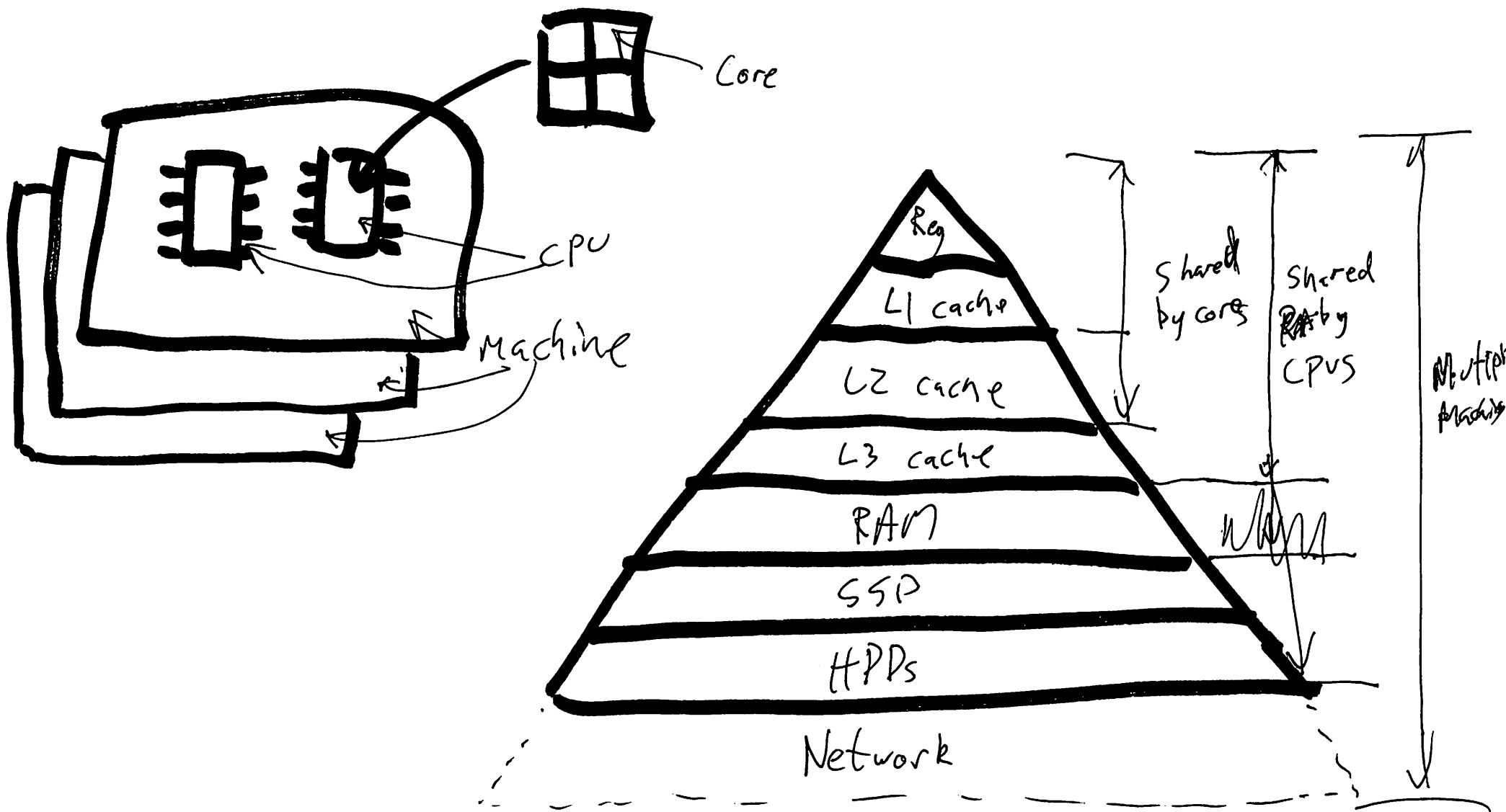
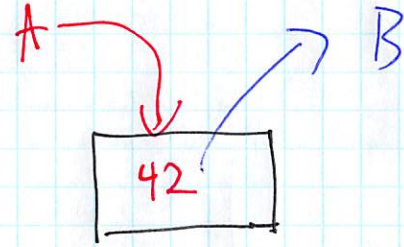


