Optimization Strategies for Parallel Linear Recursive Query Processing

Thomas Zurek
Department of Computer Science
Edinburgh University

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Overview

- linear recursive queries
- processing model
- evaluation strategies
- performance results
- conclusions

Some simple Queries

Relation $Flight(Airline, From, To)$

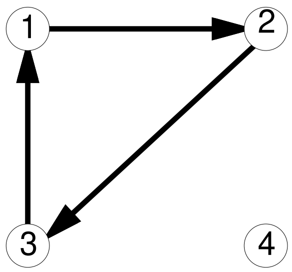
$$\begin{aligned} C(X,Z) &= Flight(A,X,Z) \\ C(X,Z) &= C(X,Y) \bowtie Flight(A,Y,Z) \end{aligned}$$

$$\begin{aligned} CA(A,X,Z) &= Flight(A,X,Z) \\ CA(A,X,Z) &= CA(A,X,Y) \bowtie Flight(A,Y,Z) \end{aligned}$$

A non-trivial Query

$$
\begin{aligned}
P(A,B,C,D) &= E(A,B,C,D) \\
P(A,B,C,D) &= P(C,A,B,E) \bowtie Q(E,D)
\end{aligned}
$$

Substitution Graph



d = 3

g = 0

2-step Rule

$$P(A,B,C,D) = P(B,C,A,F) \bowtie Q(F,E) \bowtie Q(E,D)$$

3-step Rule

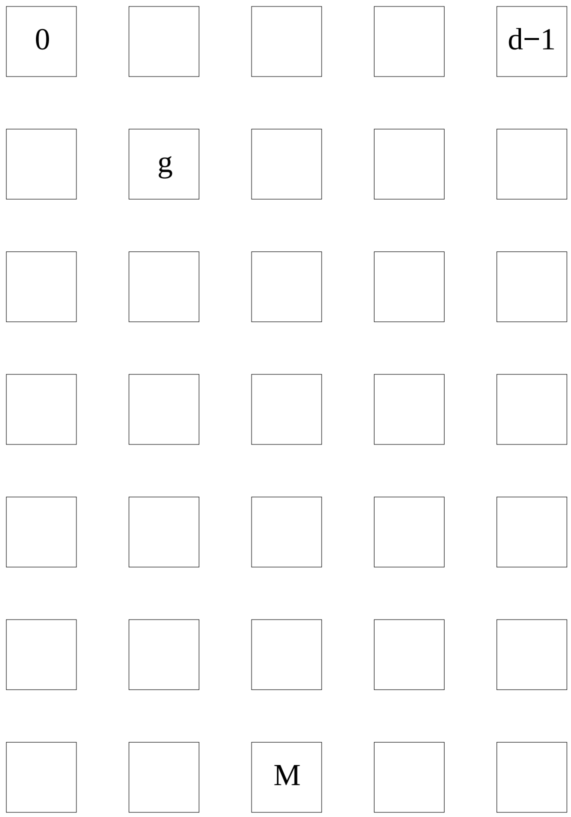
$$P(A,B,C,D) = P(A,B,C,G) \bowtie \underbrace{Q(G,F) \bowtie Q(F,E) \bowtie Q(E,D)}_{Q^3(G,D)}$$

