Scalable computation of acyclic joins

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Outline

- What is an acyclic join?
- Case study: *Star schemas*
  - Worst case performance of known algorithms
  - Using our new approach
- Our general result
- Cyclic joins

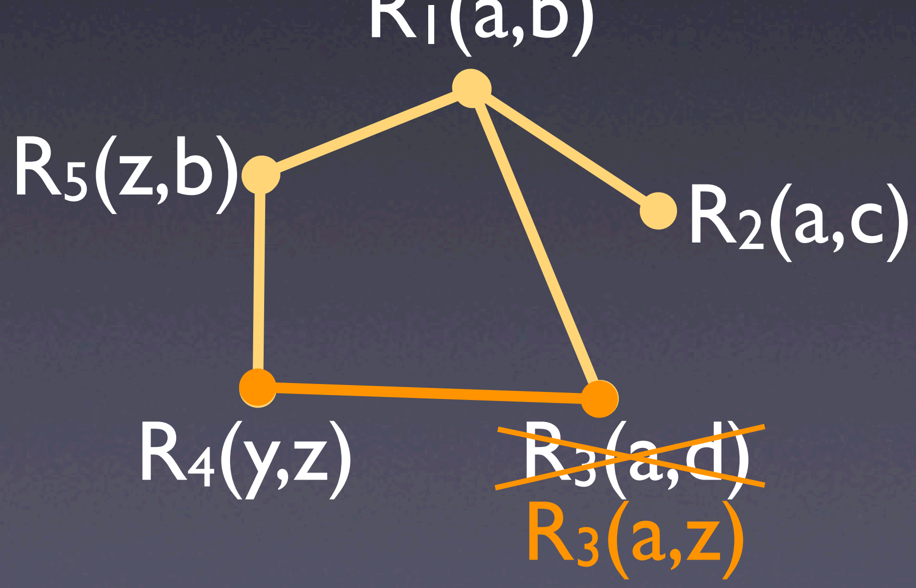
Natural join

- Given relations $R_1,\ldots,R_k$, compute the relation R consisting of all tuples whose projections (to appropriate attributes) can be found in $R_1,\ldots,R_k$.
- NP-hard in general [MSY '81].
- Special case of *acyclic joins* known to be polynomial time computable [G, YO '79], [Y '81].

Acyclic join

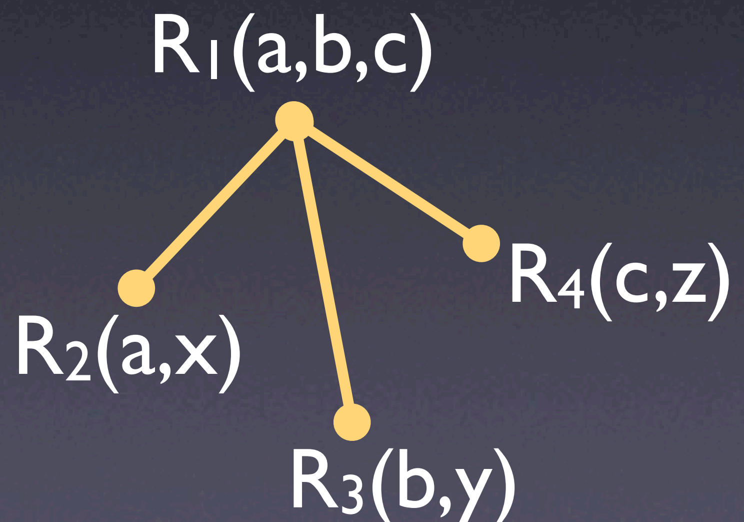
- **Definition.** A join of relations $R_1, \ldots, R_k$ is *acyclic* if there exists a tree with vertices $R_1, \ldots, R_k$ such that the join can be expressed as a theta-join with equality conditions only between adjacent relations.
- **Example**:

