Architectural design: the coordination perspective

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Reo

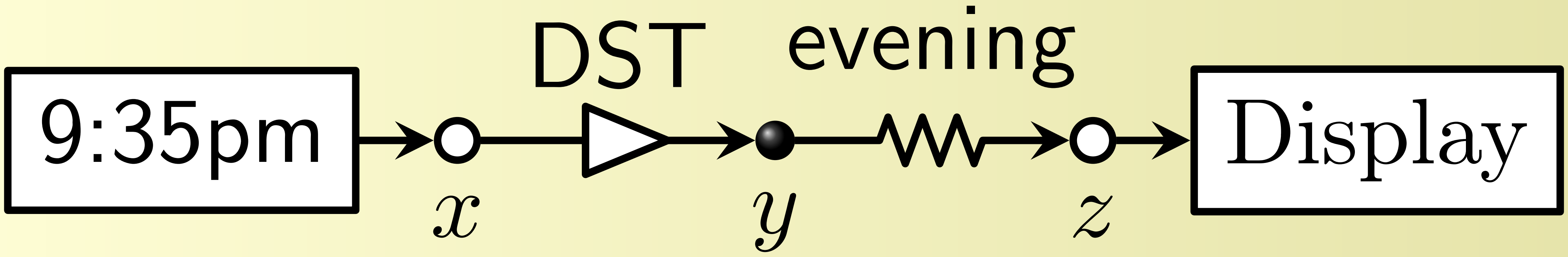
Outline

1. Visual semantics for Reo
   - Connector colouring (CC)[1]
2. Locality (concurrency)
   - partial connector colouring (PCC)[2]
3. Constraints
   - SAT solving with data for Reo[3]

[1] Dave Clarke, David Costa, and Farhad Arbab. Connector colouring I: Synchronisation and context dependency

[2] Dave Clarke and José Proença. Partial connector colouring

[3] Dave Clarke, José Proença, Alexander Lazovik, and Farhad Arbab, Channel-based coordination via constraint satisfaction
José Proença, Dave Clarke, Interactive interaction constraints

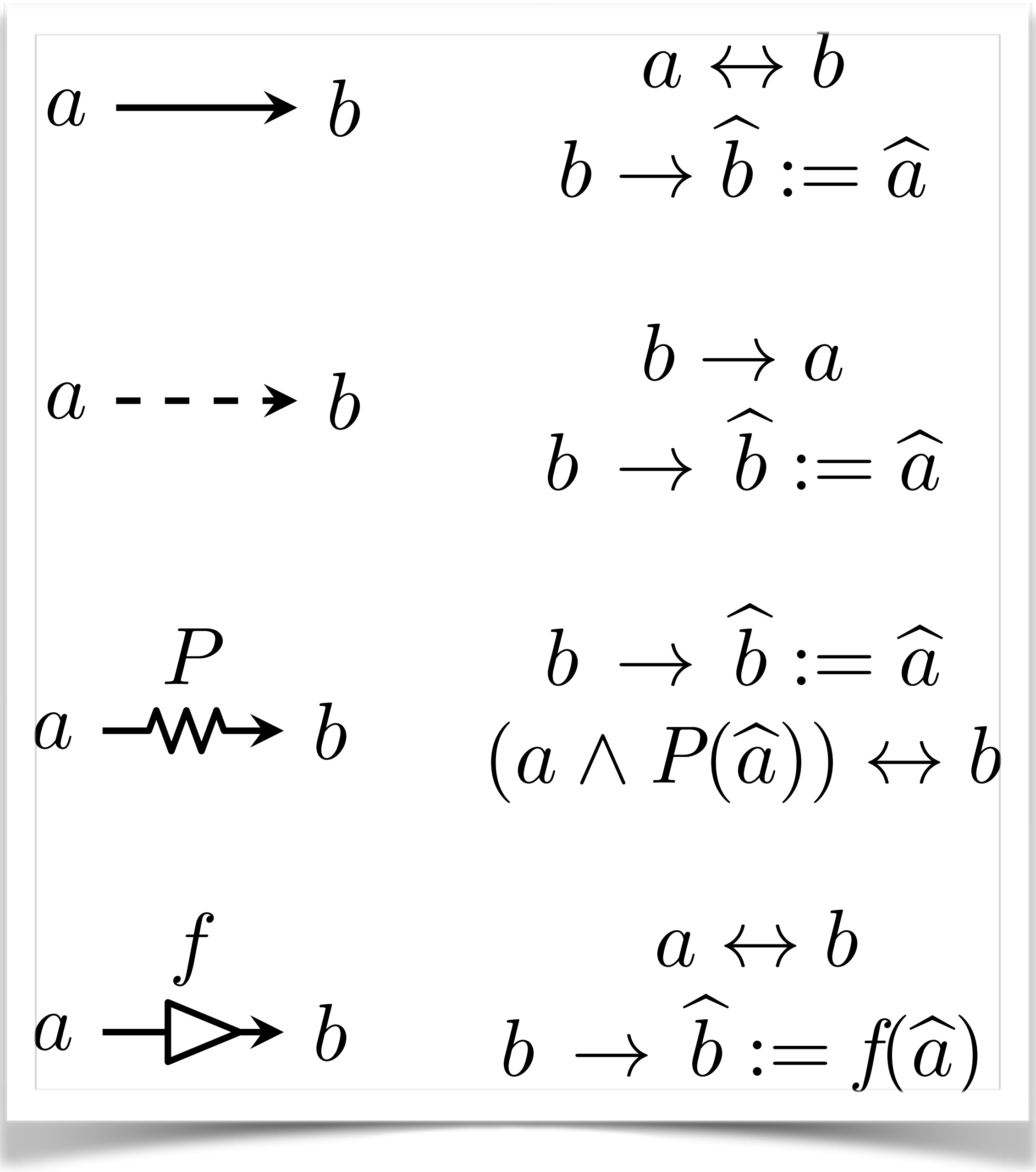


$x \to \widehat{x} := \text{9:35pm}$ $\quad$ $x \leftrightarrow y$ $\quad$ $y \to \widehat{y} := \text{DST}(\widehat{x})$

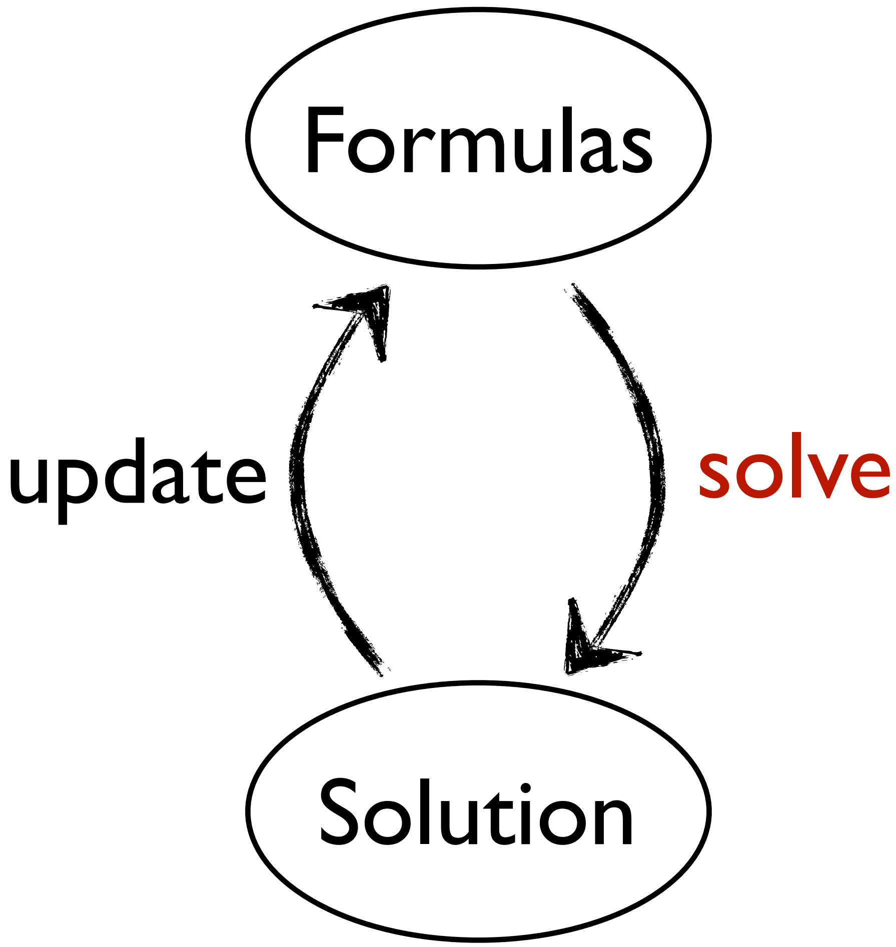
$(y \wedge \text{evening}(\widehat{y})) \leftrightarrow z$ $\quad$ $z \to \widehat{z} := \widehat{y}$

