

Key:

```
Tree
\
|-----Branch
  \
    |-----Right branch
    /
  |-----Node
    \
      |-----Left Branch

PROJECT [Attributes]
\
|-----SELECT [Conditions]
  \
    |-----[Attributes] (Project before join)
    \
      |-----[[Condtions]] (Select before join)
      \
        |-----Relation (to be joined)
        /
      |-----|><| (join with conditions) or X (cross product)
      \
        |-----Left Branch
```

A

Relational Algebra

```
PROJECT [S.SID, S.SNAME, S.RATING, S.AGE] (SELECT [S.RATING > 7] (SAILORS AS S))
```

Query Tree (optimized tree the same)

```
PROJECT [S.SID, S.SNAME, S.RATING, S.AGE]
\
|-----['S.RATING > 7']
  \
    |-----SAILORS AS S
```

B

Exception: Attribute COLOR is not in the attributes for relation SAILORS

C

Relational Algebra

```
PROJECT [B.COLOR] (SELECT [S.SID = R.SID AND R.BID = B.BID AND S.SNAME = LUBBER]
(SAILORS AS S X [RESERVES AS R X [BOATS AS B]]))
```

Initial Query Tree

```
PROJECT [B.COLOR]
\
|-----SELECT [S.SID = R.SID AND R.BID = B.BID AND S.SNAME = LUBBER]
\
|-----['SAILORS', 'S']
/
|-----X
\
|-----['BOATS', 'B']
/
|-----X
\
|-----['RESERVES', 'R']
```

Optimized Query Tree

```
PROJECT [B.COLOR]
\
|-----[S.SID]
\
|-----['S.SNAME = LUBBER']]
\
|-----SAILORS AS S
/
|-----|><| S.SID = R.SID
\
|-----[B.BID, B.COLOR]
\
|-----BOATS AS B
/
|-----|><| R.BID = B.BID
\
|-----[R.SID, R.BID]
\
|-----RESERVES AS R
```