Parallel  
Queries



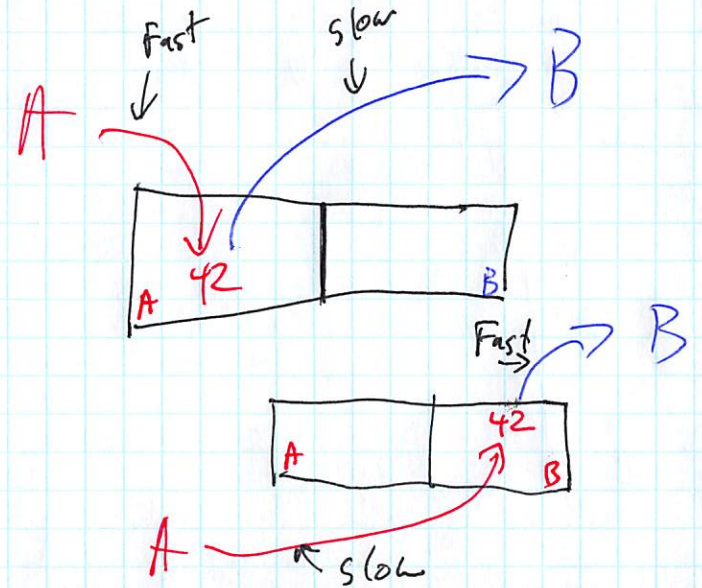
# Easy Automation Shared Memory

- RAM
- Cache
- Shared Fileserver



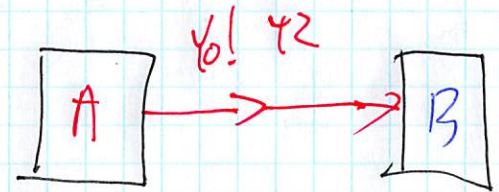
# NUMA

- AMP RAM
- Filesystems



# Message Passing

- Bus (motherboard)
- Network
- CPU interconnect



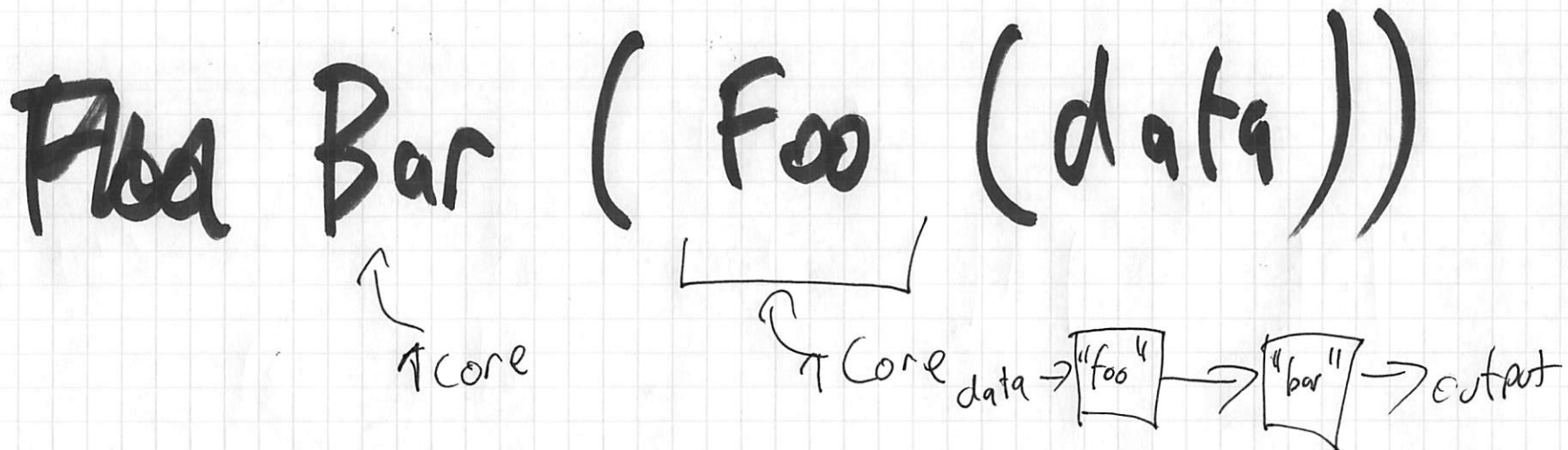
Hard Control

(Shared Nothing)

$v = \text{Foo}(\text{data})$   
 $\text{Bar}(\overset{v}{\text{data}})$