Reo as (Interactive) Constraints

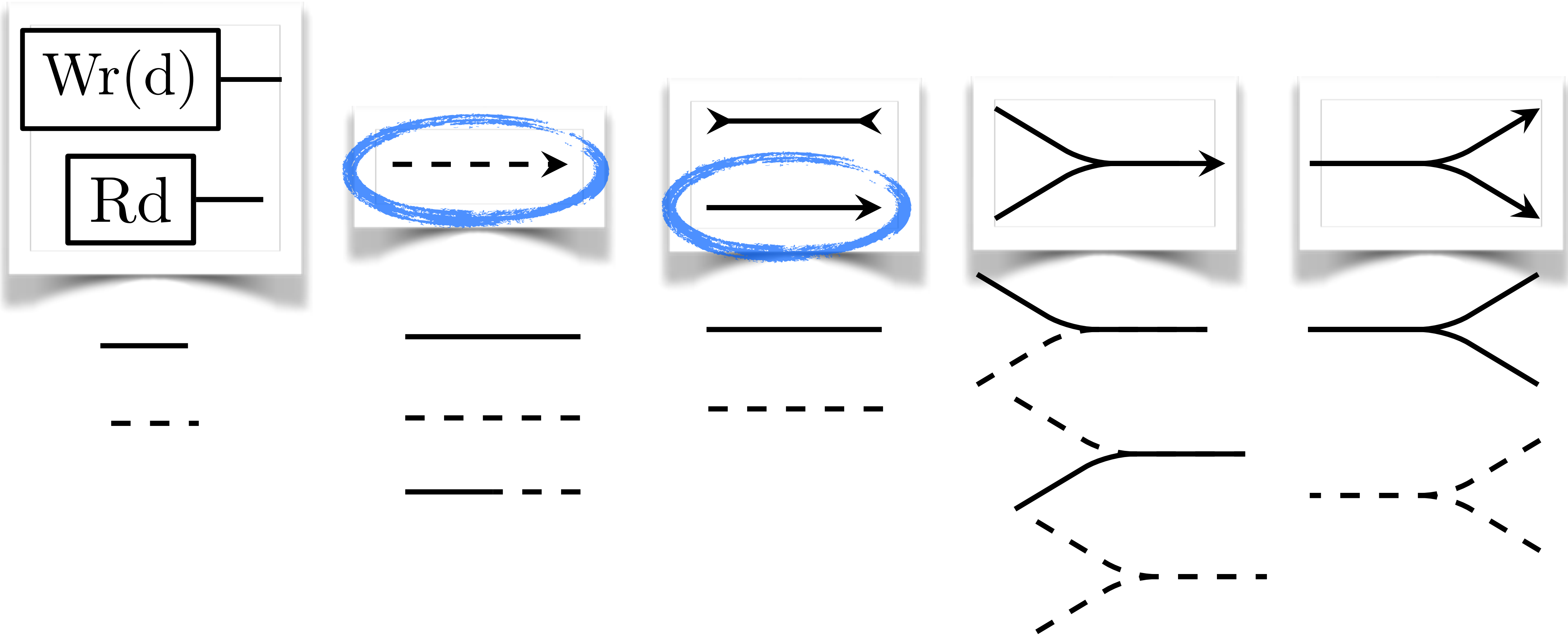
Coordination as constraint satisfaction



$a \longrightarrow b$	$a \leftrightarrow b$ $b \rightarrow \widehat{b} := \widehat{a}$
$a \dashrightarrow b$	$b \rightarrow a$ $b \rightarrow \widehat{b} := \widehat{a}$
$a \overset{P}{\rightsquigarrow} b$	$b \rightarrow \widehat{b} := \widehat{a}$ $(a \wedge P(\widehat{a})) \leftrightarrow b$
$a \overset{f}{\rhd} b$	$a \leftrightarrow b$ $b \rightarrow \widehat{b} := f(\widehat{a})$



Exercise: write constraints



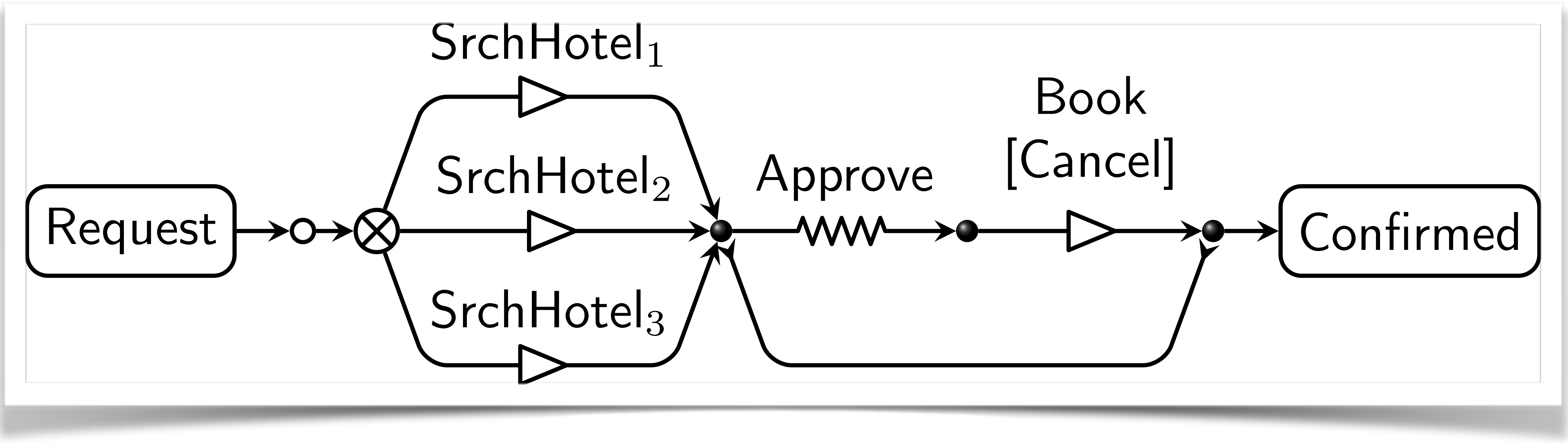
Building up constraints

- Connector colouring as constraints
- Data constraints
- Interactive constraints

Context

(need for extra interaction)

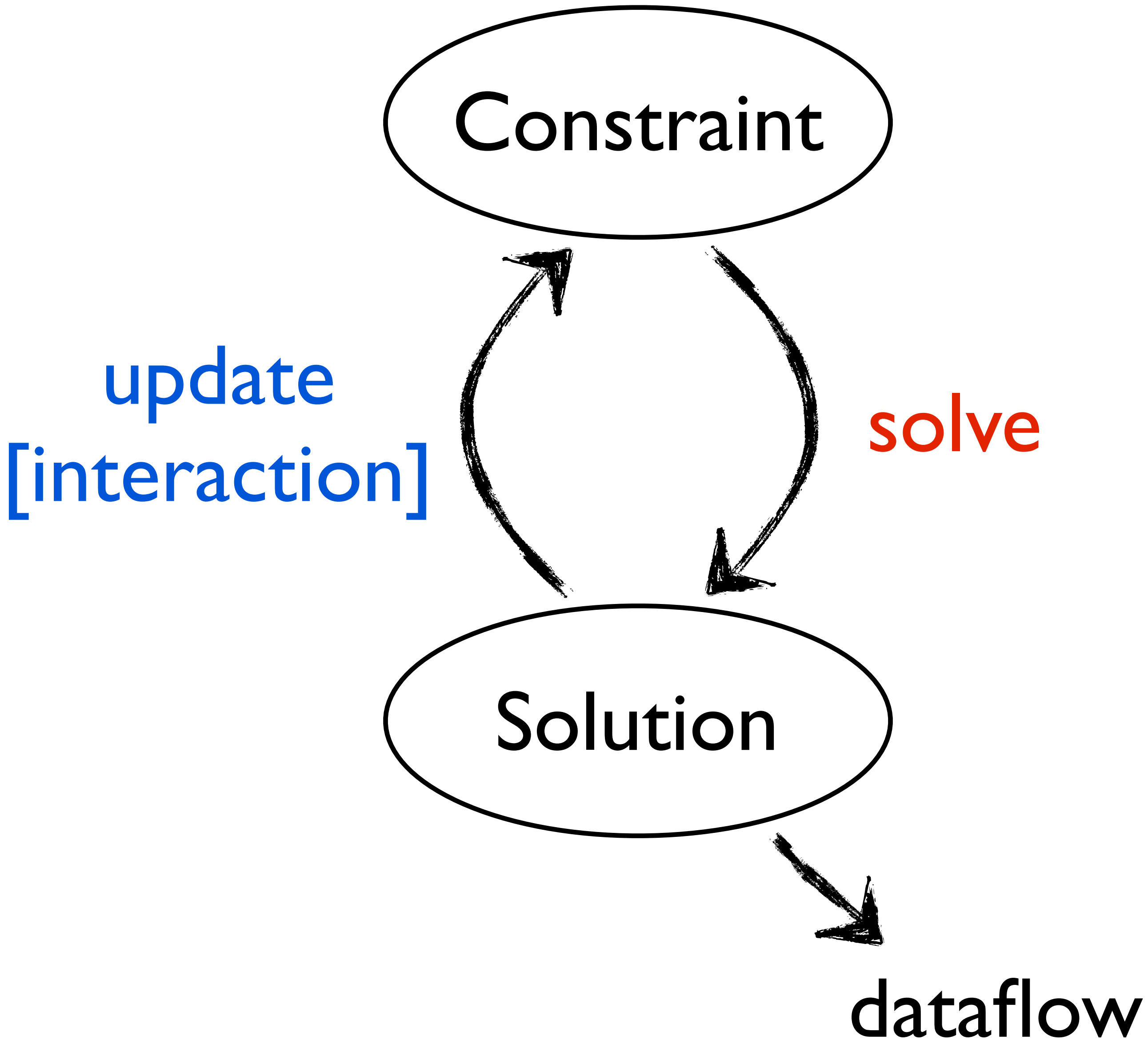
Hotel booking



- Interaction with hotel repositories
- Interaction with users
- Interaction with hotels (availability & payment)

