

# Merging merges, more or less

An aerial photograph of a multi-lane highway during what appears to be late afternoon or early morning. Two large, white buses with green stripes are merging from a side road into the main flow of traffic. The highway is filled with various cars, including sedans, SUVs, and a few taxis. The scene illustrates a complex traffic merging situation.

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# Tables on disk

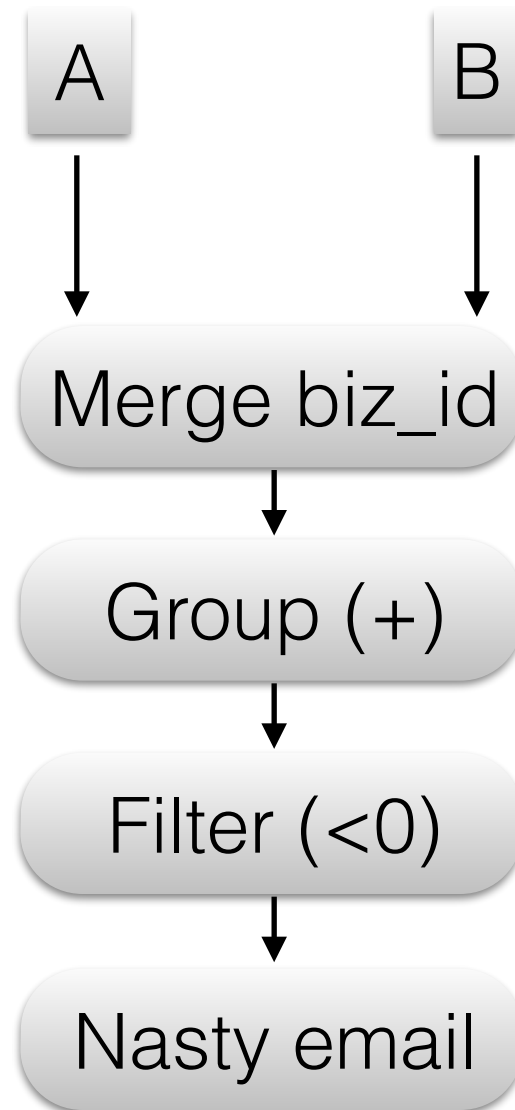
- A(ccount): { biz\_id ASC, acct\_id, amount }
- B(usiness): { biz\_id ASC, name }
- C(ar): { biz\_id ASC }

# Arrears

```
SELECT B.* FROM business B
      INNER JOIN account A
            ON B.biz_id = A.biz_id
      HAVING SUM(A.amount) < 0
      GROUP BY B.biz_id, B.name
```