$\text{Foo} = 0$       $\text{TT}$   
 $\text{Bar} = \text{TT}$       $\downarrow$   
 $\text{data} = R$       $0$   
                          $\downarrow$   
                          $R$

$\text{Foo}(\text{data}) \equiv \text{Foo}(\text{data}_1) \oplus \text{Foo}(\text{data}_2)$



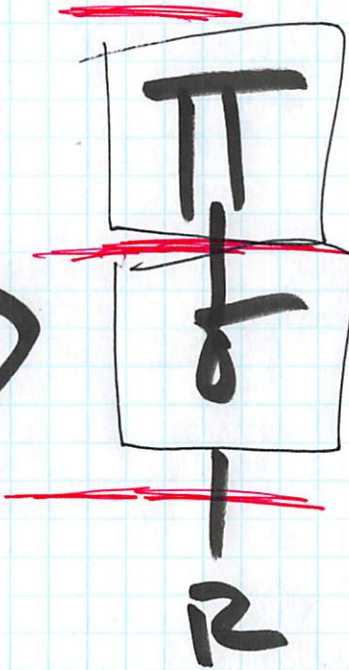
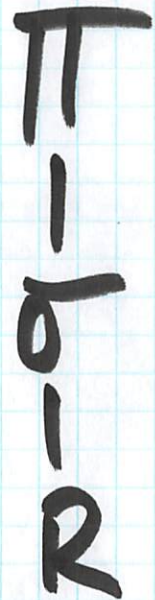


Bar(Foo(data,))

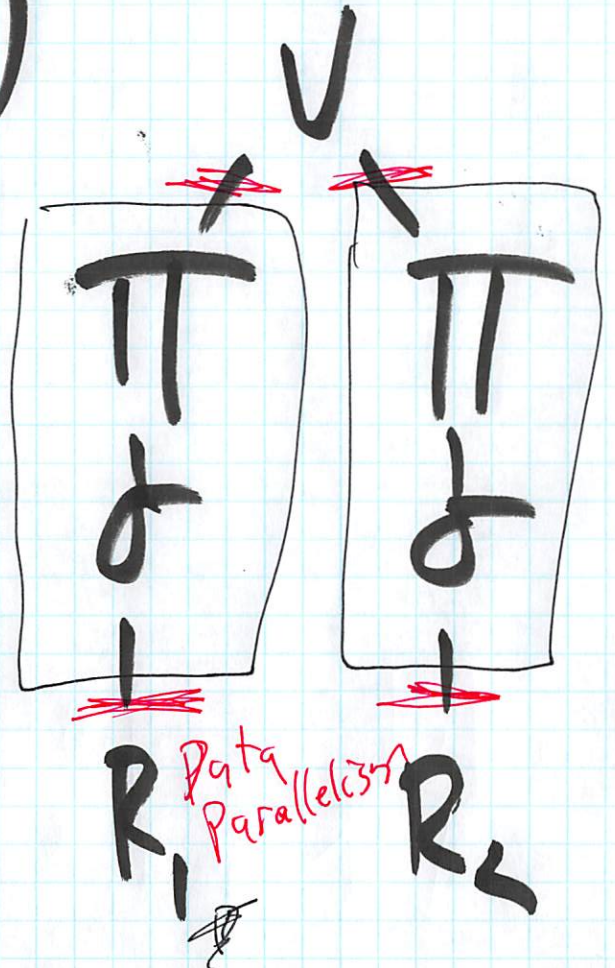
⊕

Bar(Foo(data<sub>2</sub>))

