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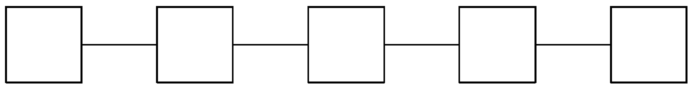
Parallel Processing of Linear Recursive Datalog Queries using Transitive Closure Algorithms

- design of data parallel algorithms
- replacing linear recursion by transitive closure

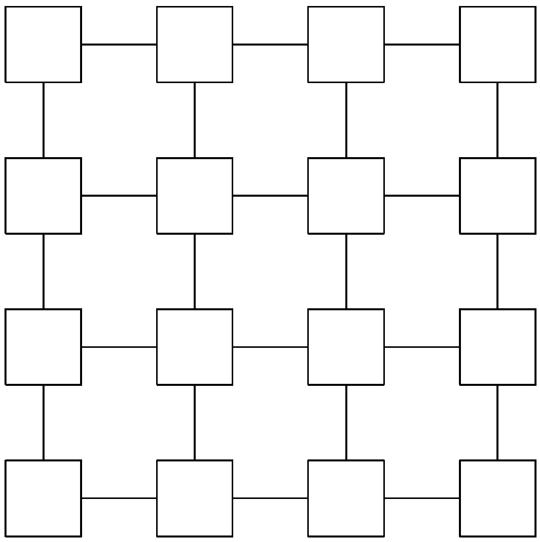
Connection Machine

- 16384 processors
- 256 kBits memory per processor
- 10D–hypercube connection
- SIMD
- 10 GBytes mass storage system

Linear Array Connection



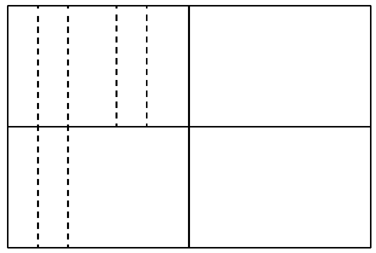
Mesh Connection



$$\begin{pmatrix} 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

for $j = 1$ **to** n **do**
    for $i = 1$ **to** n **do in parallel**
        process c_{ij}

for ($j = 0$; $j < n$; j++)
    where ([$\ldots$] [j] C == 1)
        { B = [j] [$\ldots$] C;
           C = C or B;
        }



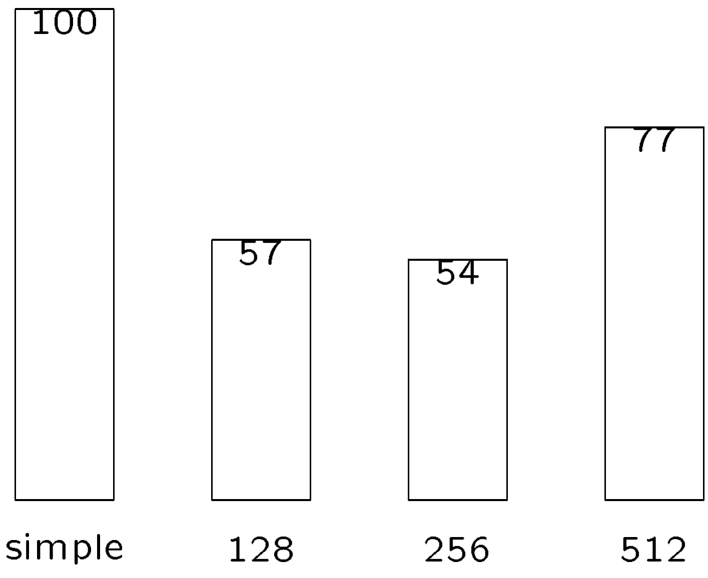
$n \times n$ matrix

$\downarrow$

$m \times m$ submatrices

for $j = 1$ **to** n **do**
  for $i = 1$ **to** n **do in parallel**
    process c_{ij}

for $q = 1$ **to** $\frac{n}{m}$ **do**
  for $p = 1$ **to** $\frac{n}{m}$ **do**
    for $j = 1$ **to** m **do**
      for $i = 1$ **to** m **do in parallel**
        process c_{ij}^{pq}