Generations

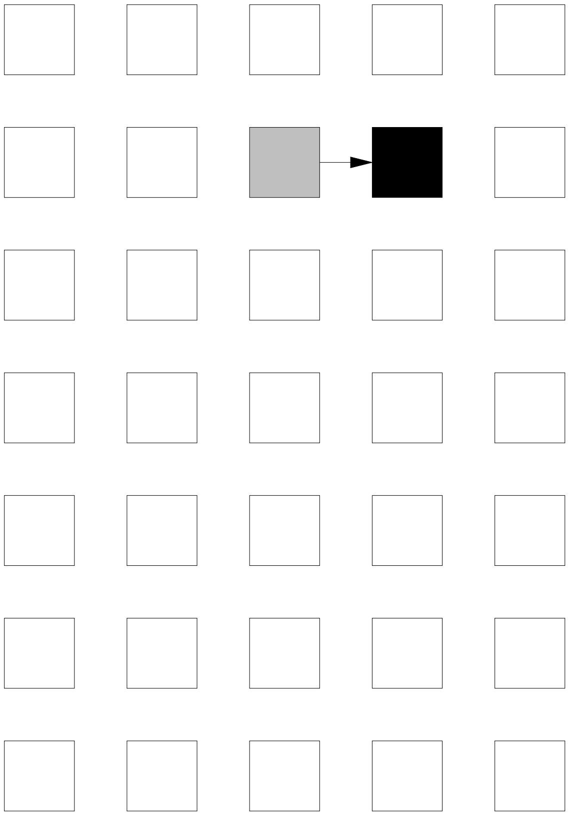
$$
\begin{aligned}
CA_0(A,X,Z) &= Flight(A,X,Z) \\
CA_1(A,X,Z) &= Flight(A,X,Y_1) \\
&\quad \bowtie\ Flight(A,Y_1,Z) \\
CA_2(A,X,Z) &= Flight(A,X,Y_2) \\
&\quad \bowtie\ Flight(A,Y_2,Y_1) \\
&\quad \bowtie\ Flight(A,Y_1,Z) \\
CA_3(A,X,Z) &= Flight(A,X,Y_3) \\
&\quad \bowtie\ Flight(A,Y_3,Y_2) \\
&\quad \bowtie\ Flight(A,Y_2,Y_1) \\
&\quad \bowtie\ Flight(A,Y_1,Z)
\end{aligned}
$$

$\boxed{0}$ $\boxed{1}$ $\boxed{2}$ $\boxed{3}$ $\cdots$ $\boxed{M}$

Generation Matrix

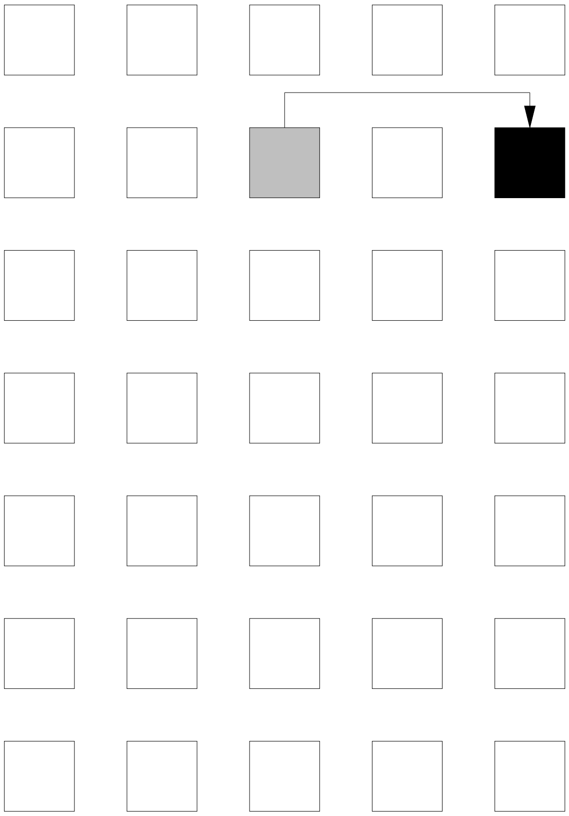


(R) Move



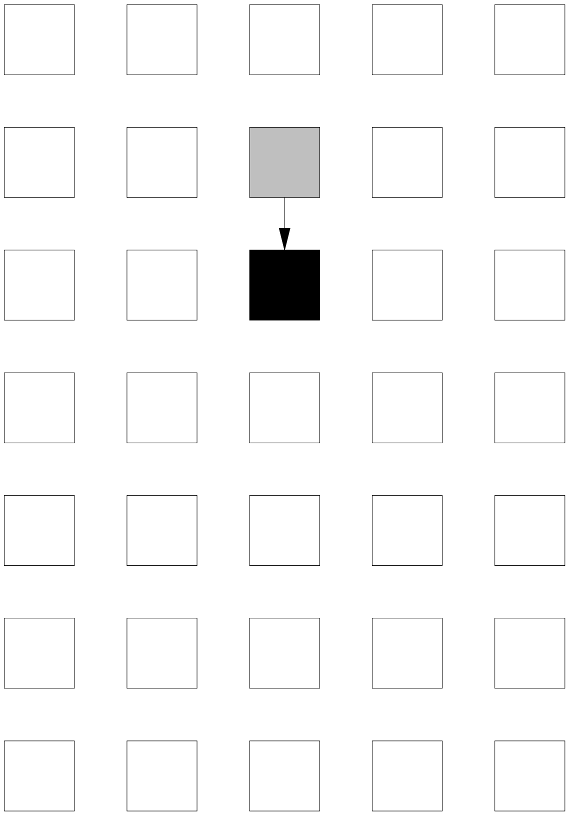
$$CA_{i+1}(A, X, Z) \;=\; CA_i(A, X, Y) \bowtie Flight(A, Y, Z)$$