cyclic join



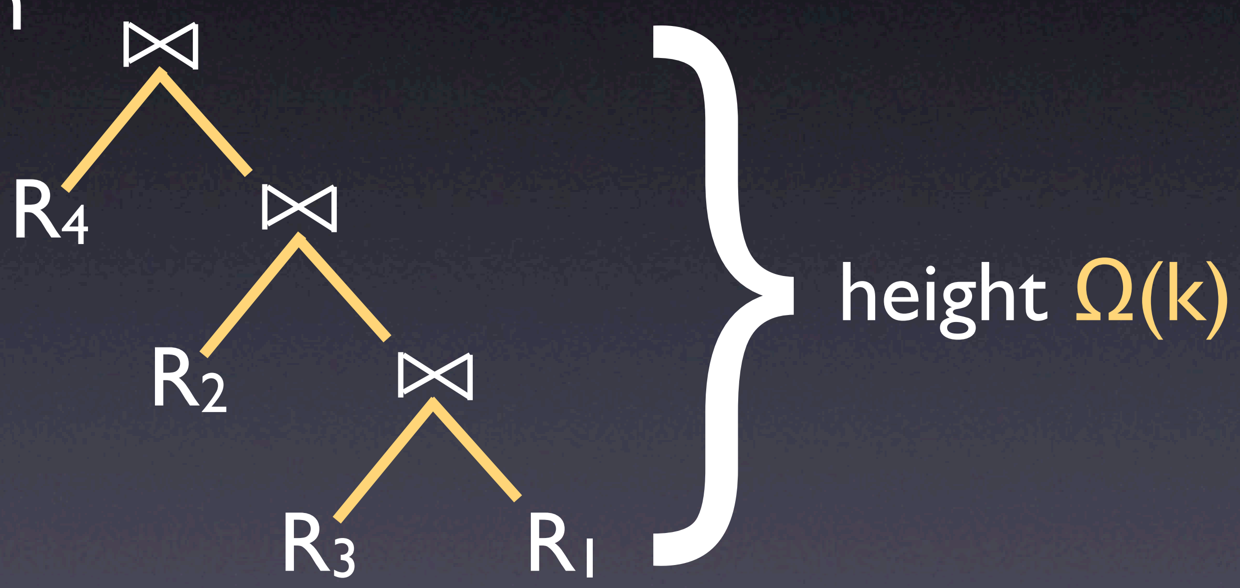
Special case: Star schema

- **Star schema**: The attribute sets of the relations are disjoint, except R_1 which contains an attribute from each of $R_2,\ldots,R_k$.
- **Example**:



Star schema join

- Natural join of $R_1, \ldots, R_k$ having a star schema.
- Any join not involving R_1 is a cartesian product.