Problem of Interaction

Coordination as constraint satisfaction



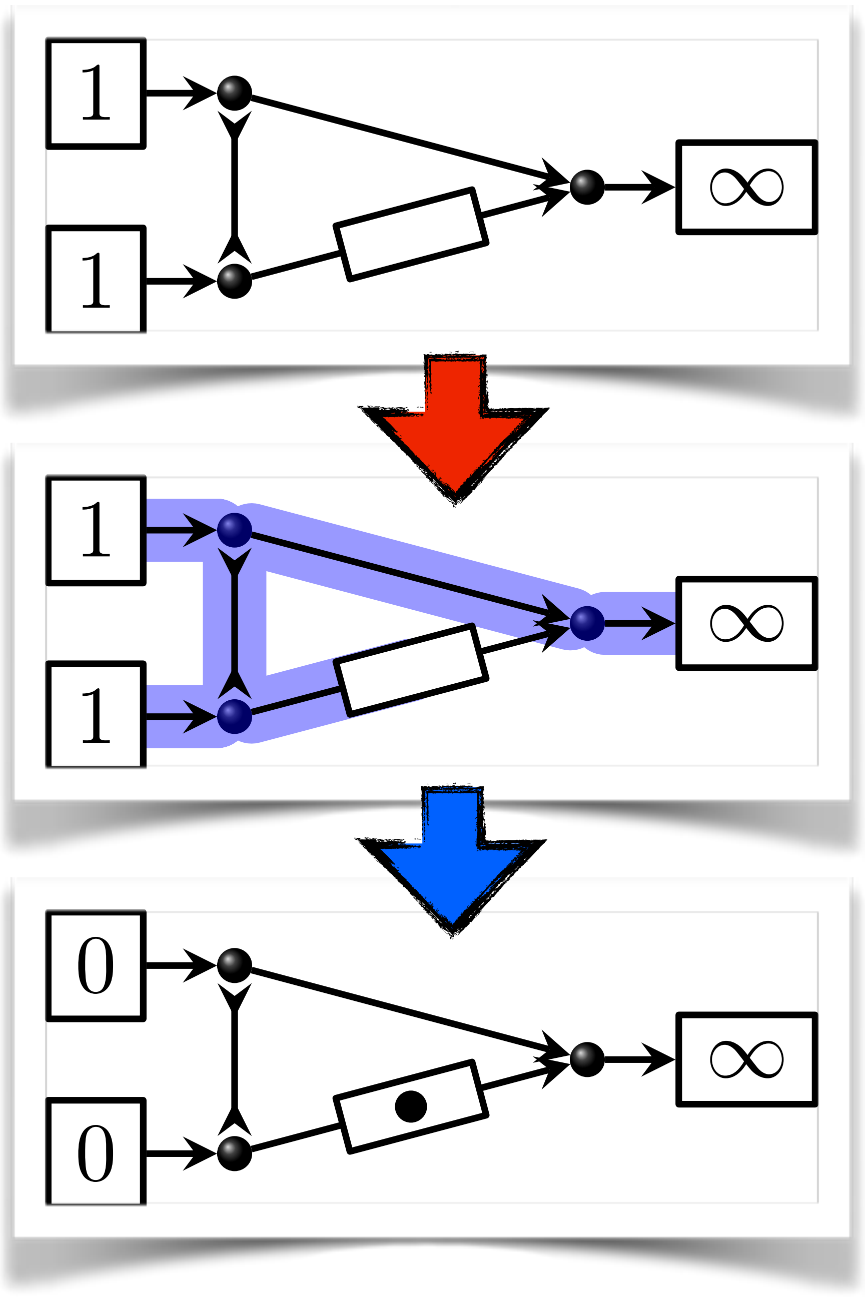
Constraint

solve

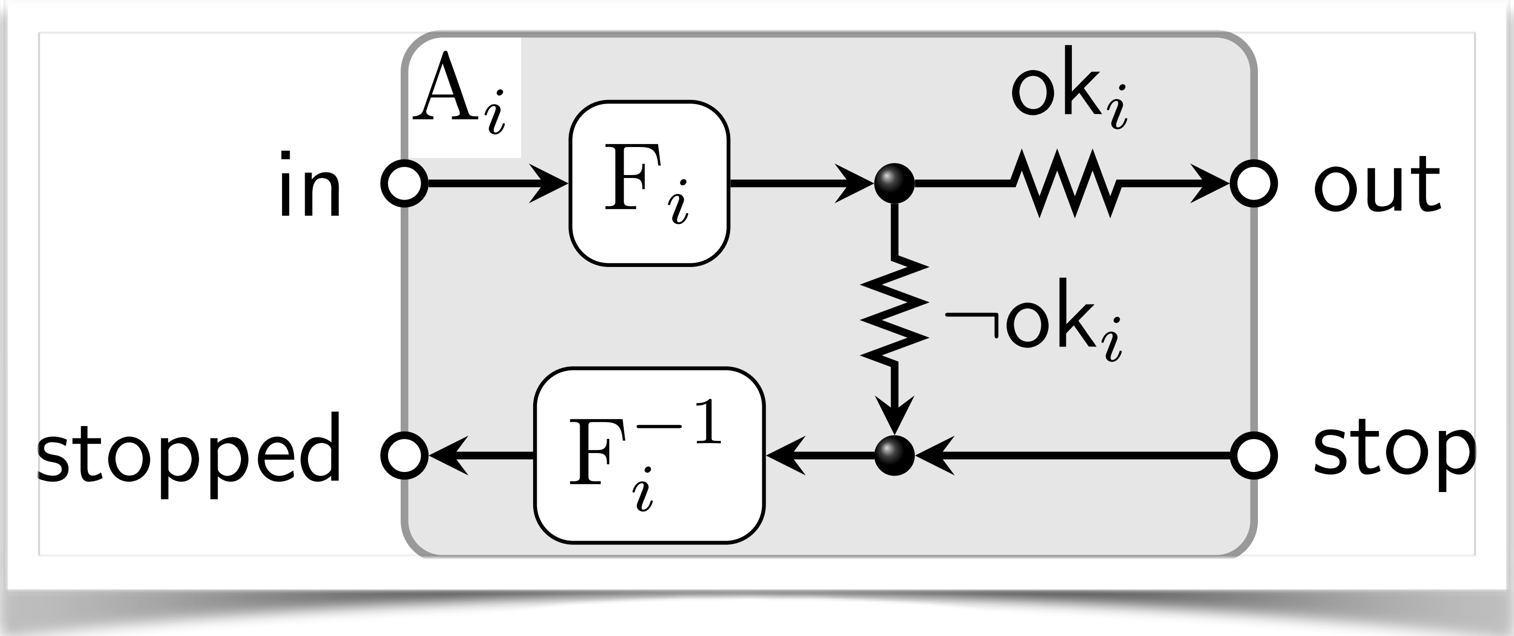
Solution

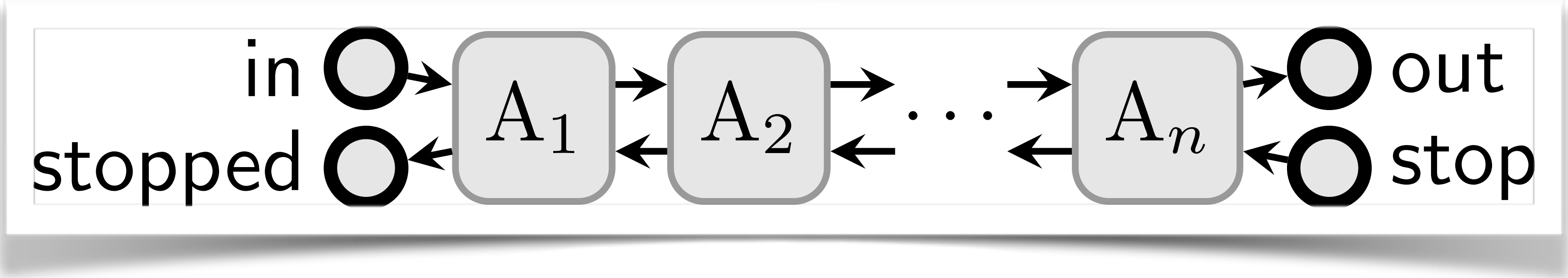
update
[interaction]