# Arrears

Query plan

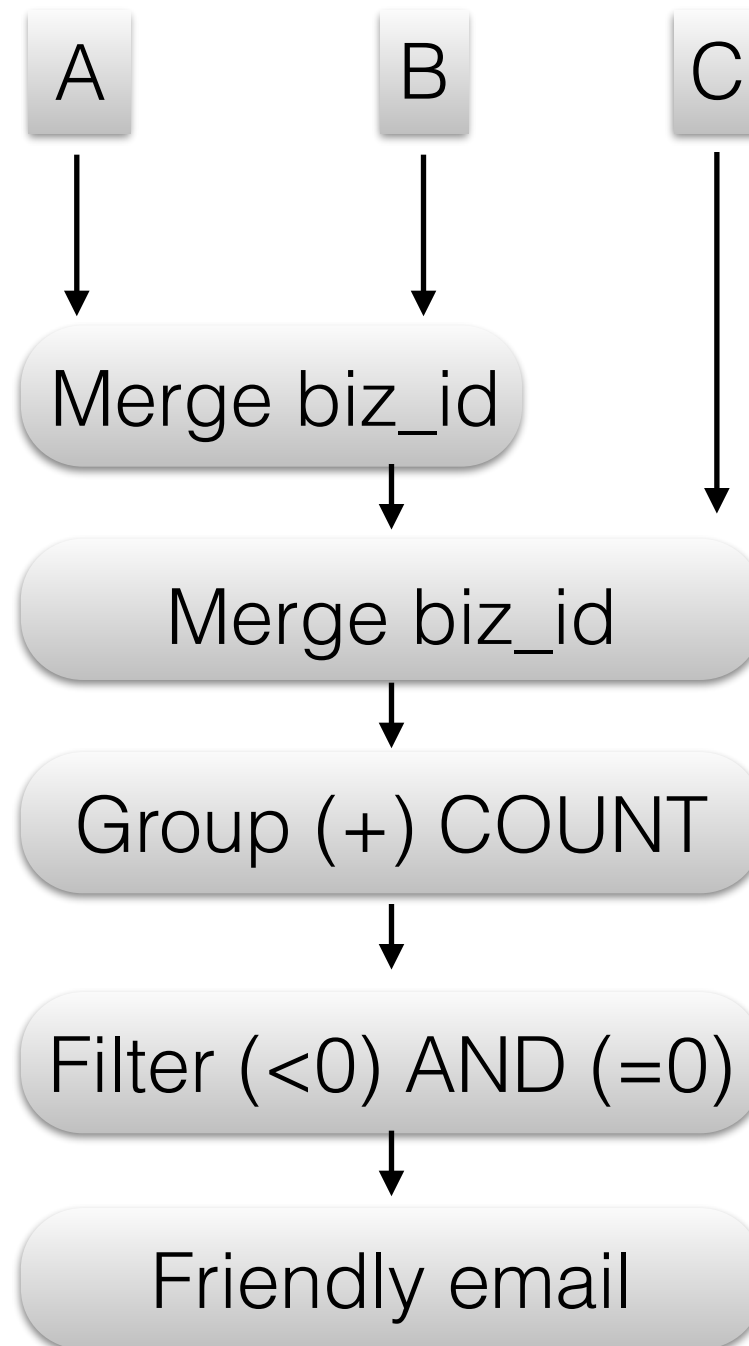


# Offer loans

```
SELECT B.* FROM business B
    INNER JOIN account A ON...
    INNER JOIN car C ON...
    HAVING SUM(A.amount) > 0
    AND COUNT(C) = 0
```

# Offer loans

Query plan







# Combinators

# Merge

	$A_k < B_k$	$A_k = B_k$	$A_k > B_k$
Move	$A \wedge \neg B$	$A \wedge B$	$\neg A \wedge B$
Output	$(A_k, A_v, B_v)$		
	$A \rightarrow \Diamond B$		$B \rightarrow \Diamond A$



# Plus-merge

	$A_k < B_k$	$A_k = B_k$	$A_k > B_k$
Move	$A \wedge \neg B$	$AB$	$\neg A \wedge B$
Output	$(A_k, A_v)$	$(A_k, A_v + B_v)$	$(B_k, B_v)$
	$A \rightarrow \Diamond B$		$B \rightarrow \Diamond A$

# Zip

True	
Move	$A \wedge B$
Output	$(A, B)$

# Append

	$ A  > 0$	$ A  = 0 \ \& \  B  > 0$
Move	$A \wedge \neg B$	$\neg A \wedge B$
Output	A	B