- Best query plan usually highly unbalanced:



- All intermediate results, and the final result, may have roughly the same size as R_1.

Worst-case complexity

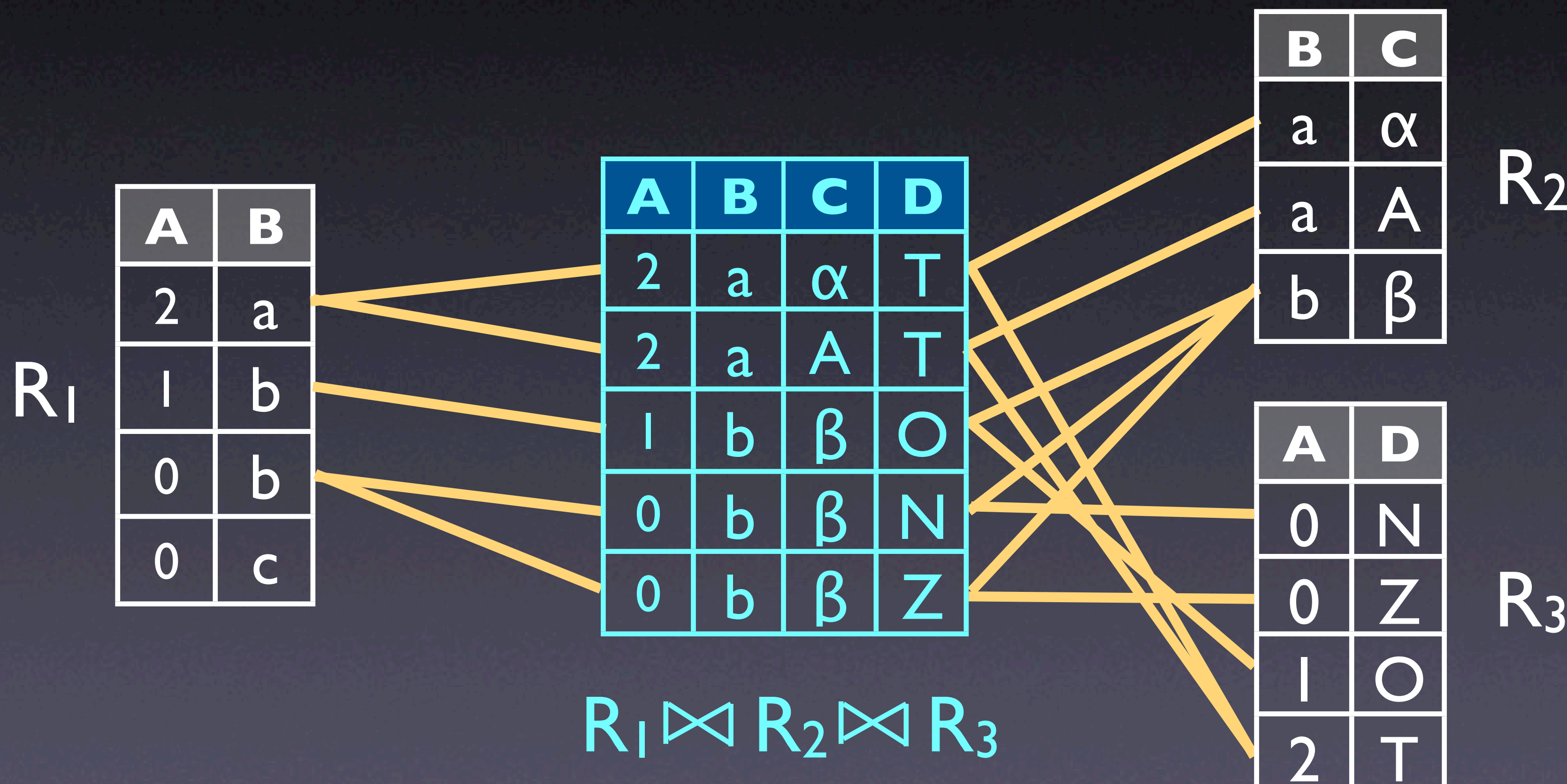
- Let n denote the size of input ($\approx$ size of output).
- Total size of inputs to binary joins $\Omega(kn)$ $\Rightarrow$