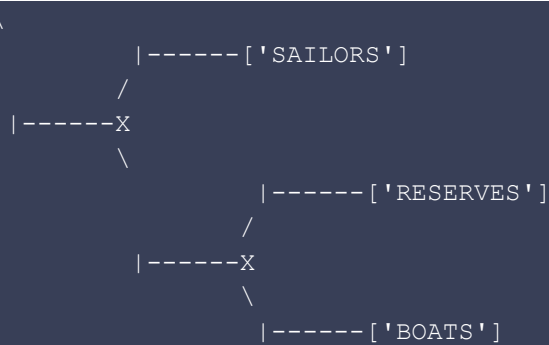
D

Relational Algebra

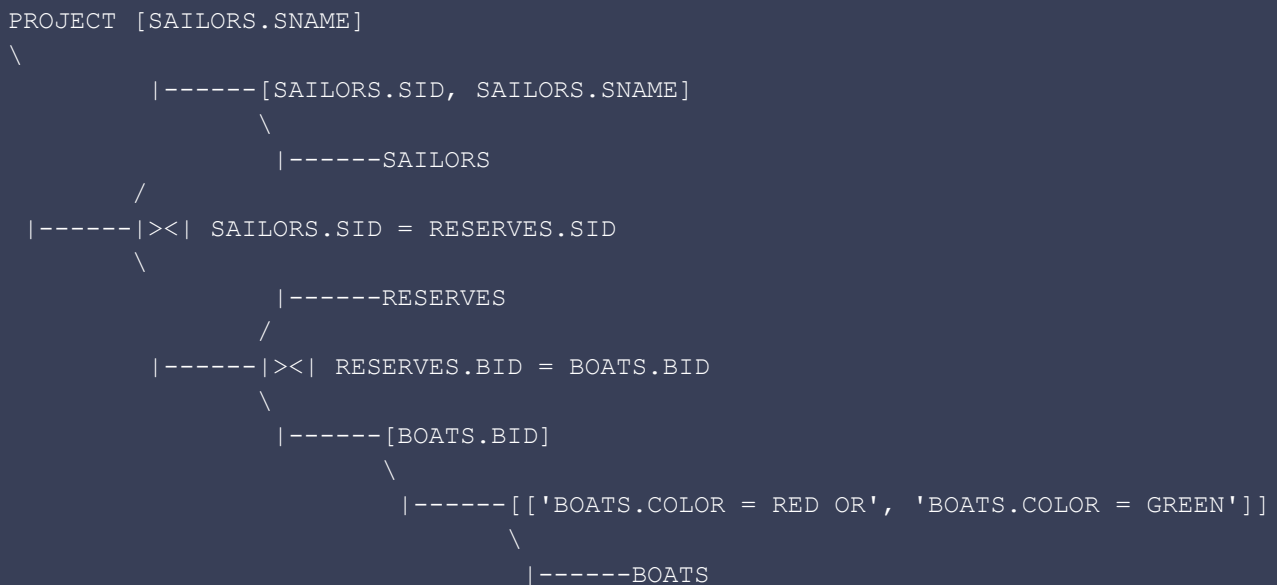
```
PROJECT [SNAME] (SELECT [SAILORS.SID = RESERVES.SID AND RESERVES.BID = BOATS.BID AND
BOATS.COLOR = RED OR BOATS.COLOR = GREEN] (SAILORS X [BOATS X [RESERVES]]))
```

Initial Query Tree

```
PROJECT [SNAME]
\
|-----SELECT [SAILORS.SID = RESERVES.SID AND RESERVES.BID = BOATS.BID AND
BOATS.COLOR = RED OR BOATS.COLOR = GREEN]
```



Optimized Query Tree



E

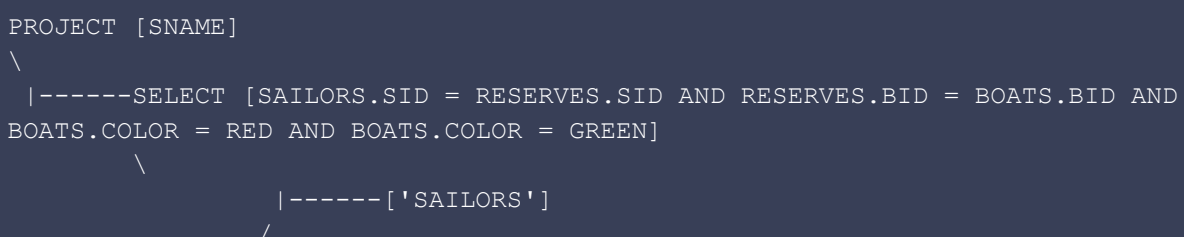
Exception: Attribute RATING is not in the attributes for relation RESERVES

F

Relational Algebra

PROJECT [SNAME] (SELECT [SAILORS.SID = RESERVES.SID AND RESERVES.BID = BOATS.BID AND BOATS.COLOR = RED AND BOATS.COLOR = GREEN] (SAILORS X [BOATS X [RESERVES]]))

Initial Query Tree



```

|-----X
  \
    |-----['RESERVES']
    /
  |-----X
    \
      |-----['BOATS']

```

Optimized Query Tree

```

PROJECT [SAILORS.SNAME]
\
  |-----[SAILORS.SID, SAILORS.SNAME]
  \
    |-----SAILORS
  /
|-----|><| SAILORS.SID = RESERVES.SID
\
  |-----RESERVES
  /
|-----|><| RESERVES.BID = BOATS.BID
\
  |-----[BOATS.BID]
  \
    |-----['BOATS.COLOR = RED AND', 'BOATS.COLOR = GREEN']
    \
      |-----BOATS