Bar



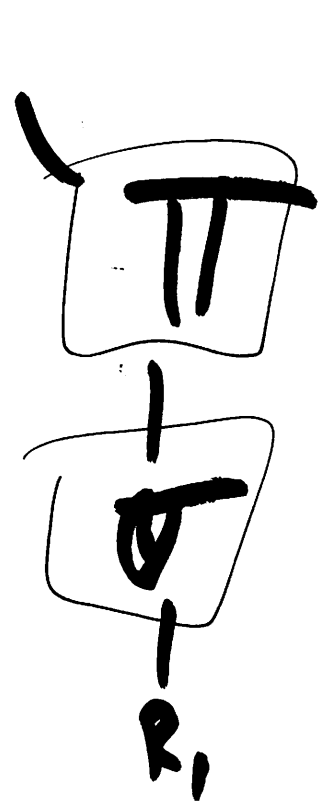
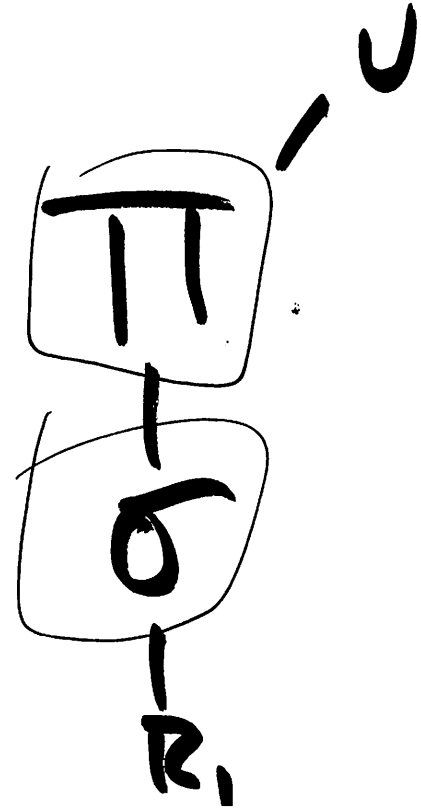
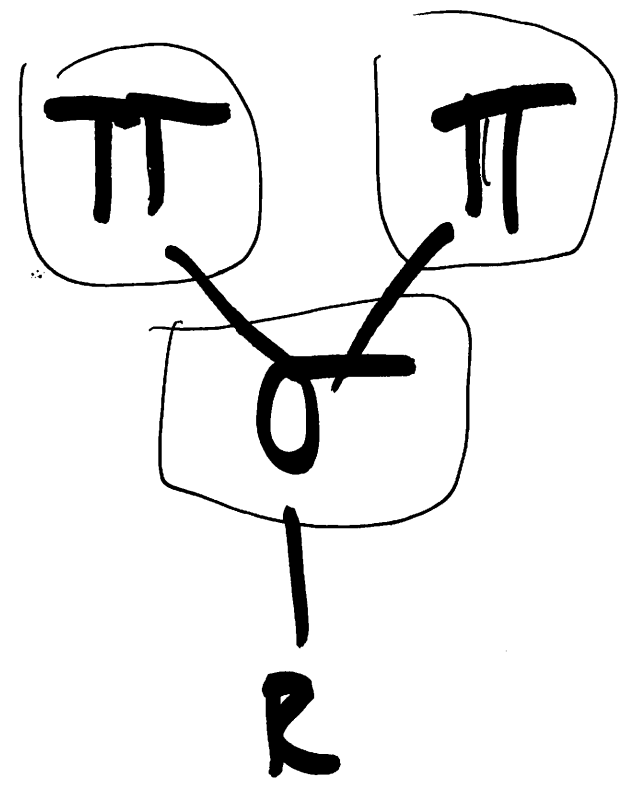
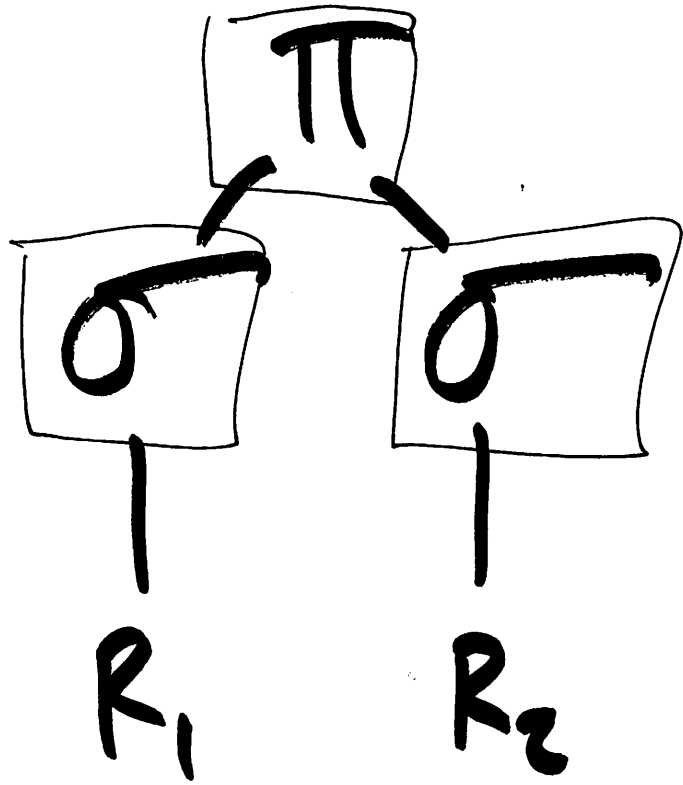
Pipeline Parallelism