$$\begin{cases} \Omega(kn) \text{ time on a RAM} \\ \Omega(kn/B) \text{ I/Os in the I/O model} \end{cases}$$

- Pipelining and indexing don't help asymptotically.
- <u>Next</u>: Eliminating the dependence on k.

New approach

- *Abandon* the idea of intermediate results.
- Compute relationship between input and output.



New approach

- *Abandon* the idea of intermediate results.
- Compute relationship between input and output.

R_1

A	B	
2	a	1, 2
1	b	3
0	b	4, 5
0	c	

$R_1 \bowtie R_2 \bowtie R_3$

	A	B	C	D
1	2	a	α	T
2	2	a	A	T
3	1	b	β	O
4	0	b	β	N
5	0	b	β	Z

R_2

	B	C
1	a	α
2	a	A
3, 4, 5	b	β

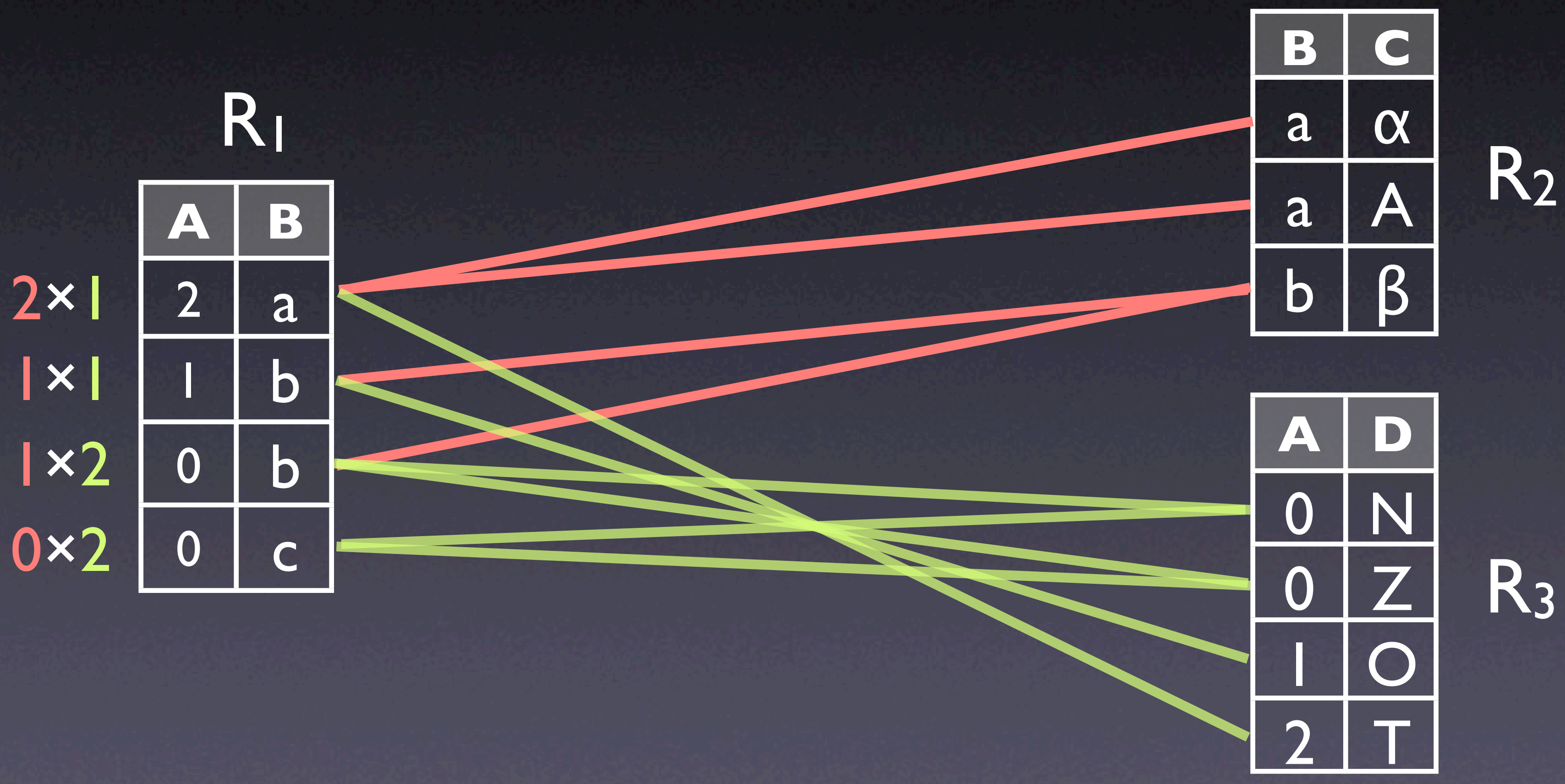