```

G

Relational Algebra

```

PROJECT [S.SID] (SELECT [S.SID = R.SID AND R.BID = B.BID AND B.COLOR = RED AND NOT
S2.SID = R2.SID AND R2.BID = B2.BID AND B2.COLOR = GREEN] (SAILORS AS S X [RESERVES AS
R X [BOATS AS B X [SAILORS AS S2 X [RESERVES AS R2 X [BOATS AS B2]]]]]))

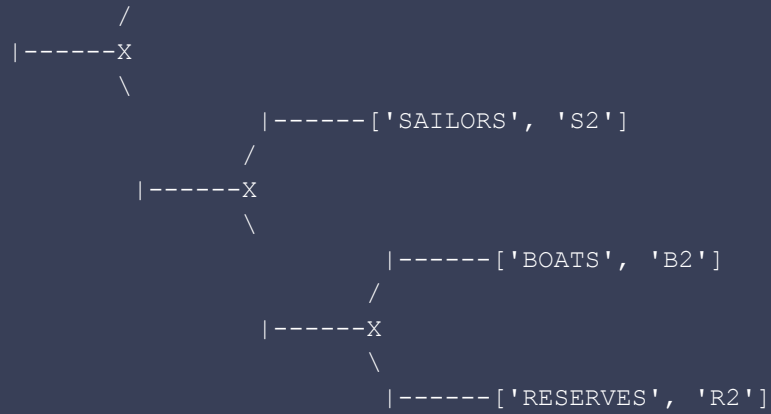
```

Initial Query Tree

```

PROJECT [S.SID]
\
  |-----SELECT [S.SID = R.SID AND R.BID = B.BID AND B.COLOR = RED AND NOT S2.SID =
R2.SID AND R2.BID = B2.BID AND B2.COLOR = GREEN]
  \
    |-----['SAILORS', 'S']
    /
  |-----X
    \
      |-----['RESERVES', 'R']
      /
    |-----X
      \
        |-----['BOATS', 'B']

```



Optimized Query Tree

```

PROJECT [S.SID]
\
  |-----[S.SID, S.SID]
  \
    |-----SAILORS AS S
  /
|-----|><| S.SID = R.SID
\
  |-----[R.SID, R.BID]
  \
    |-----RESERVES AS R
  /
|-----|><| R.BID = B.BID
\
  |-----[B.BID]
  \
    |-----[['B.COLOR = RED']]
    \
      |-----BOATS AS B
    /
  |-----X
  \
    |-----[S2.SID]
    \
      |-----SAILORS AS S2
    /
|-----|><| S2.SID = R2.SID
\
  |-----[B2.BID]
  \
    |-----[['B2.COLOR = GREEN']]
    \
      |-----BOATS AS B2
    /
|-----|><| R2.BID = B2.BID
\
  |-----[R2.SID, R2.BID]
  \
    |-----RESERVES AS R2
  
```

H

Relational Algebra

```
PROJECT [S.SNAME] (SELECT [S.SID = R.SID AND R.BID = 103] (SAILORS AS S X [RESERVES AS R]))
```

Initial Query Tree

```
PROJECT [S.SNAME]
 \
  |-----SELECT [S.SID = R.SID AND R.BID = 103]
   \
    |-----['RESERVES', 'R']
     /
    |-----X
     \
    |-----['SAILORS', 'S']
```

Optimized Query Tree

```
PROJECT [S.SNAME]
 \
  |-----[R.SID]
   \
    |-----[['R.BID = 103']]
     \
    |-----RESERVES AS R
     /
    |-----|><| S.SID = R.SID
     \
    |-----[S.SNAME, S.SID]
     \
    |-----SAILORS AS S
```

I

Exception: Relation RESERVE not in the database.