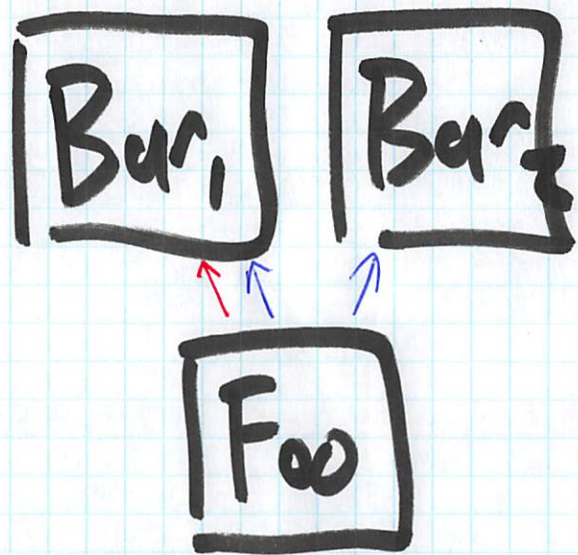
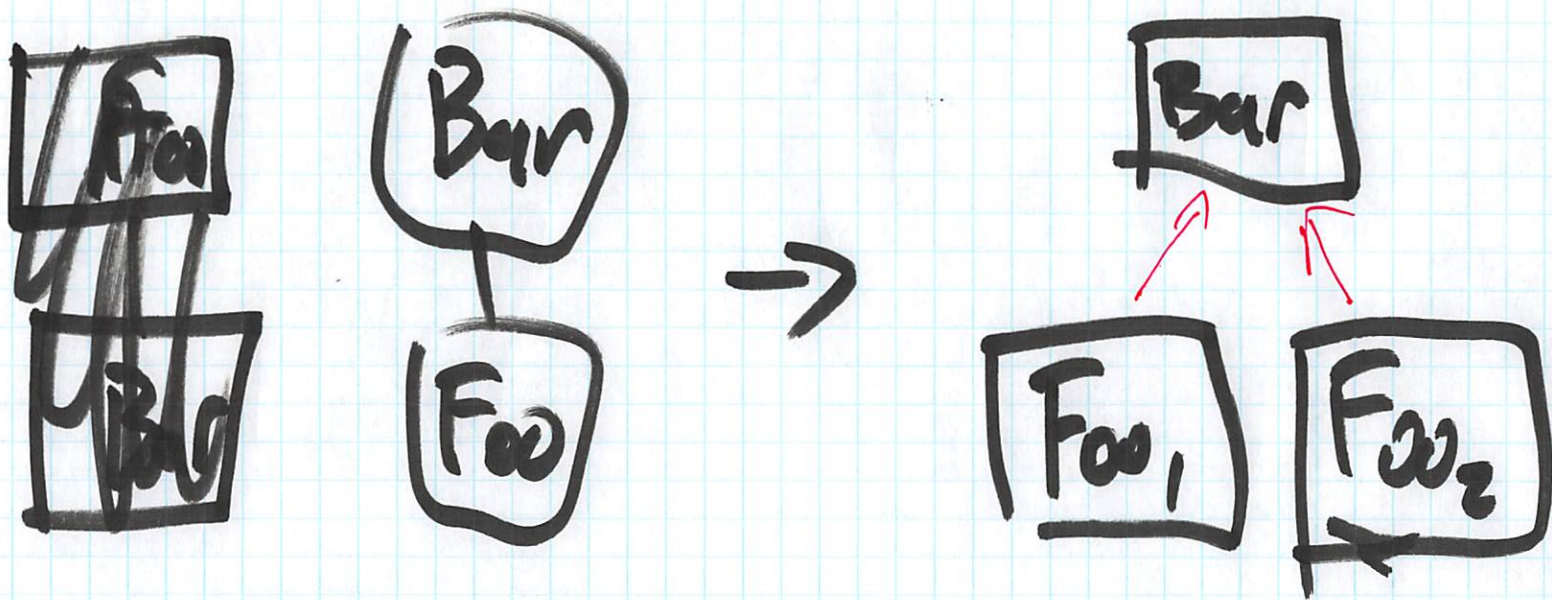
Data Parallelism

