Parallel Queries
Easy Automation

**Shared Memory**
- RAM
- Cache
- Shared Fileserver

**NUMA**
- AMD RAM
- Filesystems

**Message Passing**
- Bus (motherboard)
- Network
- CPU interconnect

(Shared Nothing)
\[
\begin{align*}
  v &= \text{Foo}(\text{data}) \\
  \text{Bar}(\text{data}) &= \text{Foo}(\text{data}) \\
  \text{Foo}(\text{data}) &= \text{Foo}(\text{data}_1) \oplus \text{Foo}(\text{data}_2) \\
  \text{Pluck Bar}(\text{Foo}(\text{data})) \\
  \text{Core data} &\rightarrow \text{"foo"} & \text{"bar"} &\rightarrow \text{output}
\end{align*}
\]
\[ \text{Bar}(\text{Foo}(\text{data},)) \]

\[ \cong \]

\[ \text{Bar}(\text{Foo}(\text{data}_2)) \]

\[ \text{Bar} \]

\[ \begin{array}{ccc}
    \pi_0 & \to & \pi_1 \\
    \text{R} & & \text{R}
\end{array} \]

\[ \bigcup \]

\[ \begin{array}{ccc}
    \pi_0 & \to & \pi_1 \\
    \text{R} & & \text{R}
\end{array} \]

\[ \text{Data Parallelism} \]

\[ \text{Pipeline Parallelism} \]
- 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

\[ \Pi(t_1) \cup \Pi(t_2) = \Pi(t_1 \cup t_2) \]
\[ \sigma(t_3) \cup \Pi(t_2) \cup \Pi(t_3) \cup \Pi(t_4) \]
Unit of computation: 1 tuple

Unit of computation: Group "+1"

Unit of computation: tuple²
All R tuples such that R is in R → S

All R tuples such that R in R ⊆ S → ε

All sets of S in R → ε

All sets of R in R → ε

All sets of R → ε

All sets of R → ε