(R2) Move



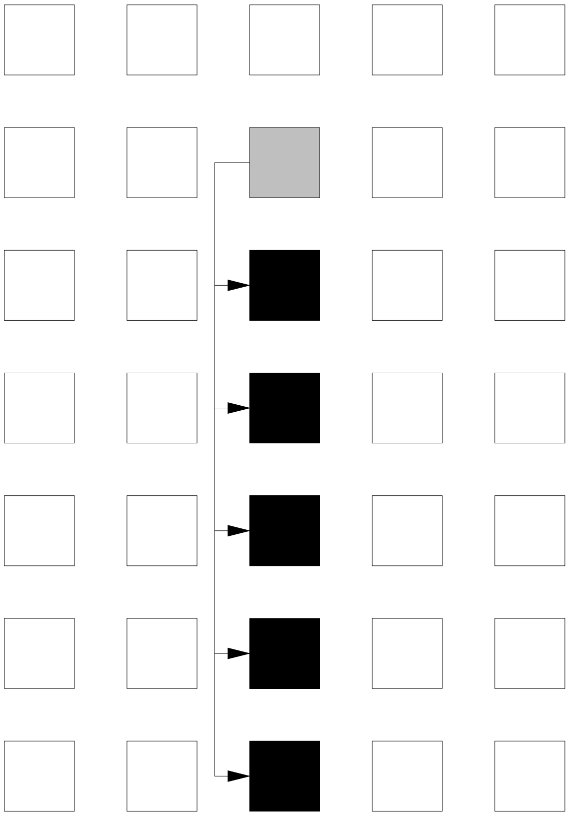
$$CA_{i+2}(A, X, Z) = CA_i(A, X, Y_1) \bowtie Flight(A, Y_1, Y_2) \bowtie Flight(A, Y_2, Z)$$

(Rd) Move



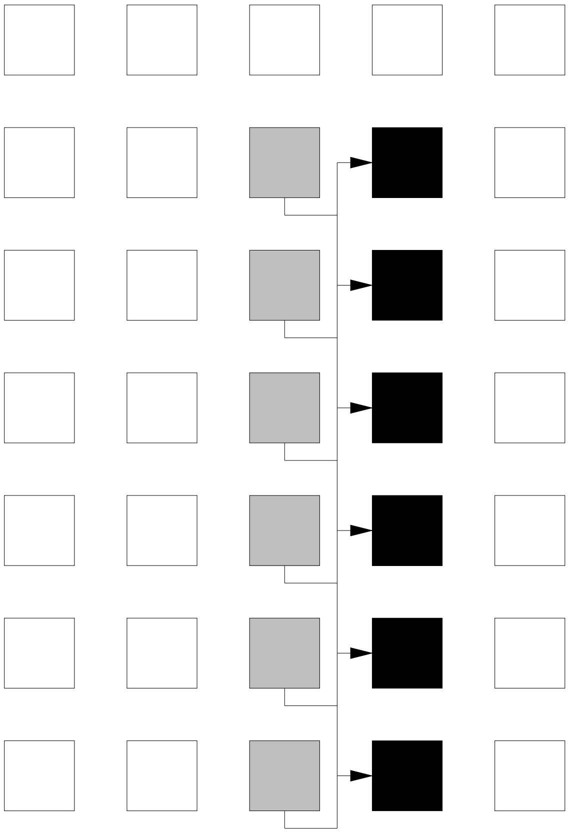
$$
\begin{aligned}
CA_{i+d}(A,X,Z) = CA_i(A,X,Y_1) \quad & \bowtie \quad Flight(A,Y_1,Y_2) \\
& \bowtie \quad \ldots \\
& \bowtie \quad Flight(A,Y_d,Z)
\end{aligned}
$$