R<sub>1</sub>

R<sub>2</sub>





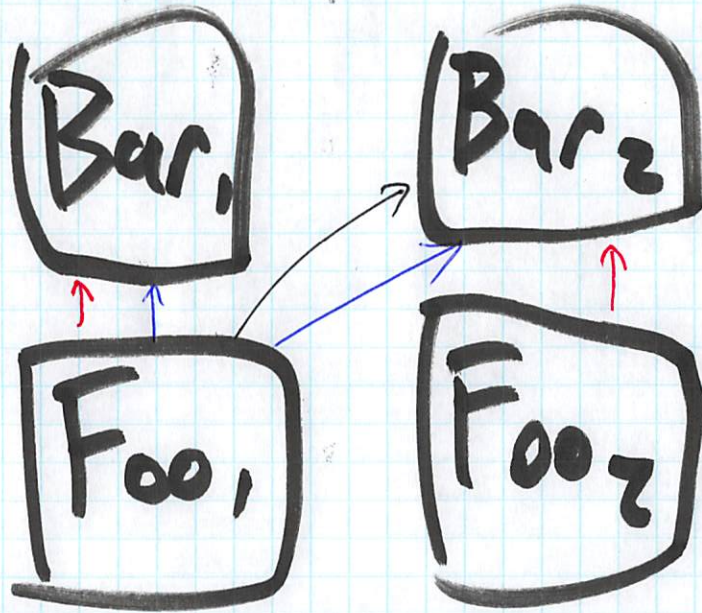


↑ Possibility 1  
each output "unit"  
goes to a different bar

↑ Possibility 2  
each unit copied  
to all bars



each "unit"