dataflow

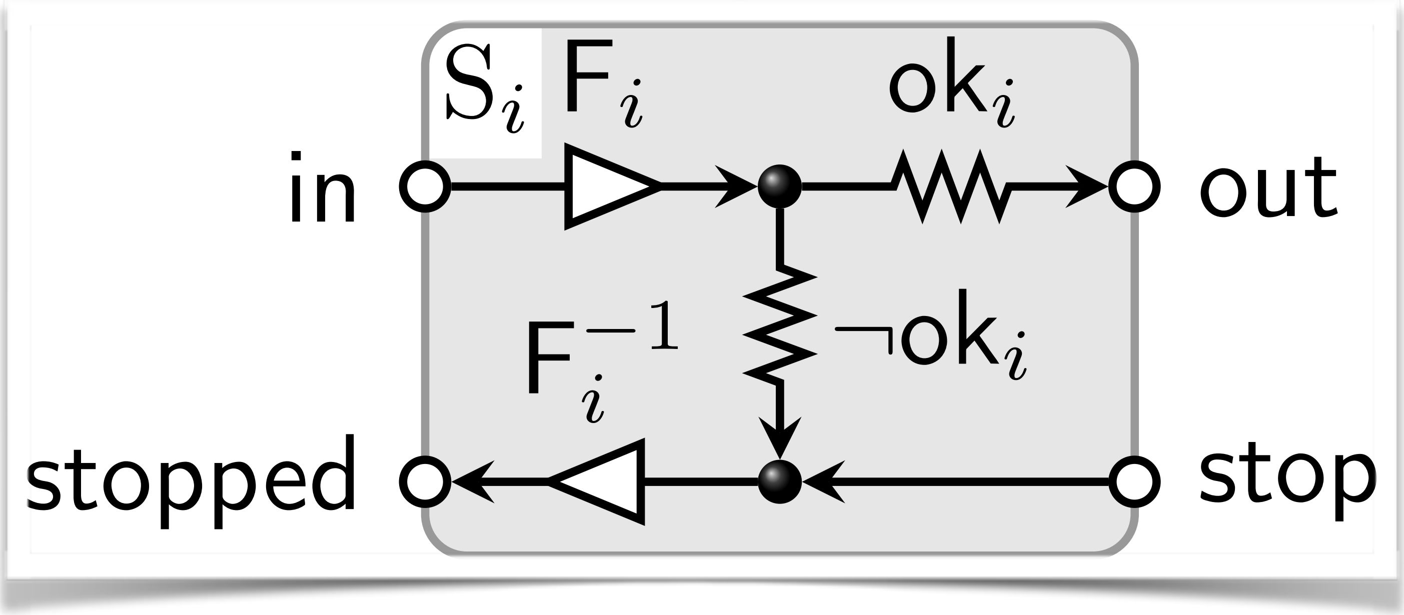


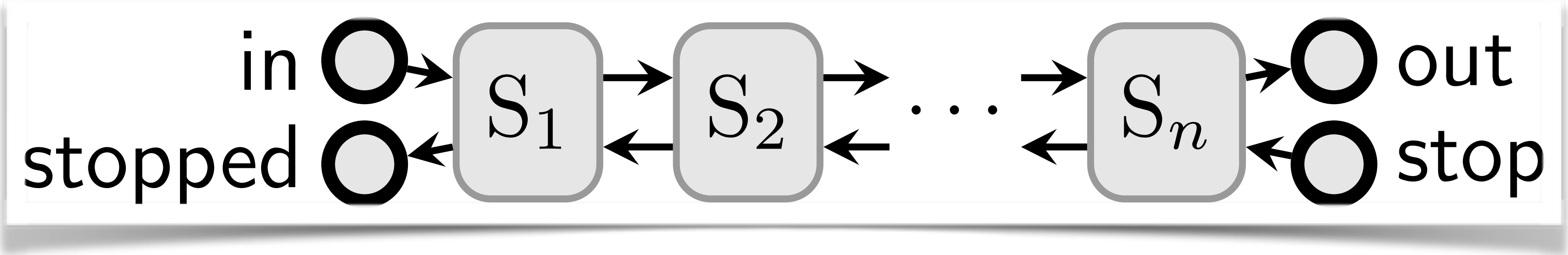
Asynchronous transactions





Synchronous transactions





Problem

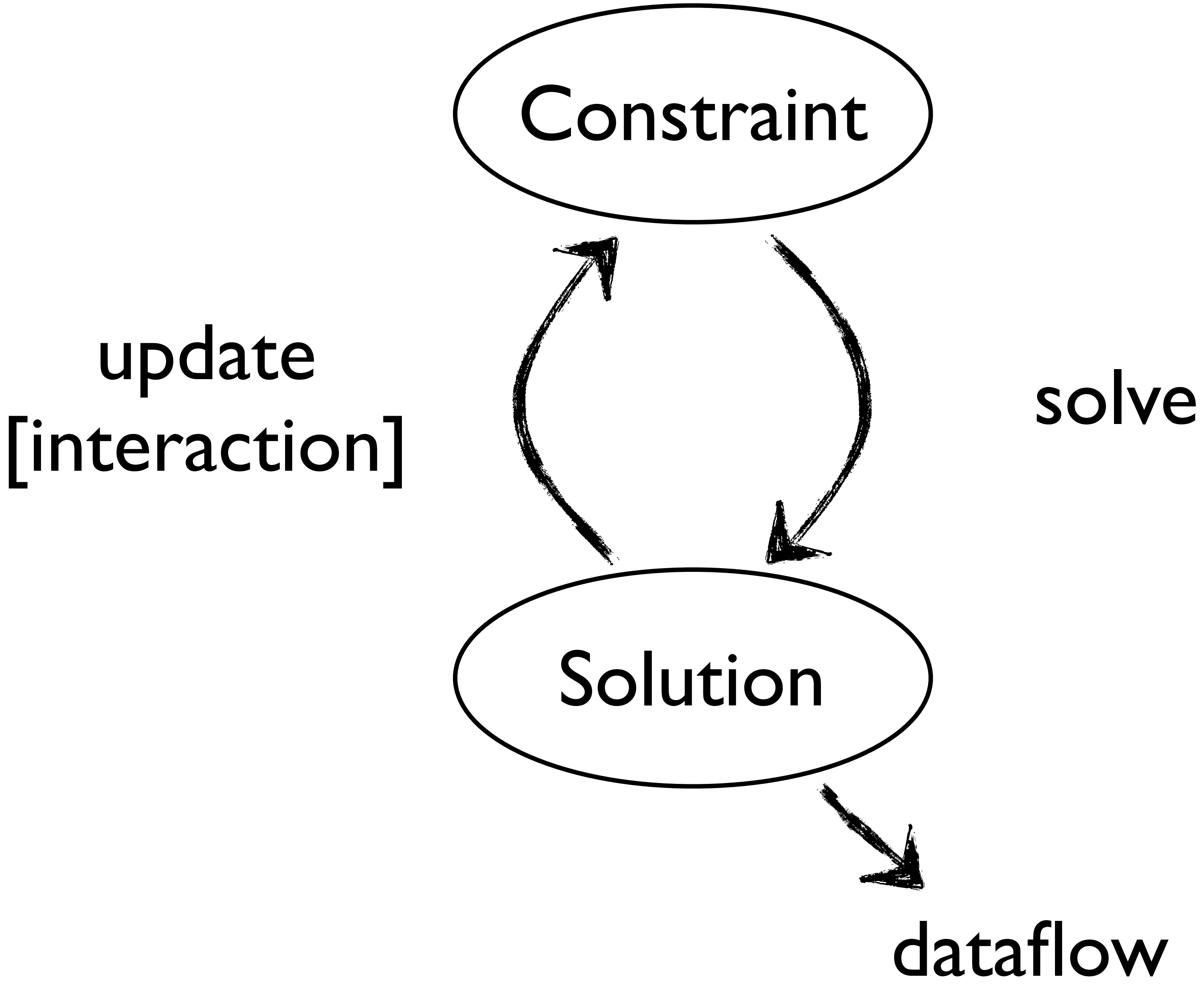
Interaction or Synchrony

but not both

Solution

Interactive Interaction Constraints

Coordination as constraint satisfaction



Constraint

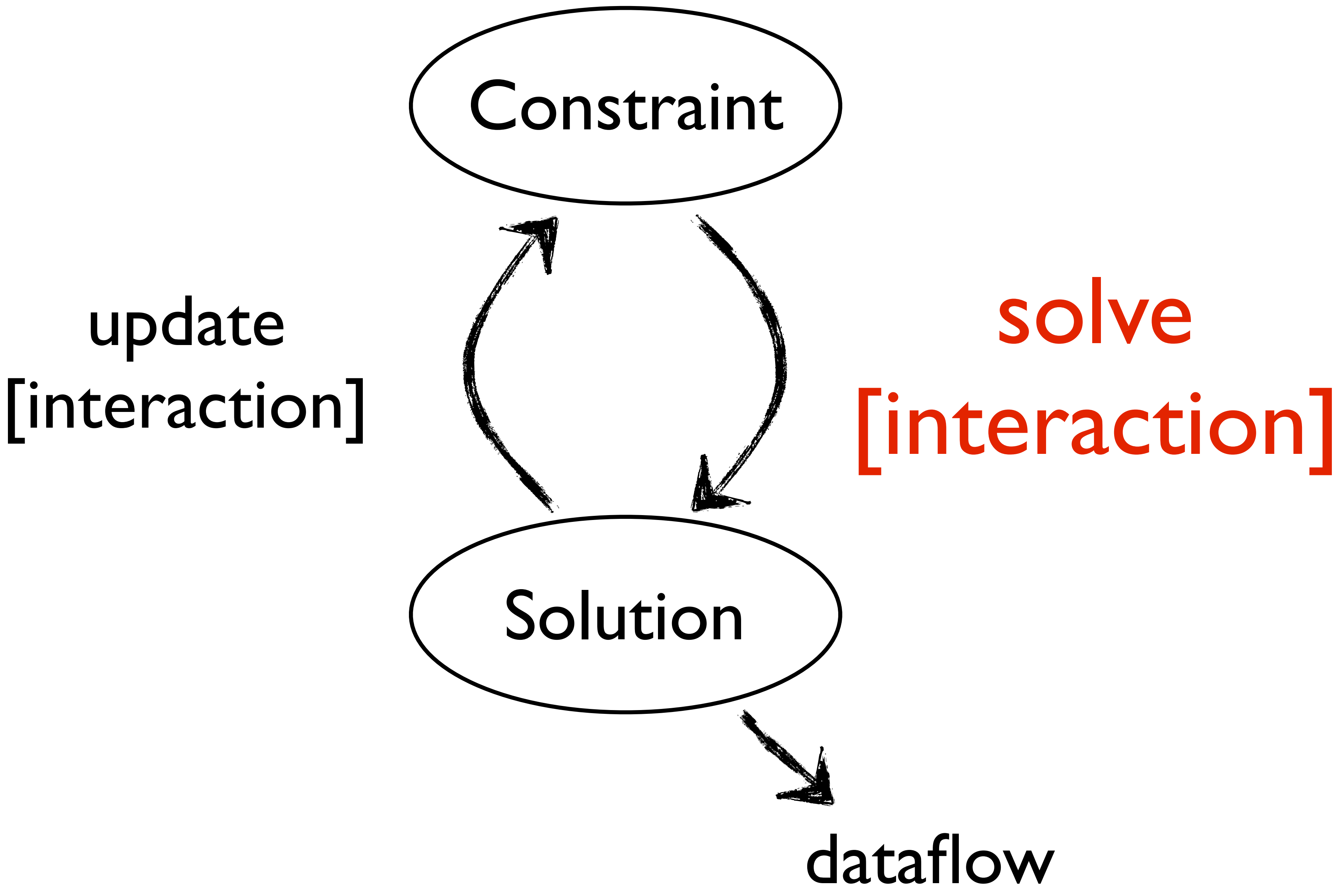
update
[interaction]

solve

Solution

dataflow

Coordination as interactive constraint satisfaction



Constraint

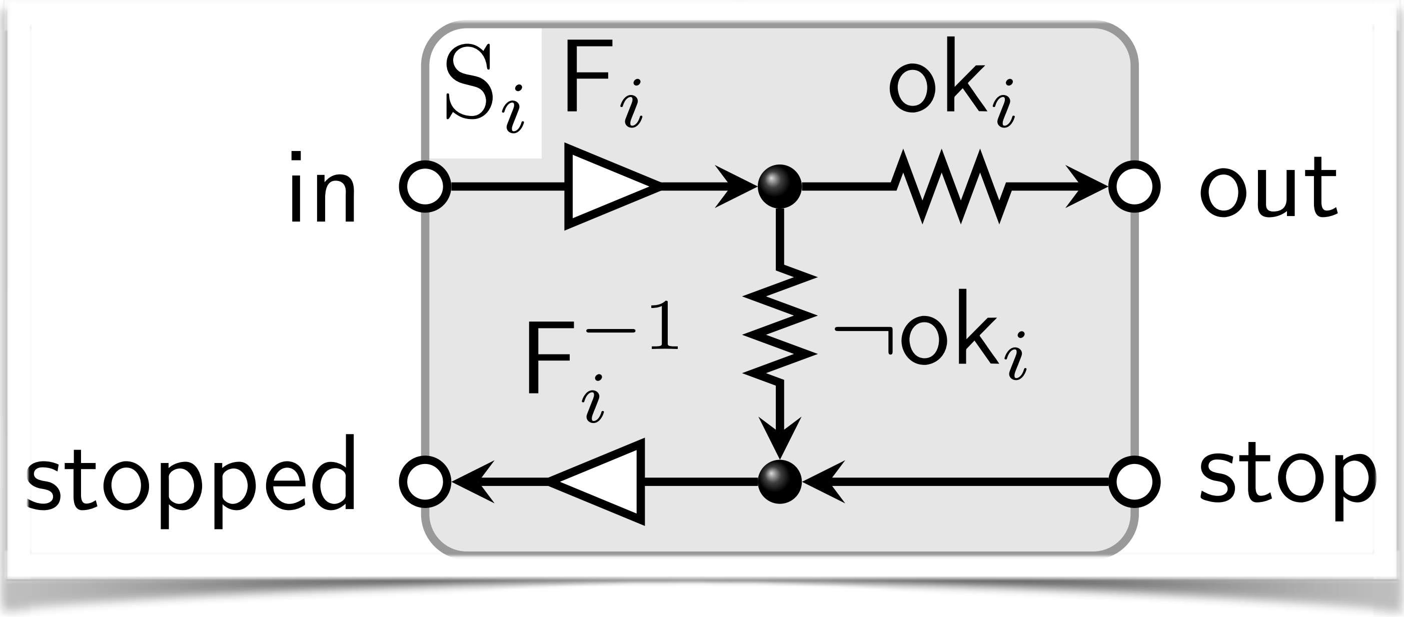
update [interaction]

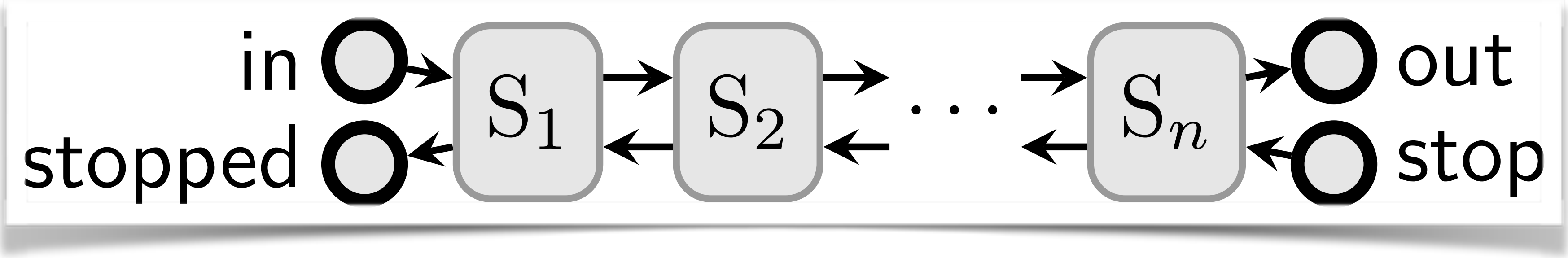
solve [interaction]