(TC) move

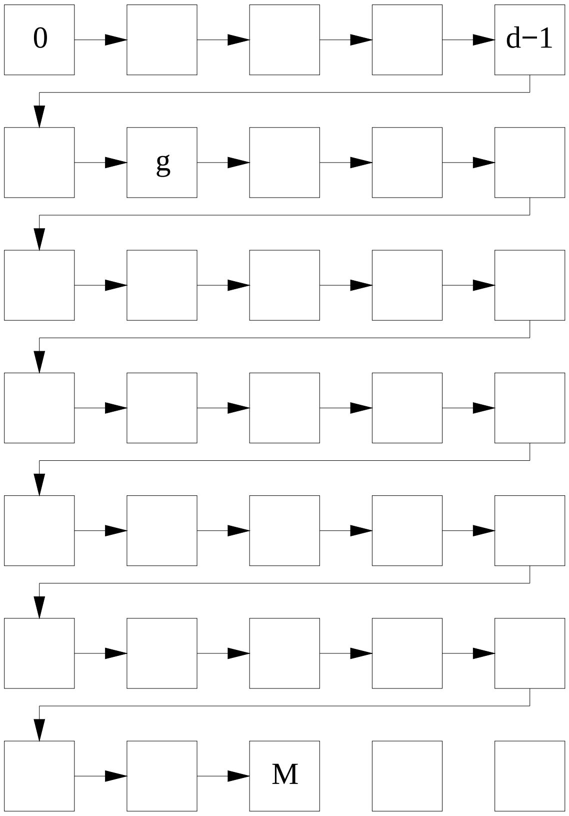


$$CA_{i+nd}(A,X,Z) \;=\; CA_i(A,X,Y) \bowtie [Flight^d(A,Y,Z)]^{tc}$$

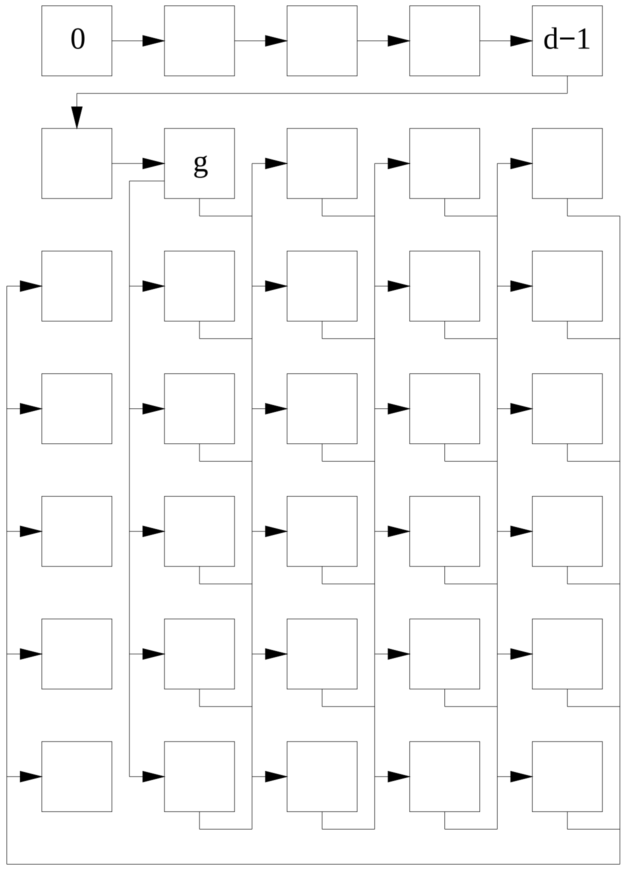
Data-Parallel (R) Move



Bottom-Up Strategy