$$A \rightarrow \Diamond B$$

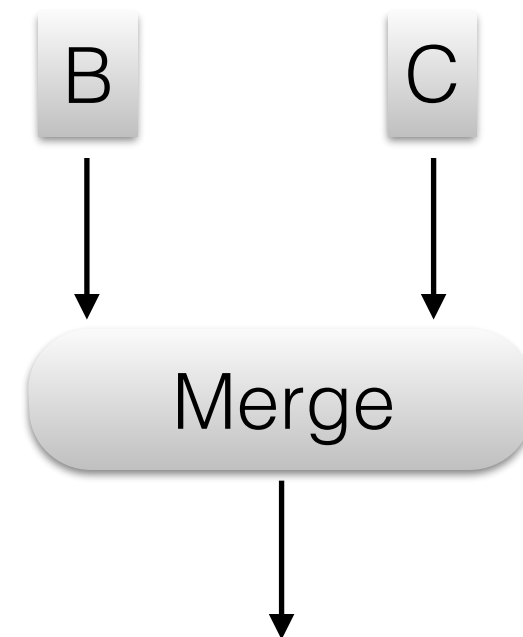
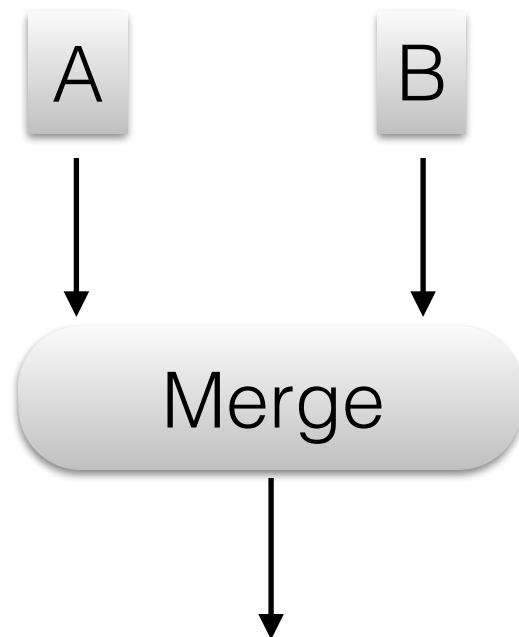




Fusion



# What can we fuse?



## Lemmas

	<b>A &lt; B</b>	<b>A = B</b>	<b>A &gt; B</b>
<b>A</b>	$\neg B$	B	$\neg A$
<b>B</b>	$\neg A$	A	B

$$A \rightarrow \Diamond B$$

$$B \rightarrow \Diamond A$$

$$B \rightarrow \Diamond C$$

$$C \rightarrow \Diamond B$$

	<b>B &lt; C</b>	<b>B = C</b>	<b>B &gt; C</b>
<b>B</b>	$\neg C$	C	$\neg B$
<b>C</b>	$\neg B$	B	C



# What can we fuse?

	$A < B$	$A = B$	$A > B$
$B < C$			
$B = C$			
$B > C$			

merge A B

	$A < B$	$A = B$	$A > B$
$A \neg B$			
$A B$			
$\neg A B$			

Lemmas

$$A \rightarrow \Diamond B$$

$$B \rightarrow \Diamond A$$

$$B \rightarrow \Diamond C$$

$$C \rightarrow \Diamond B$$

merge B C

	$B < C$	$B = C$	$B > C$
$B \neg C$			
$B C$			
$\neg B C$			

# What can we fuse?

	$A < B$	$A = B$	$A > B$
$B < C$	$A < B \wedge B < C \rightarrow (A \neg B) \wedge (B \neg C)$		
$B = C$			
$B > C$			

merge A B

	$A < B$	$A = B$	$A > B$
	$A \neg B$	$A B$	$\neg A B$

Lemmas

$$A \rightarrow \Diamond B$$

$$B \rightarrow \Diamond A$$

$$B \rightarrow \Diamond C$$

$$C \rightarrow \Diamond B$$

merge B C

$B < C$	$B \neg C$
$B = C$	$B C$
$B > C$	$\neg B C$

# What can we fuse?

	$A < B$	$A = B$	$A > B$
$B < C$	A		
$B = C$			
$B > C$			

merge A B

	$A < B$	$A = B$	$A > B$
$A \neg B$		A B	$\neg A B$

Lemmas

$$A \rightarrow \Diamond B$$

$$B \rightarrow \Diamond A$$

$$B \rightarrow \Diamond C$$

$$C \rightarrow \Diamond B$$

merge B C

	$B < C$	$B = C$	$B > C$
$B \neg C$		B C	$\neg B C$

# What can we fuse?

	$A < B$	$A = B$	$A > B$
$B < C$	$A$	$A=B \wedge B < C \rightarrow (AB) \wedge (B \neg C)$	
$B = C$			
$B > C$			

