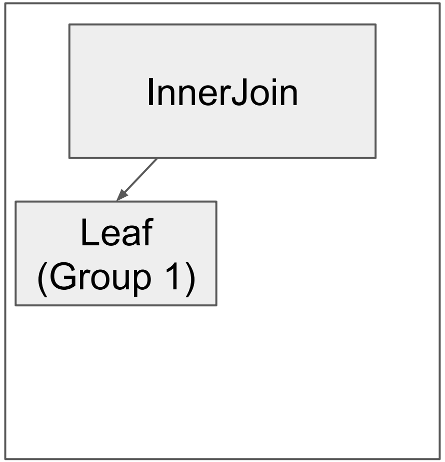

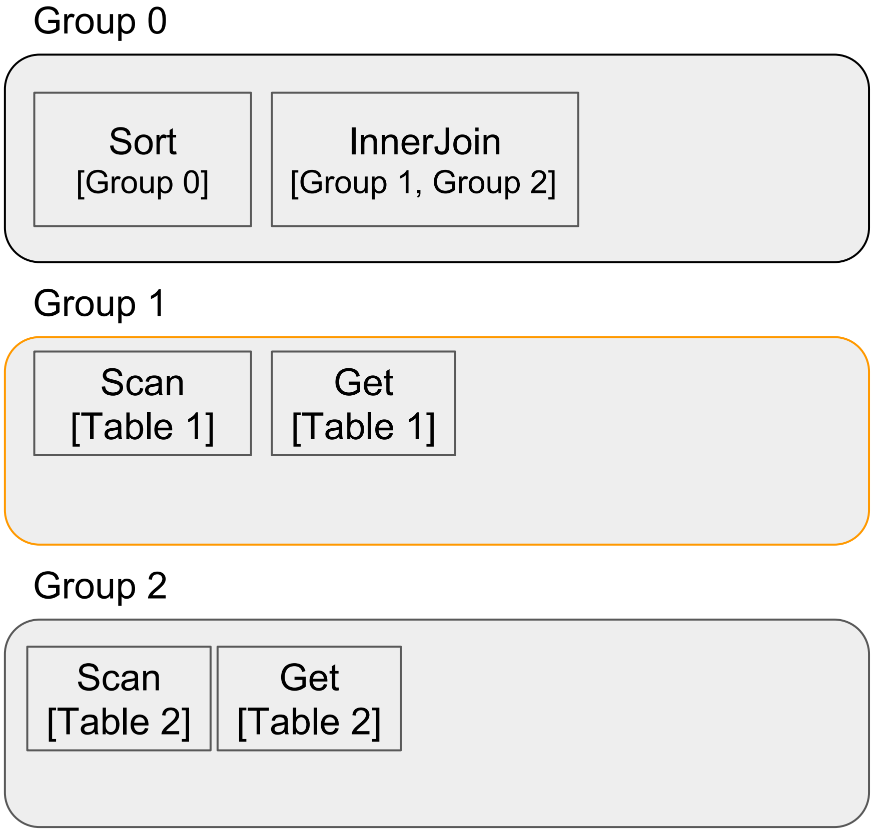
Group 0

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[Group 0]

InnerJoin
[Group 1, Group 2]

Group 1

Scan
[Table 1]

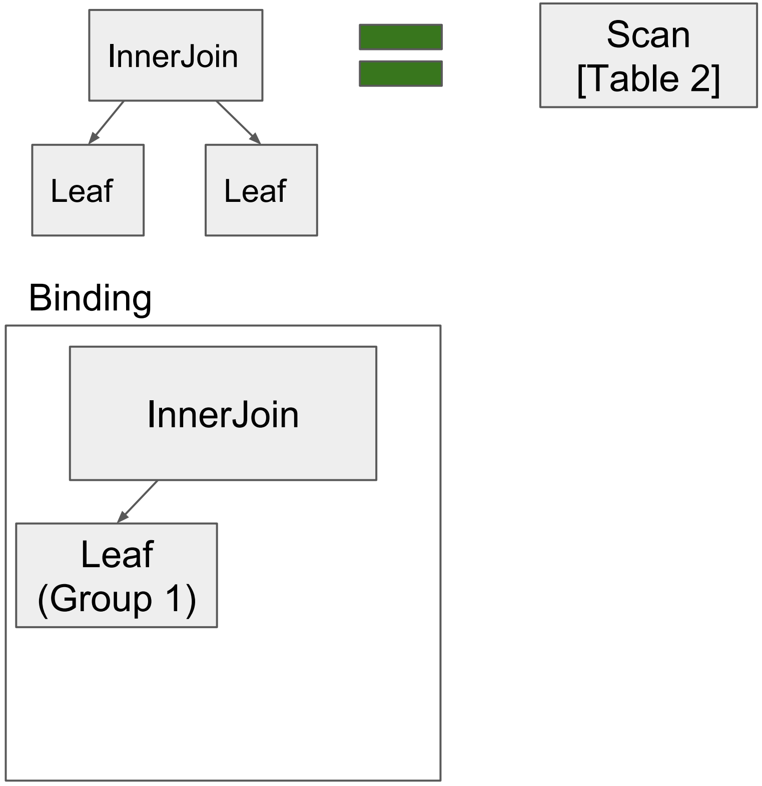
Get
[Table 1]