R_3

	A	D
4	0	N
5	0	Z
3	1	O
1,2	2	T

sort by row numbers

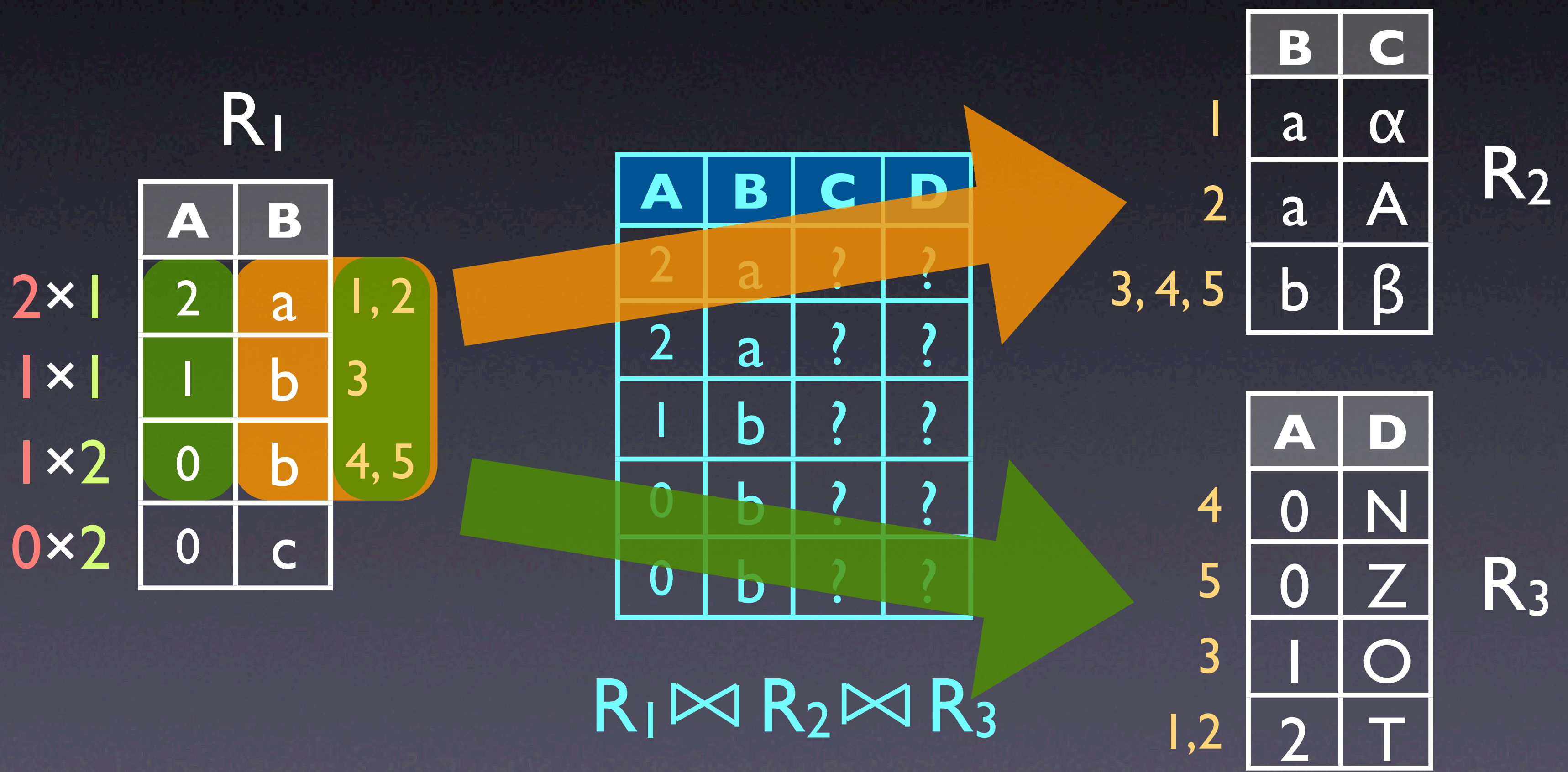
Implementation

1. Count number of tuples matching each tuple in R_1.



Implementation

1. Count number of tuples matching each tuple in R_1.
2. Enumerate the output tuples.

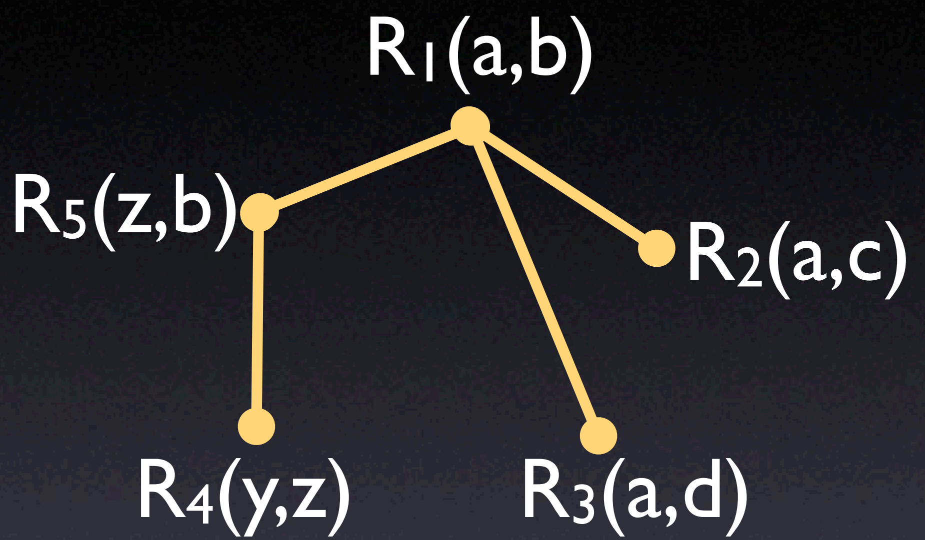


General algorithm

- More complicated application of the same ideas — guided by the tree of the acyclic join.
- *Counting phase* proceeds bottom-up in tree — computes #tuple occurrences in sub-joins.
- *Enumeration phase* proceeds top-down — assigns output tuple numbers to all tuples.
- *Sort* to produce the result.