Performance Results for $n = 1024$

Datalog Query (1)

$$p(X,Z) \;:-\; e(X,Z)$$
$$p(X,Z) \;:-\; p(X,Y),\, q(X,Y,Z).$$

Bottom-up Evaluation

$$p(X,Z) \;:-\; e(X,Z).$$

$$p(X,Z) \;:-\; e(X,Y_1),\, q(X,Y_1,Z).$$

$$p(X,Z) \;:-\; e(X,Y_2),\, q(X,Y_2,Y_1),\, q(X,Y_1,Z).$$

$$\ldots$$

$$p(X,Z) \;:-\; e(X,Y_n),\, q(X,Y_n,Y_{n-1}),\, \ldots,\, q(X,Y_1,Z).$$

$$\ldots$$

Datalog Query (2)

$$p(U,V,Z) \;:-\; e(U,V,Z)$$
$$p(U,V,Z) \;:-\; p(V,U,Y),\, q(U,Y,Z).$$

Bottom-up Evaluation

$$p(U,V,Z) \;:-\; e(U,V,Z).$$

$$p(U,V,Z) \;:-\; e(V,U,Y_1),\, q(U,Y_1,Z).$$

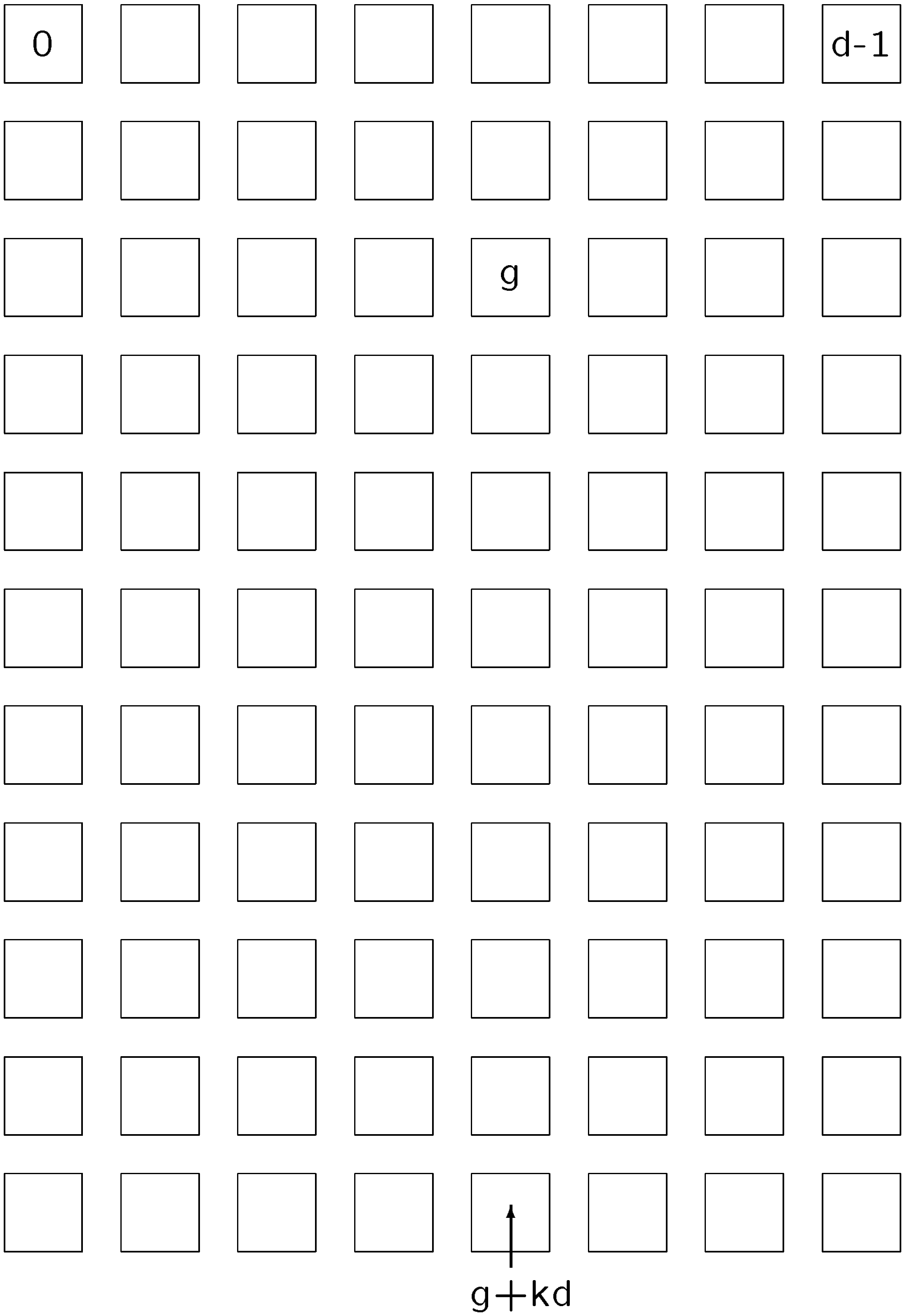
$$p(U,V,Z) \;:-\; e(U,V,Y_2),\, q(V,Y_2,Y_1),\, q(U,Y_1,Z).$$