Group 2

Scan
[Table 2]

Get
[Table 2]

Pattern Matching



InnerJoin

Leaf

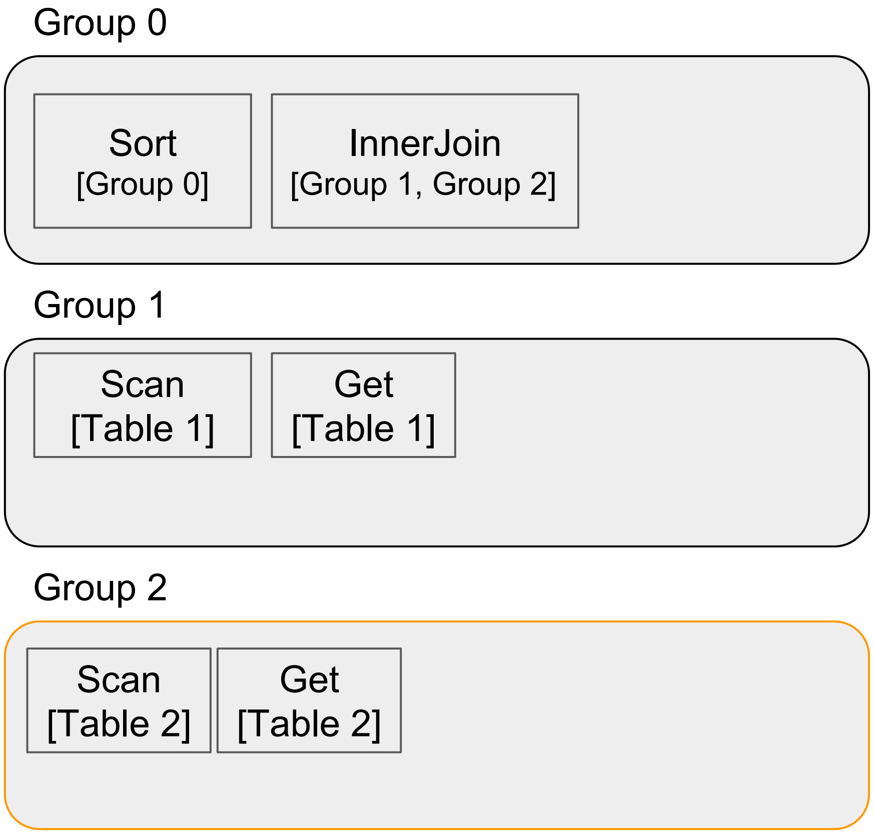
Leaf

Scan
[Table 2]

Binding

InnerJoin

Leaf
(Group 1)



Group 0

Sort
[Group 0]

InnerJoin
[Group 1, Group 2]

Group 1

Scan
[Table 1]

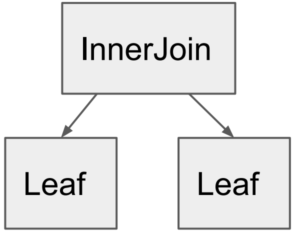
Get
[Table 1]

Group 2

Scan
[Table 2]

Get
[Table 2]