Solution

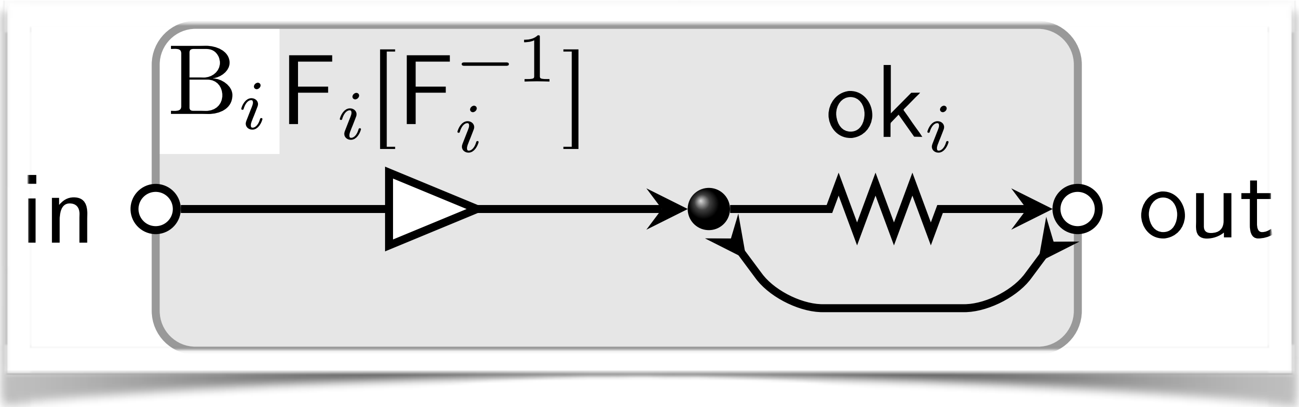
dataflow

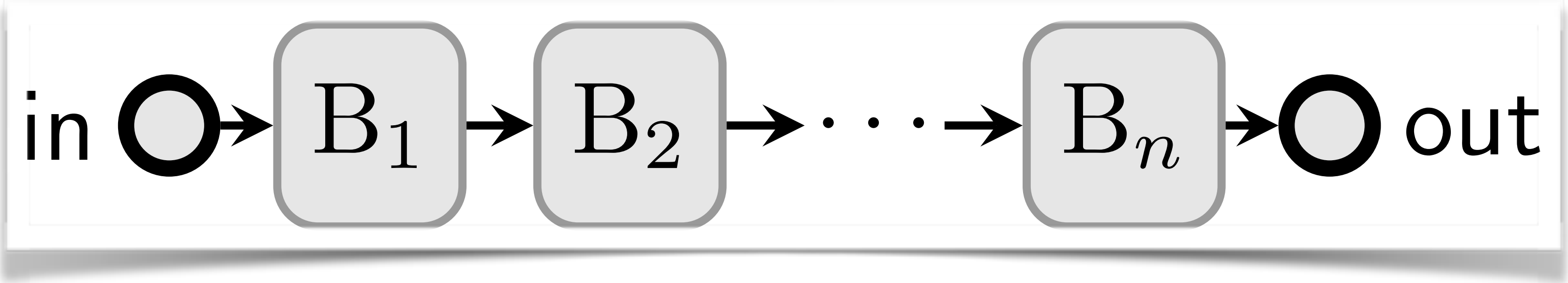
Synchronous transactions



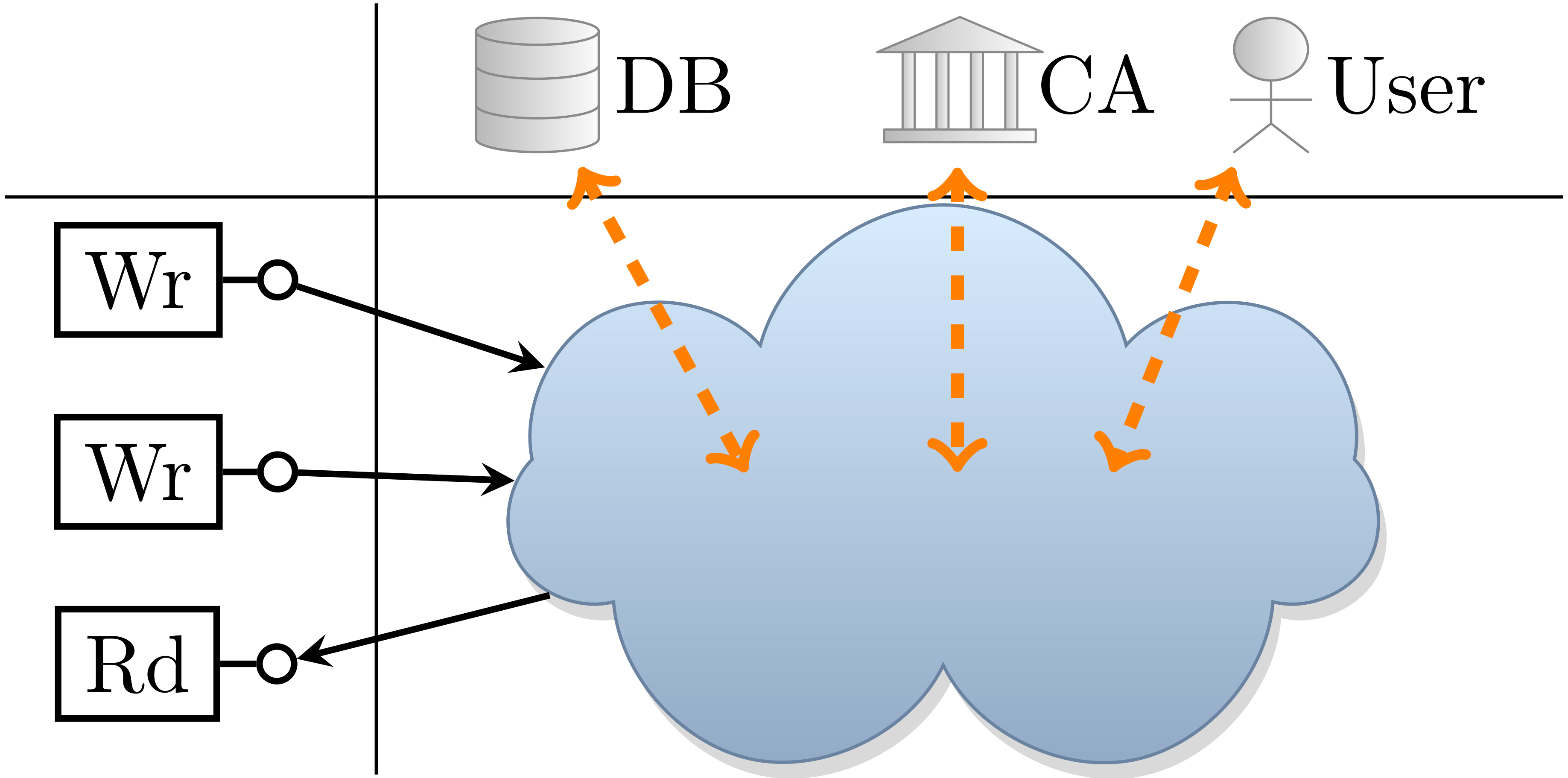


Synchronous transactions

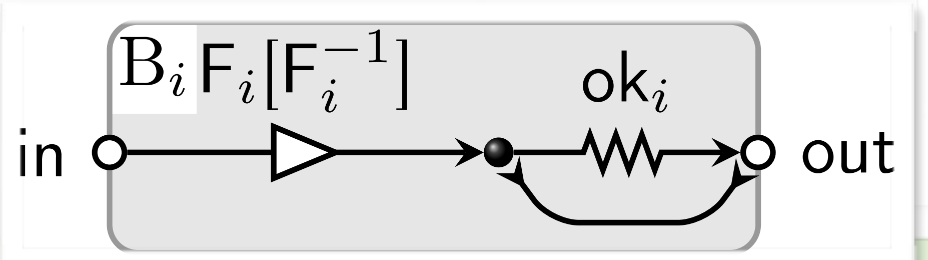


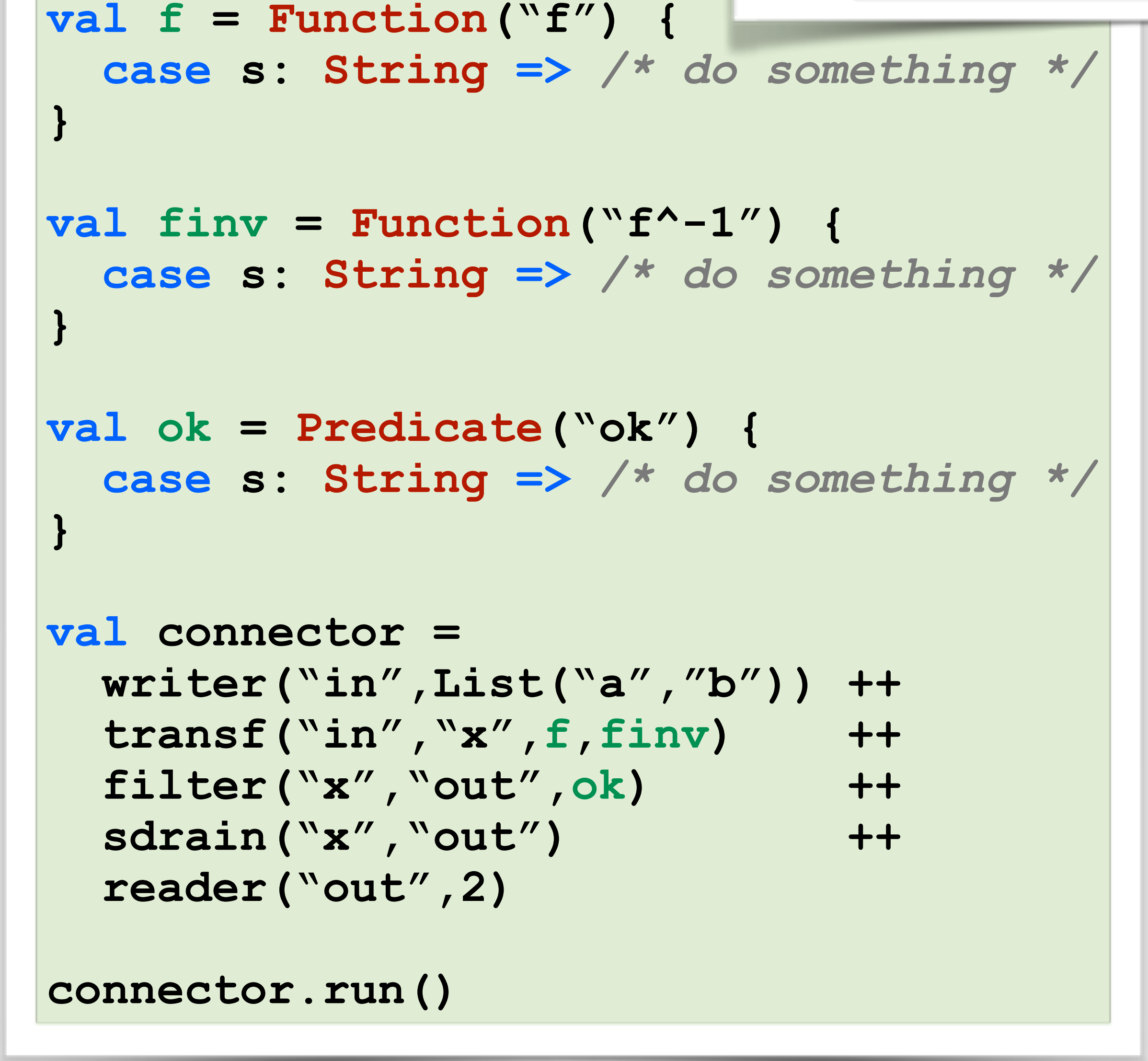


Interactive Interaction Constraints

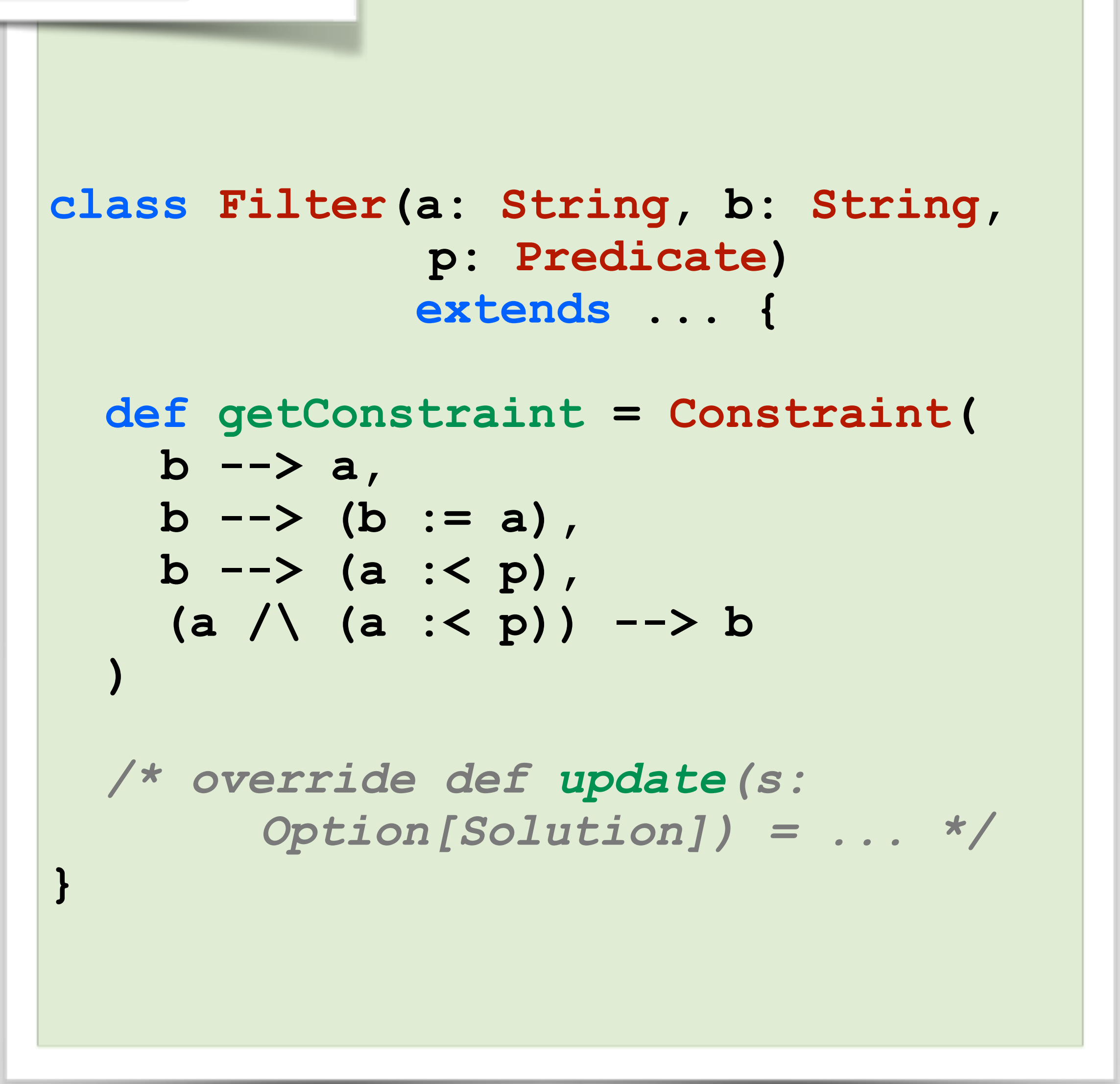


Scala / Java implementation

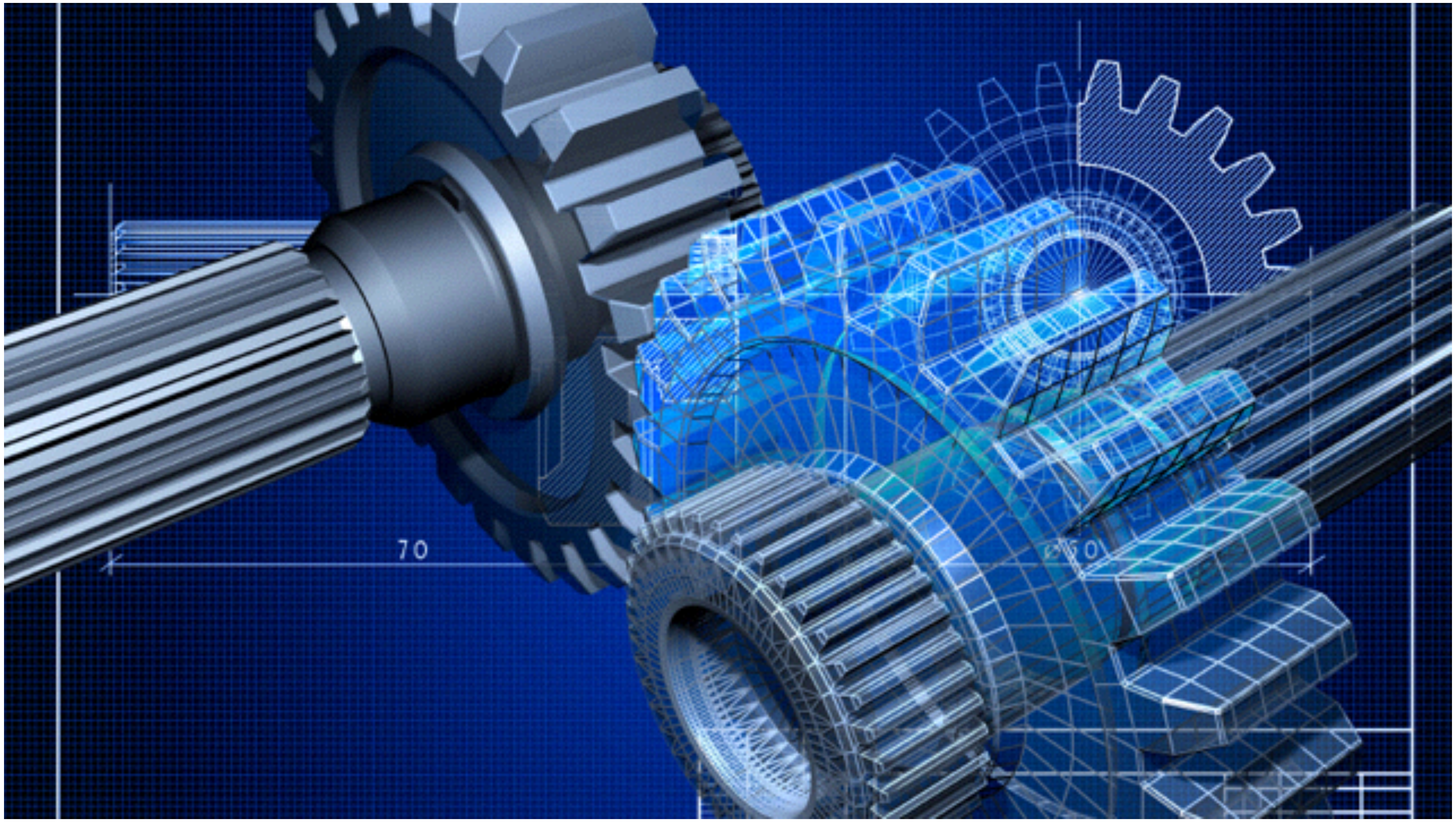




```
val f = Function(“f”) {
  case s: String => /* do something */
}

val finv = Function(“f^-1”) {
  case s: String => /* do something */
}