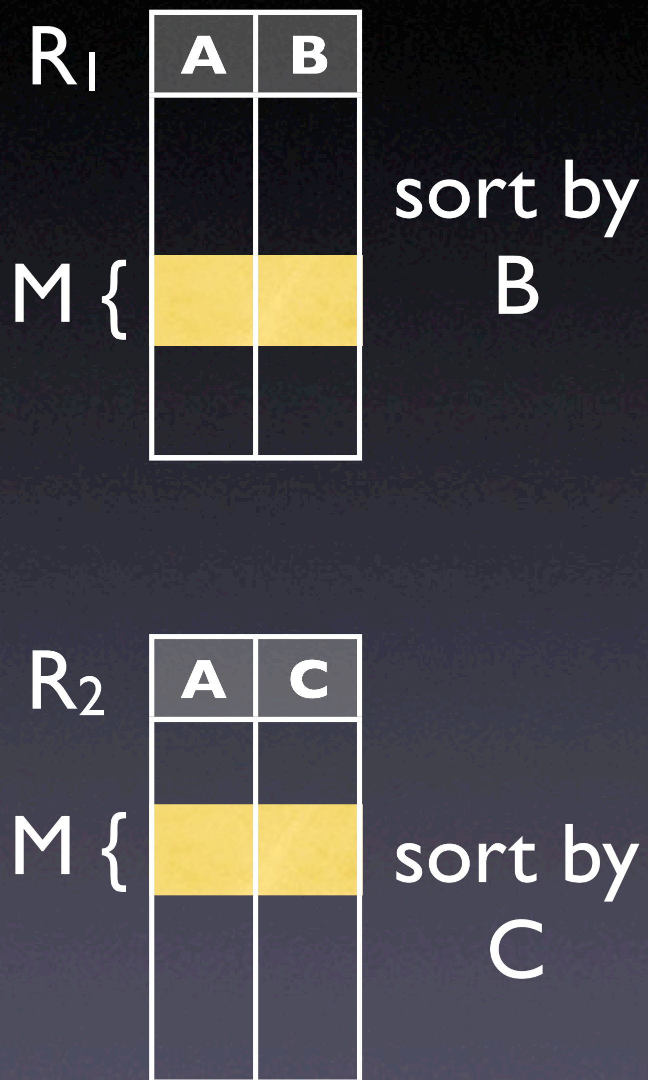
General result

- Acyclic join of k relations.
- Let n denote the input size plus the size of data involved in the equality conditions of the join.
  Let z denote the output size.

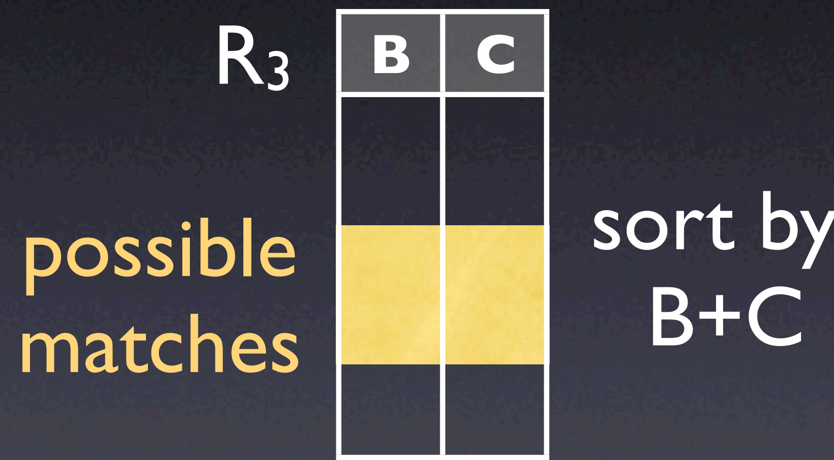


- We can compute the join in
  - O(sort(n+z)) I/Os on external memory
  - O(n+z) expected time on a RAM

Cyclic joins: 3-cycles



<u>Analysis</u>: Each tuple in R_3 is a possible match $O(n/M)$ times.



$O(n^2/(MB)+\text{sort}(n))$ I/Os

(previously: $O(n^2/B)$ I/Os)

Conclusion

- Relational algebra forms the basis of query languages, but it is not always the best basis for query processing!
- We saw two examples where evaluation based on a relational algebra expression is suboptimal.

Open problems

- Experimental evaluation — how many relations are needed before the new algorithm is better?
- Are any cyclic joins computable in sorting complexity (worst case)?
- Which other join graphs can be handled in $\tilde{O}(n^2/(MB))$ I/Os (worst case)?
  Status: 3-cycles and 4-cycles.

Thank you!