J

Relational Algebra

```
PROJECT [S.SNAME] (SELECT [R.BID = B.BID AND R.SID = S.SID] (SAILORS AS S X [RESERVES AS R X [BOATS AS B]]))
```

Initial Query Tree

```

PROJECT [S.SNAME]
\
|-----SELECT [R.BID = B.BID AND R.SID = S.SID]
\
      |-----['SAILORS', 'S']
      /
|-----X
      \
            |-----['RESERVES', 'R']
            /
            |-----X
            \
            |-----['BOATS', 'B']

```

Optimized Query Tree

```

PROJECT [S.SNAME]
\
      |-----[S.SNAME, S.SID]
      \
      |-----SAILORS AS S
      /
|-----|><| R.SID = S.SID
      \
            |-----[R.BID, R.SID]
            \
            |-----RESERVES AS R
            /
            |-----|><| R.BID = B.BID
            \
            |-----[B.BID]
            \
            |-----BOATS AS B

```

K

Relational Algebra

```

PROJECT [S.SNAME] (SELECT [S.AGE > MAX(S2.AGE) AND S2.RATING = 10] (SAILORS AS S X
[SAILORS AS S2]))

```

Initial Query Tree

```

PROJECT [S.SNAME]
\
|-----SELECT [S.AGE > MAX(S2.AGE) AND S2.RATING = 10]
\
      |-----['SAILORS', 'S2']
      /
|-----X
      \
            |-----['SAILORS', 'S']

```

Optimized Query Tree

```
PROJECT [S.SNAME]
\
  |-----[ ['S2.RATING = 10']]
  \
    |-----SAILORS AS S2
  /
|-----X
\
  |-----[S.SNAME]
  \
    |-----[ ['S.AGE > MAX(S2.AGE) ']]
    \
      |-----SAILORS AS S
```

L

Relational Algebra

```
GROUP BY [B.BID] (PROJECT [B.BID, COUNT(*) AS RESERVATIONCOUNT] (SELECT [R.BID = B.BID
AND B.COLOR = RED] (BOATS AS B X [RESERVES AS R])))
```

Initial Query Tree

```
GROUP BY [B.BID]
\
  |-----PROJECT [B.BID, COUNT(*) AS RESERVATIONCOUNT]
  \
    |-----SELECT [R.BID = B.BID AND B.COLOR = RED]
    \
      |-----['RESERVES', 'R']
      /
    |-----X
    \
      |-----['BOATS', 'B']
```

Optimized Query Tree

```
GROUP BY [B.BID]
\
  |-----PROJECT [B.BID, COUNT(*) AS RESERVATIONCOUNT]
  \
    |-----[R.BID]
    \
      |-----RESERVES AS R
    /
  |-----|><| R.BID = B.BID
  \
```



```

|-----[B.BID, B.BID]
  \
    |-----[['B.COLOR = RED']]
      \
        |-----BOATS AS B

```

M

Relational Algebra

```

HAVING [B.COLOR = RED] (GROUP BY [B.BID] (PROJECT [B.BID, COUNT(*) AS RESERVATIONCOUNT]
(SELECT [R.BID = B.BID AND B.COLOR = RED] (BOATS AS B X [RESERVES AS R])))

```

Initial Query Tree

```

HAVING [B.COLOR = RED]
\
|-----GROUP BY [B.BID]
  \
    |-----PROJECT [B.BID, COUNT(*) AS RESERVATIONCOUNT]
      \
        |-----SELECT [R.BID = B.BID AND B.COLOR = RED]
          \
            |-----['RESERVES', 'R']
              /
            |-----X
              \
                |-----['BOATS', 'B']

```

Optimized Query Tree

```

HAVING [B.COLOR = RED]
\
|-----GROUP BY [B.BID]
  \
    |-----PROJECT [B.BID, COUNT(*) AS RESERVATIONCOUNT]
      \
        |-----[R.BID]
          \
            |-----RESERVES AS R
              /
        |-----|><| R.BID = B.BID
          \
            |-----[B.BID, B.BID]
              \
                |-----[['B.COLOR = RED']]
                  \
                    |-----BOATS AS B

```

N

Exception: Relation or alias SAILOR is not used in this query

O

Exception: Invalid syntax near or at "AVE ("