merge A B

	$A < B$	$A = B$	$A > B$
$A \neg B$		$AB$	$\neg AB$

Lemmas

$$A \rightarrow \Diamond B$$

$$B \rightarrow \Diamond A$$

$$B \rightarrow \Diamond C$$

$$C \rightarrow \Diamond B$$

merge B C

	$B < C$	$B = C$	$B > C$
$B \neg C$		$BC$	$\neg BC$

# What can we fuse?

	$A < B$	$A = B$	$A > B$
$B < C$	A	AB	B
$B = C$	A	ABC	BC
$B > C$	AC	C	C

merge A B

$A < B$	$A = B$	$A > B$
$A \neg B$	$A B$	$\neg A B$

Lemmas

$$A \rightarrow \Diamond B$$

$$B \rightarrow \Diamond A$$

$$B \rightarrow \Diamond C$$

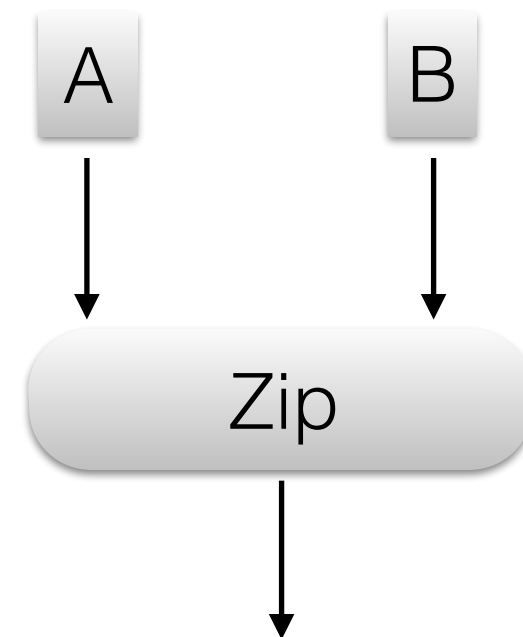
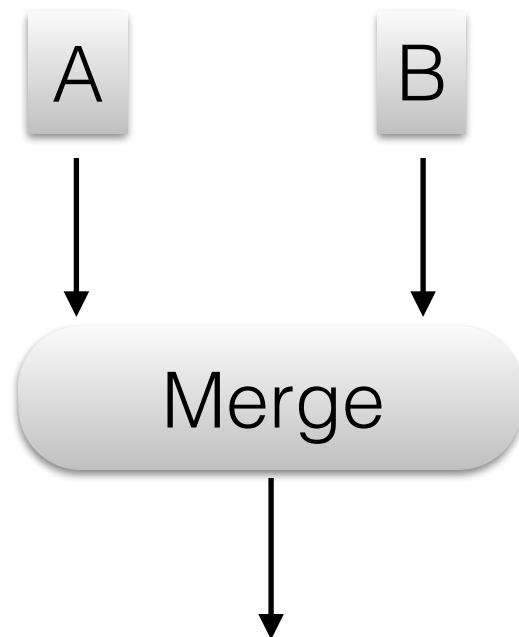
$$C \rightarrow \Diamond B$$

merge B C

$B < C$	$B = C$	$B > C$
$B \neg C$	$B C$	$\neg B C$



# What *can't* we fuse?



Lemmas

$A \rightarrow \Diamond B$

$B \rightarrow \Diamond A$

$A < B$ $A = B$ $A > B$		
A	AB	B

True	AB

# What *can't* we fuse?

	$A < B$	$A = B$	$A > B$
True	$A < B \Rightarrow (A \neg B) \wedge (AB)$		

merge A B

	$A < B$	$A = B$	$A > B$
	A	AB	B

Lemmas

$$A \rightarrow \Diamond B$$

$$B \rightarrow \Diamond A$$

zip A B

True	AB

# What *can't* we fuse?

	$A < B$	$A = B$	$A > B$
True	$B \wedge \neg B$		

merge A B

	$A < B$	$A = B$	$A > B$
	A	AB	B

Lemmas

$A \rightarrow \Diamond B$

$B \rightarrow \Diamond A$

zip A B

True	AB

# Thanks

*I'd love to know about related work*