val ok = Predicate(“ok”) {
  case s: String => /* do something */
}

val connector =
  writer(“in”,List(“a”,”b”)) ++
  transf(“in”,“x”,f,finv)    ++
  filter(“x”,“out”,ok)       ++
  sdrain(“x”,“out”)          ++
  reader(“out”,2)

connector.run()
```



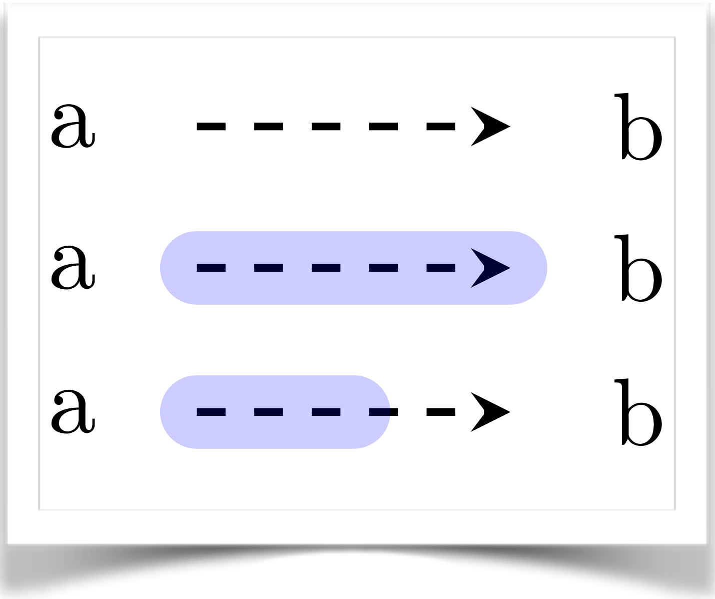
```
class Filter(a: String, b: String,
             p: Predicate)
             extends ... {

  def getConstraint = Constraint(
    b --> a,
    b --> (b := a),
    b --> (a :< p),
    (a /\ (a :< p)) --> b
  )

  /* override def update(s:
       Option[Solution]) = ... */
}
```