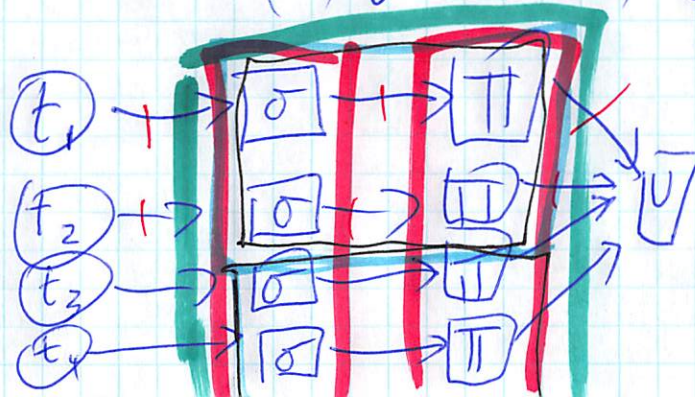


- 1) Goes to random Bar
- 2) Goes to specific Bar
- 3) Goes to all Bars

R	A	B
1	2	$t_1$
3	4	$t_2$
5	6	$t_3$
7	8	$t_4$

$$\Pi(t_1) \cup \Pi(t_2) \equiv \Pi(t_1 \cup t_2)$$

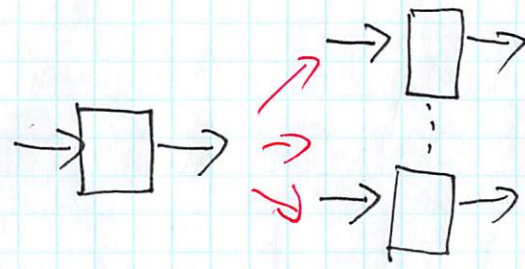
~~$$\sigma \Pi \sigma(t_1) \cup \Pi \sigma(t_2) \cup \Pi \sigma(t_3) \cup \Pi \sigma(t_4)$$~~





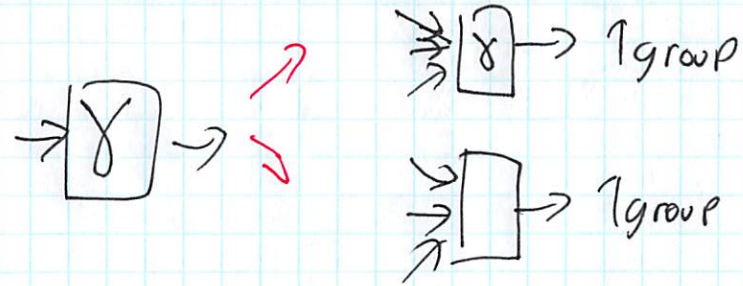
$\sigma$   $\pi$   $\cup$

Unit of computation:  
↑ tuple



$\gamma$

Unit of computation:  
Group  
" + "



$\times$   ~~$\times$~~

Unit of computation:  
tuple<sup>2</sup>



**R/A**

1  
2  
3  
4

**S/B**

1  
2  
3  
4

All R tuples  
S tuples  $\in \{1, 2\}$

All R tuples  
S tuples  $\in \{3, 4\}$

R

	1	2	3	4
1	$\langle 1, 1 \rangle$	$\langle 1, 2 \rangle$	-	-
2	$\langle 2, 1 \rangle$			
3	$\langle 3, 4 \rangle$			
4				

All of R  
All of S



	1	2	3	4
1	█	X	X	X
2	X	█	X	X
3	X	X	█	X
4	X	X	X	█

	[1 2]	[3 4]
1	█	█ X
2	█	█ X
3	X	█
4	X	█

	1 2	3 4
1	█	X
2	█	█
3	█	█
4	█	█

S.B < R.A