Pattern Matching



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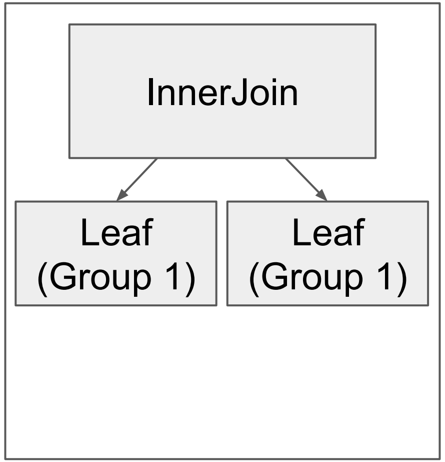
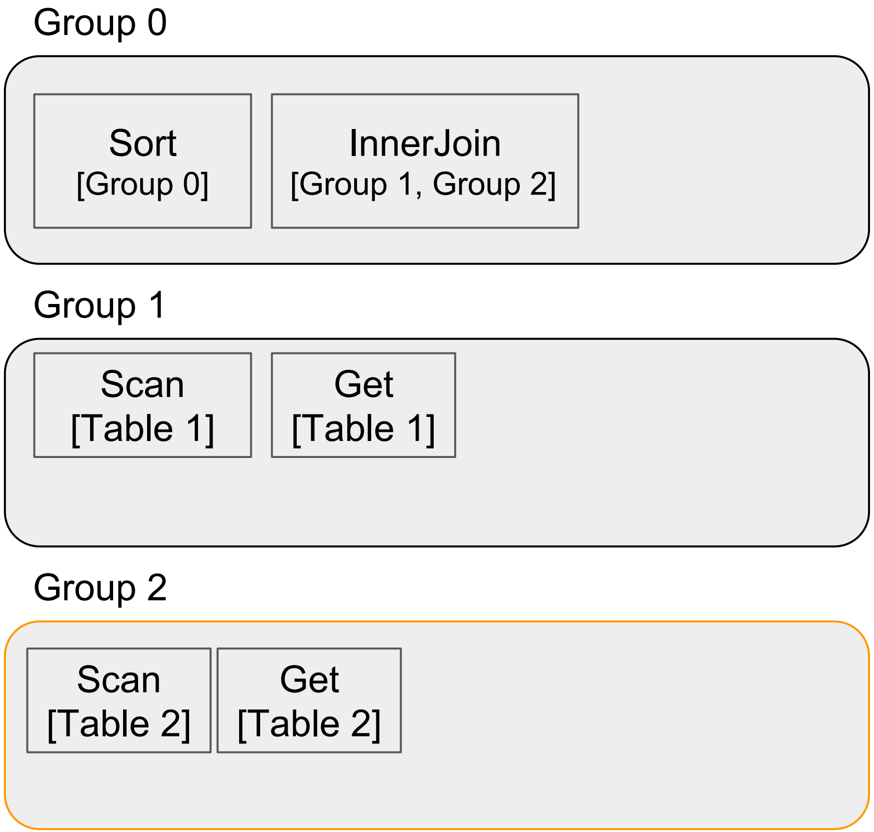
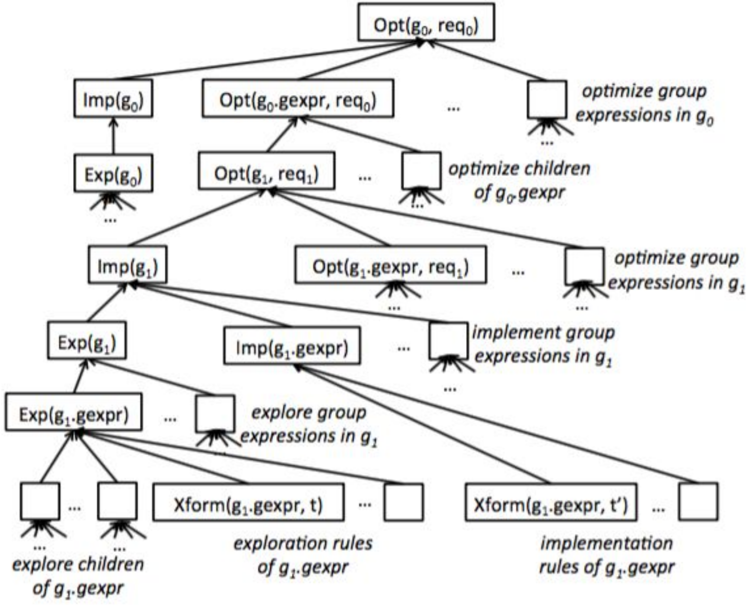




Plan Exploration

- Series of individual tasks
    - Optimization
    - Exploration
    - Rule Application
    - Costing
- Kicks off by optimizing root group
    - Recursively optimize input groups for each operator variant



Credit: Orca Paper

Demo

Retrospective

- Implementing the basic infrastructure was a significant undertaking
    - Synthesizing a concrete implementation from several decades of research
    - Designing extensible representations
    - Generic search process that is invariant of specific rules or operators
- Shuttling between Postgres, Peloton, and the optimizer representation
    - Converting from Postgres query
    - Converting back into Peloton plan

Still to be done

- Optimizer core
  - Implement statistics for cost calculation
    - Table sampling
    - Join intermediate sampling
  - Additional memoization
    - Some rules are still being explored and applied redundantly
- Extensions to base functionality - Logical, Physical operators and rules
  - Operators
    - Merge & nested loop join
    - Index scan
    - Insert, update, delete
    - Aggregate
    - Subqueries
  - Rules
    - Predicate pushdown & pullup
    - Subquery fusion
    - Aggregate pushdown
    - etc...

Future Work

- End-to-end planning, analysis, and compilation
    - Most compilers work directly in terms of the code to be executed
    - RDBMs abstract away from low-level operator representation
        - Use a high-level and simple cost model
- Semi-static and dynamic replanning
    - Semi-static
        - Generate a tree of potential static plans at points of high variance
    - Dynamic
        - Perform initial coarse & guided optimization pass
        - Refine after executing predicates and joins