More about constraints

CC2 as constraints

- [*Colouring:* End → {Flow, NoFlow}]
- *Formula:* Boolean over End
- *Composition* = conjunction

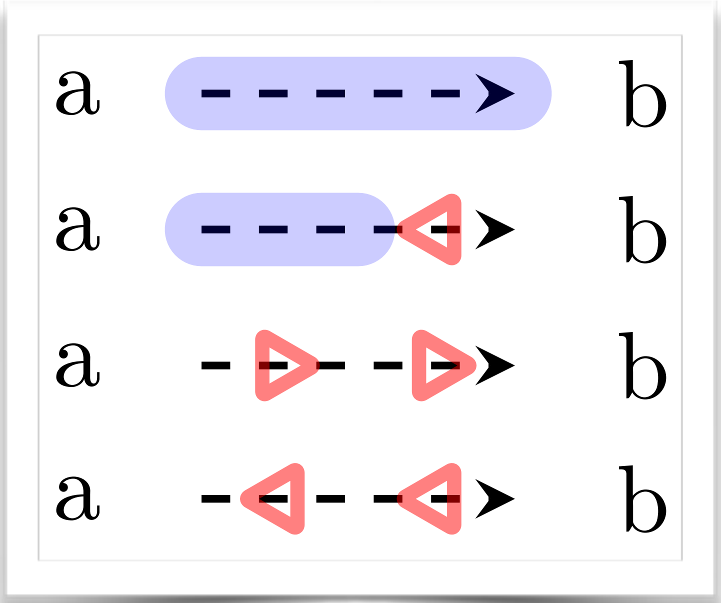


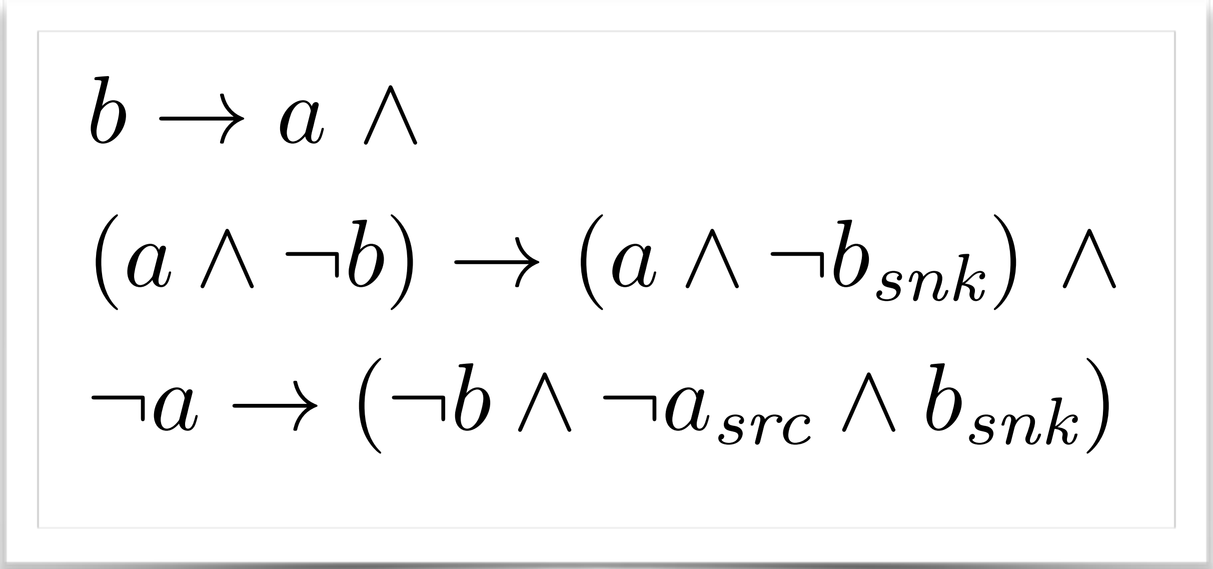
$$(\neg a \wedge \neg b) \;\; \vee \\ (a \wedge b) \;\; \vee \\ (a \wedge \neg b)$$

$$b \rightarrow a$$

CC3 as constraints

- [*Colouring:* End → {Flow, GiveReason, GetReason}]
- *Formula:* Boolean over End, End_{src}, End_{snk}
- a = flow on a ; a_{src} = give reason ; $\neg b_{snk}$ = get reason



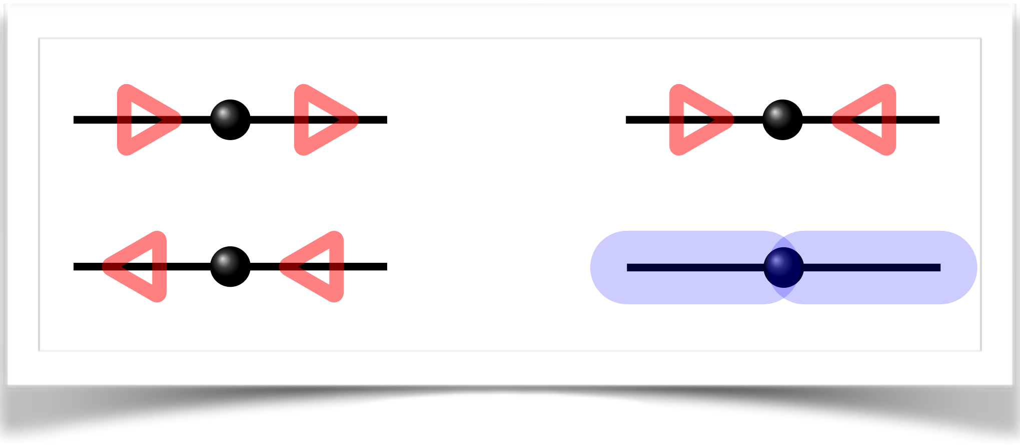


$$b \to a \land$$
$$(a \land \neg b) \to (a \land \neg b_{snk}) \land$$
$$\neg a \to (\neg b \land \neg a_{src} \land b_{snk})$$

CC3 as constraints

Composition

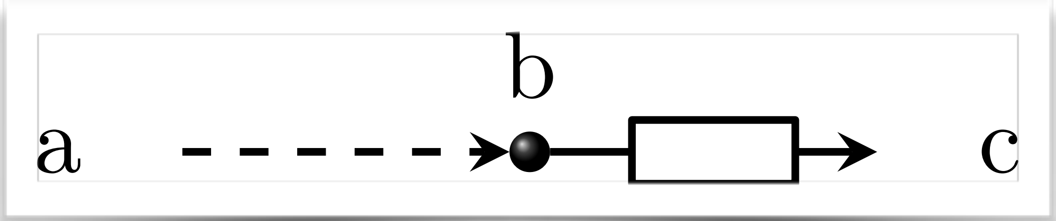
- a = flow on a ; a_{src} = give reason ; $\neg b_{snk}$ = get reason
- one-to-one composition: source to sink ends



$$\forall x \quad \cdot \quad x_{snk} \ \vee \ x_{src}$$

CC3 as constraints

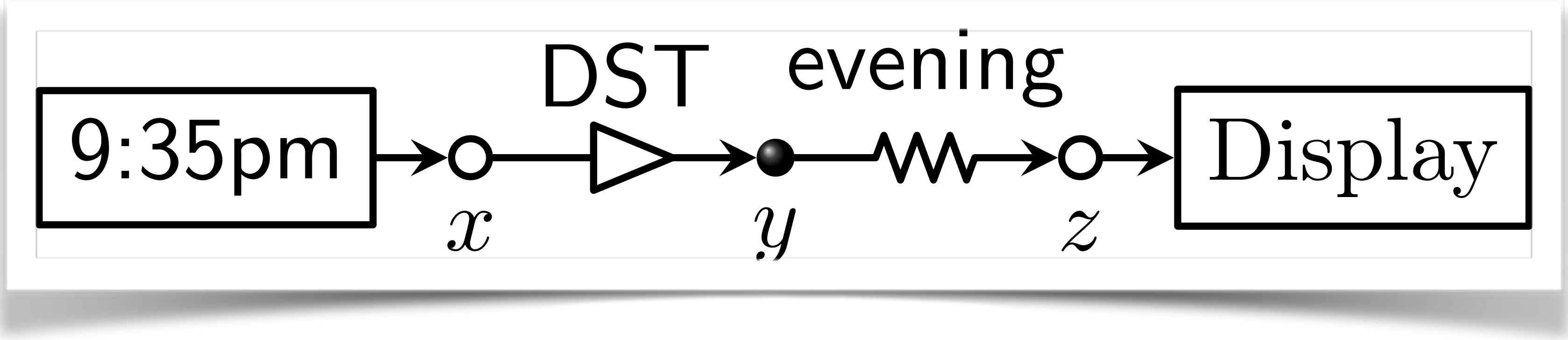
example



$$
\begin{aligned}
\phi \quad = \quad & b \rightarrow a \wedge \neg c \\
& (a \wedge \neg b) \rightarrow (a \wedge \neg b_{snk}) \ \wedge \\
& \neg a \rightarrow (\neg b \wedge \neg a_{src} \wedge b_{snk}) \ \wedge \\
& (\neg b \rightarrow \neg b_{src}) \wedge c_{snk} \wedge \\
& b_{src} \vee b_{snk}
\end{aligned}
$$

$$
\begin{aligned}
\{a \wedge b \wedge \neg c \wedge c_{snk}\} \quad & \models \quad \phi \\
\{\neg a \wedge \neg b \wedge \neg c \wedge \neg a_{src} \wedge b_{snk} \wedge \neg b_{src} \wedge c_{snk}\} \quad & \models \quad \phi
\end{aligned}
$$

Data constraints

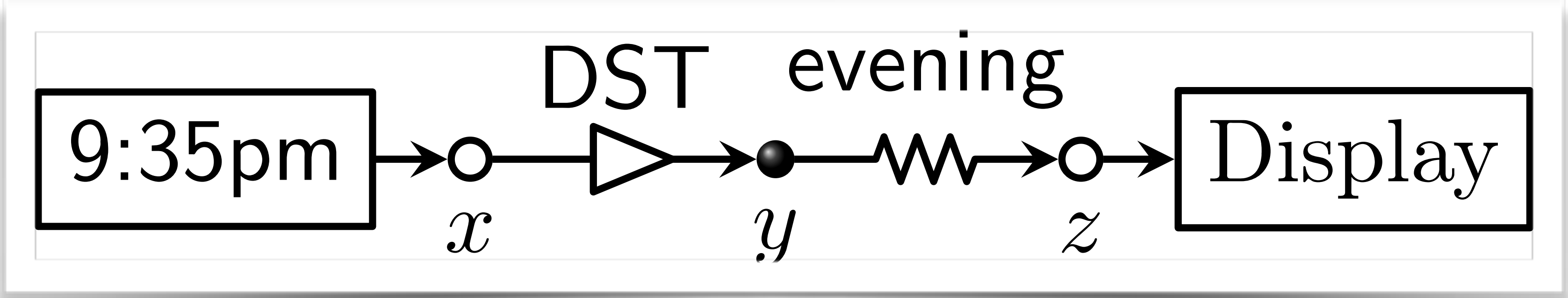


$$x \to \widehat{x} := \text{9:35pm} \qquad x \leftrightarrow y \qquad y \to \widehat{y} := \text{DST}(\widehat{x})$$

$$(y \wedge \text{evening}(\widehat{y})) \leftrightarrow z \qquad z \to \widehat{z} := \widehat{y}$$

How to solve this?