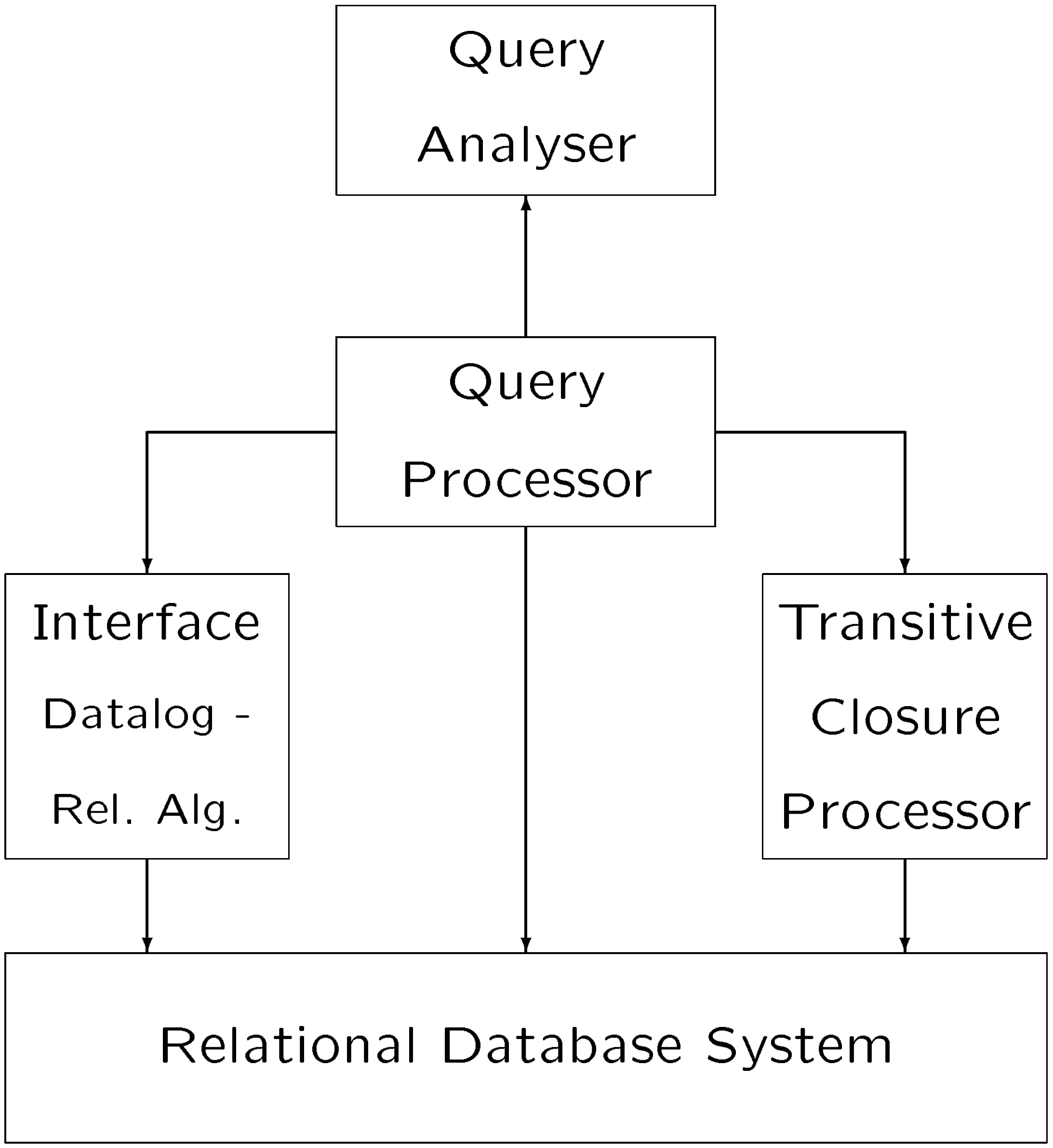
$$\ldots$$

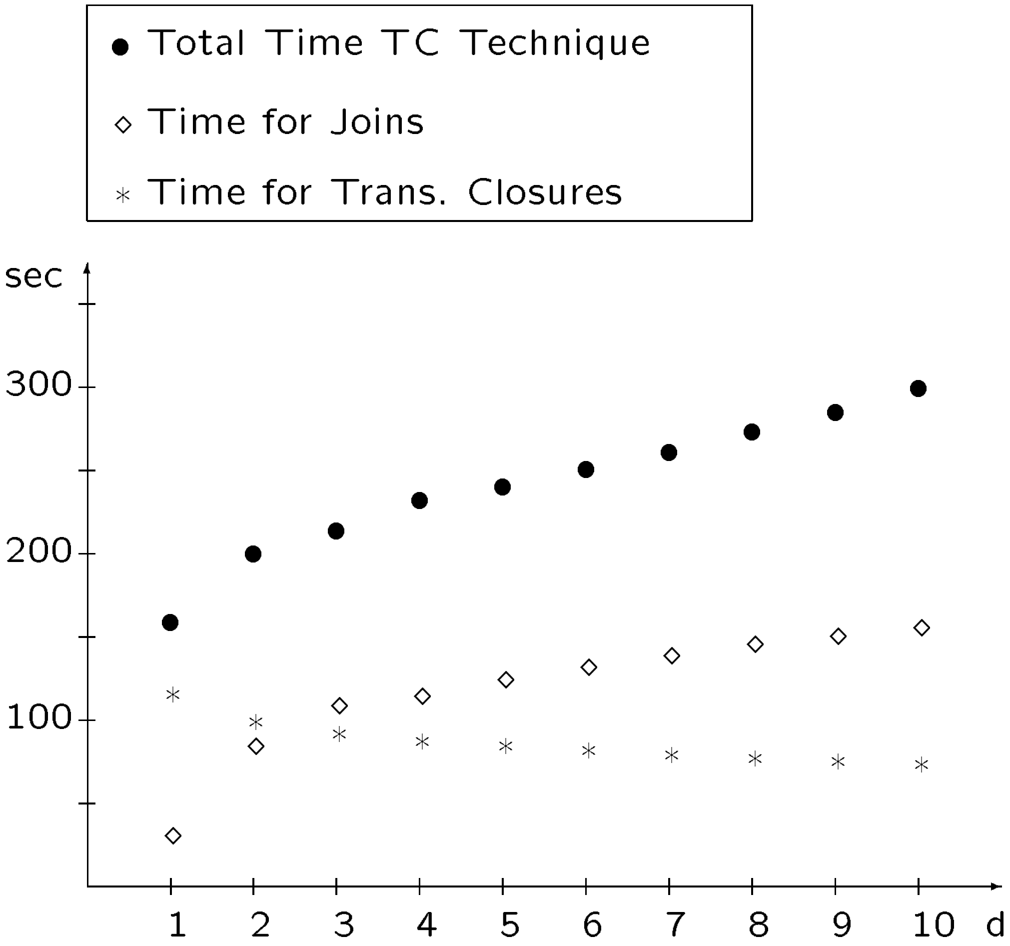
Substitution Graph

d-step Rule

$$p(U,V,Z) \;:-\; p(U,V,Y_2),\, \underbrace{q(V,Y_2,Y_1),\, q(U,Y_1,Z)}_{q'(U,V,Y_2,Z)}.$$


0
d-1
g
g+kd


Query
Analyser
Query
Processor
Interface
Datalog -
Rel. Alg.
Transitive
Closure
Processor
Relational Database System



Total Time TC Technique
Time for Joins
Time for Trans. Closures
sec
300
200
100
1
2
3
4
5
6
7
8
9
10
d