Transitive Closure Strategy



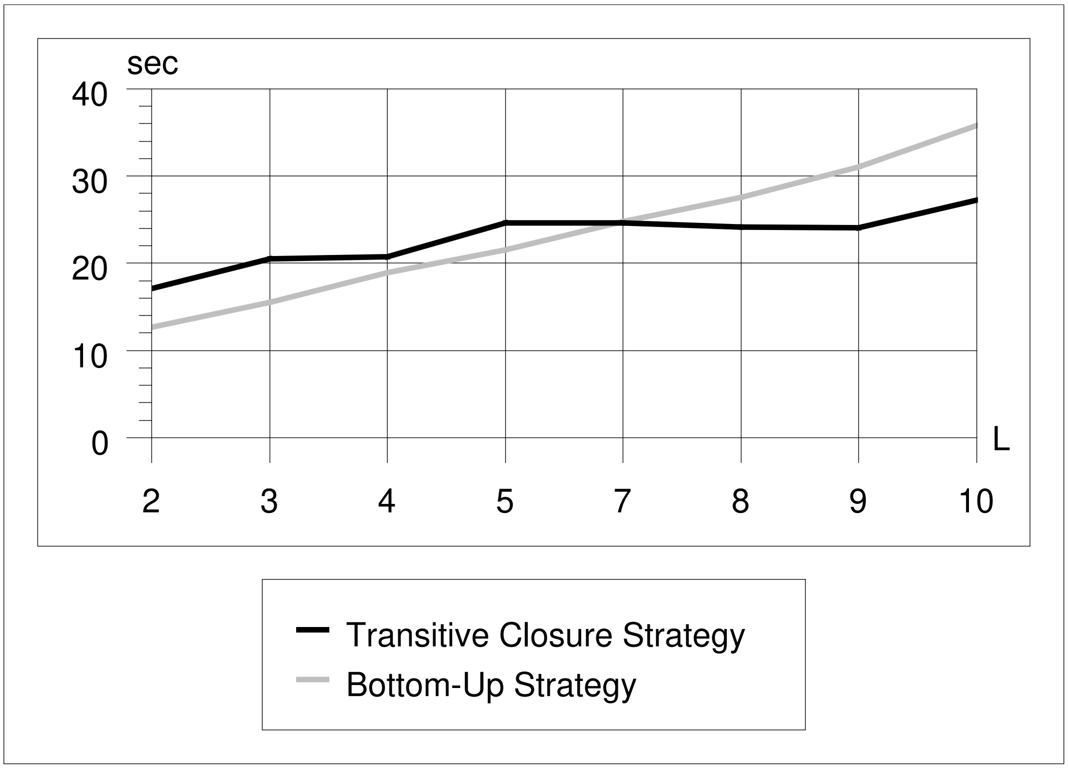
Parallel Aspects

- Parallelizing the Strategy
  - data parallel moves
  - moves in parallel
- Parallelizing the Moves
  - parallel (R) move
  - parallel (TC) move