Predicate abstraction



original

$x \rightarrow \widehat{x} := 9{:}35\text{pm} \qquad x \leftrightarrow y \qquad y \rightarrow \widehat{y} := \text{DST}(\widehat{x})$

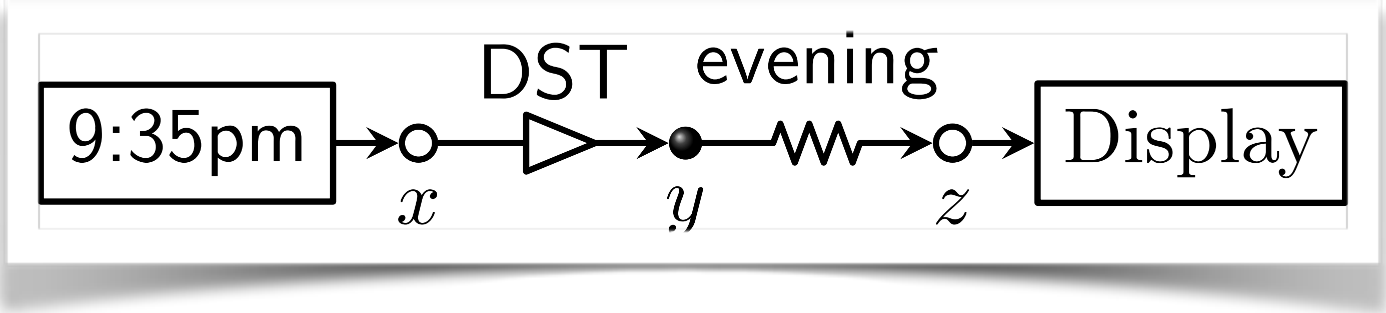
$(y \wedge \text{evening}(\widehat{y})) \leftrightarrow z \qquad z \rightarrow \widehat{z} := \widehat{y}$

boolean

$x \rightarrow \widehat{x}_{\text{ev.dst}} := [\text{evening}(\text{DST}(9{:}35\text{pm}))] \qquad x \leftrightarrow y$

$y \rightarrow \widehat{y}_{\text{ev}} := \widehat{x}_{\text{ev.dst}} \qquad (y \wedge \widehat{y}_{\text{ev}}) \leftrightarrow z$

Interaction via Choco



boolean

$$x \to \widehat{x}_{\text{ev.dst}} := [\text{evening}(\text{DST}(\text{9:35pm}))] \qquad x \leftrightarrow y$$

$$y \to \widehat{y}_{\text{ev}} := \widehat{x}_{\text{ev.dst}} \qquad (y \wedge \widehat{y}_{\text{ev}}) \leftrightarrow z$$

interactive

$$x \to \text{XPred}(\text{ev.dst}, x, \text{9:35pm}) \qquad x \leftrightarrow y$$

$$y \to \widehat{y}_{\text{ev}} := \widehat{x}_{\text{ev.dst}} \qquad (y \wedge \widehat{y}_{\text{ev}}) \leftrightarrow z$$

Interaction via Choco

9:35pm

- instance of a Choco constraint
- reacts when x or $\widehat{x}_{\text{ev.dst}}$ is instantiated
- $\neg x \Rightarrow \widehat{x}_{\text{ev.dst}}$ can be anything
- $x \Rightarrow \widehat{x}_{\text{ev.dst}} = \text{ev(dst(9:35pm))}$

boolean

$x \to \widehat{x}_{\text{ev.dst}}$ $=[\text{evening(DST(9:35pm))}]$ $\qquad x \leftrightarrow y$

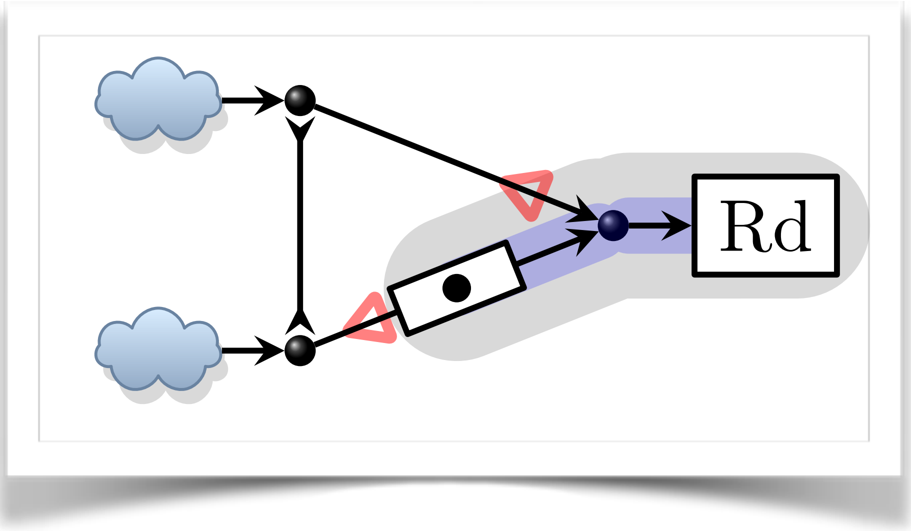
$y \to \widehat{y}_{\text{ev}} := \widehat{x}_{\text{ev.dst}} \qquad (y \wedge \widehat{y}_{\text{ev}}) \leftrightarrow z$

interactive

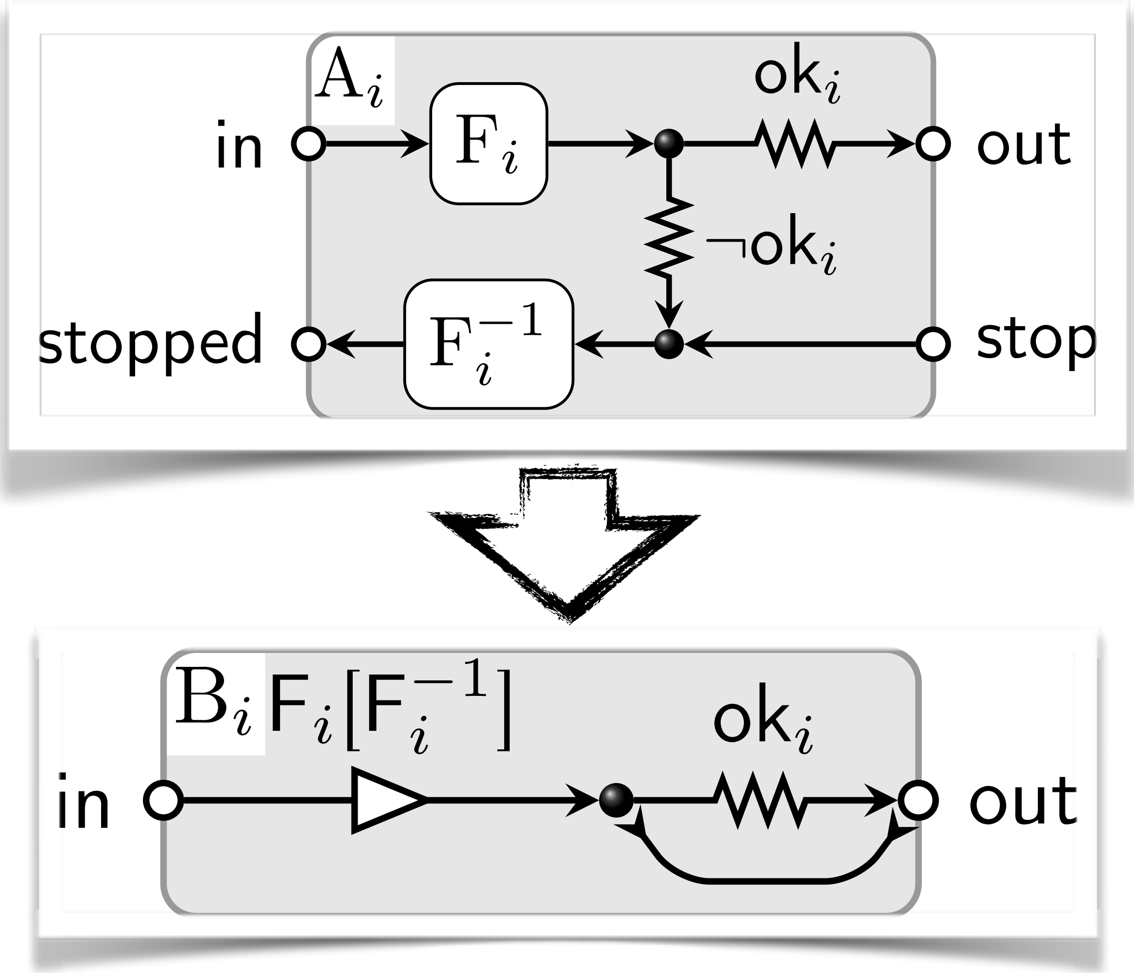
$x \to \text{XPred(ev.dst}, x, \text{9:35pm)} \qquad x \leftrightarrow y$

$y \to \widehat{y}_{\text{ev}} := \widehat{x}_{\text{ev.dst}} \qquad (y \wedge \widehat{y}_{\text{ev}}) \leftrightarrow z$

Wrapping up



- Reo and connector colouring



- Interactive constraint solving
- Expose the atomicity of Reo to components

Ongoing experiments

- Avoiding pre-processing (SMT instead of SAT) $\exists a, \hat{a} \cdot \psi$
- Compiling steps:
- Heuristics for identifying potential partial colourings
- Combining local and interactive constraints (probably to a journal)