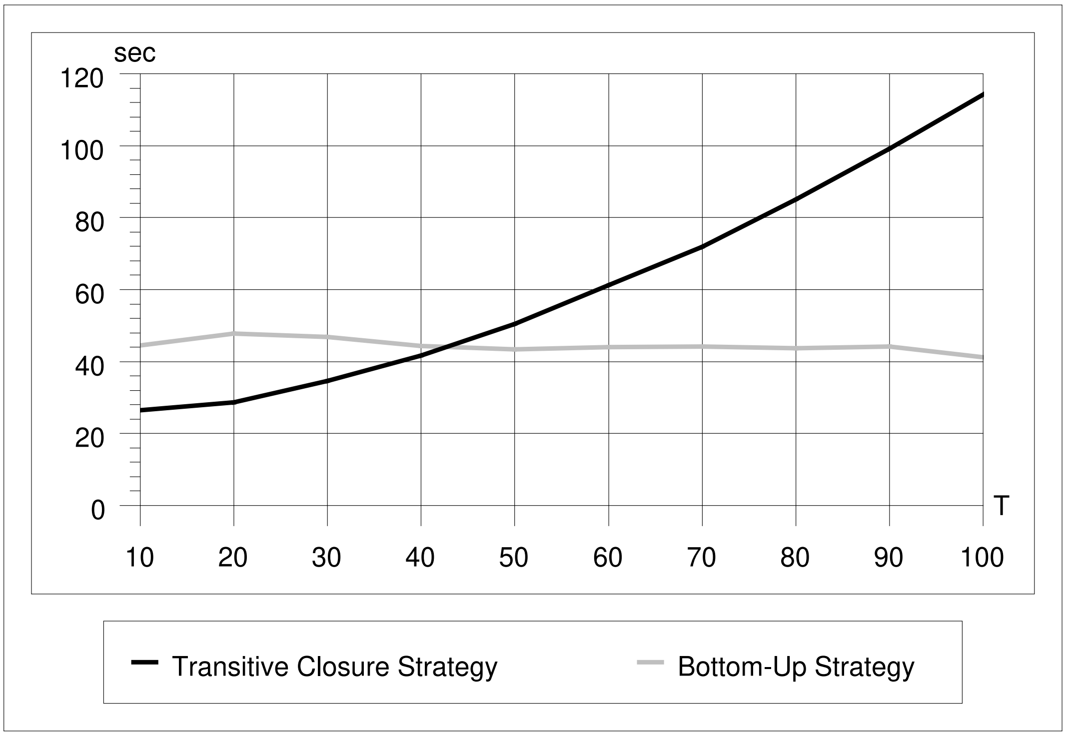
The Connection Machine CM-200

- data parallel SIMD architecture,
- 16384 processors,
- 256 kBit local memory per processor,
- 10 GBytes parallel mass storage,
- 25 MBytes per second data transfer rate

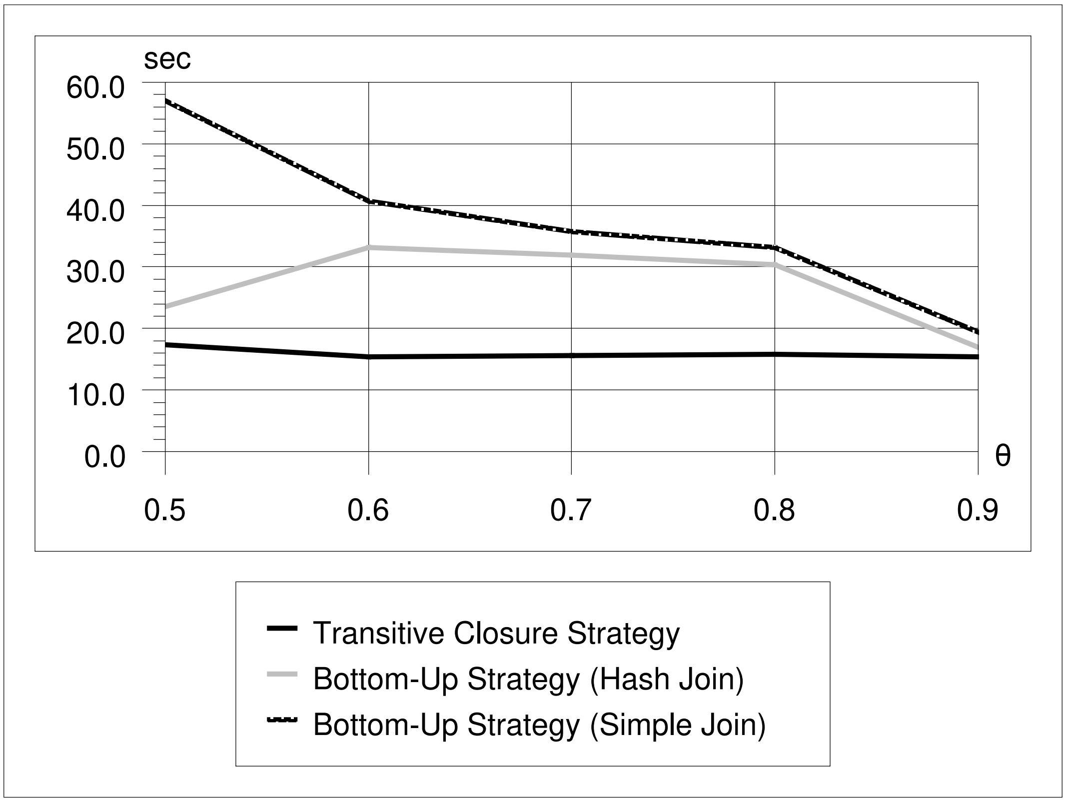
Length of the Longest Path



Number of Transitive Closures



Data Skew


sec
60.0
50.0
40.0
30.0
20.0
10.0
0.0
θ
0.5
0.6
0.7
0.8
0.9
Transitive Closure Strategy
Bottom-Up Strategy (Hash Join)
Bottom-Up Strategy (Simple Join)

Conclusions

- 2 techniques in 1 processing model
- small set of simple operators
- covers problem of *data-dependent* number of transitive closures
- fits in traditional optimizer architecture
- results confirm transitive closure strategy