Wednesday

Fine-grained justifications

Schedule for today

- Superfluousness
- Laconic and precise justifications
- Discussion
- Tool session: Explanation Workbench

Superfluousness

The story so far ...

- Justifications are great:
  they contain no superfluous axioms
- But they can still contain superfluous *parts* of axioms!

Superfluousness

- Some justifications contain large axioms
- Not all parts thereof are relevant
- Problems:
  - Justification is hard to understand
  - If repair = removing the whole axiom, then we might lose other entailments

Superfluousness

Example 1: $A \sqsubseteq B \sqcap C$

$C \sqsubseteq D \sqcap \neg D$

A is unsatisfiable,

but if we delete the first axiom,
we'll lose the entailment $A \sqsubseteq B$. *(Over-repair)*

Superfluousness

Example 2: Explanation in SWOOP (TAMBIS ontology)

Axioms causing the inference
alpha-helix = owl:Nothing:
1) (alpha-helix ⊆ protein-secondary-structure)
2) |_(protein-secondary-structure ⊆ protein-structure)
3) |_(protein-structure = (biological-structure ∩ (∀structure-of . macromolecular-compound) ∩ (∃structure-of . macromolecular-compound)))
4) |_(macromolecular-compound = ((∃has-length . residue-number) ∩ (∀polymer-of . small-organic-molecular-compound) ∩ (= 1 has-molecular-weight) ∩ (molecule ∩ compound) ∩ (= 1 has-length) ∩ (∃polymer-of . small-organic-molecular-compound) ∩ (∃has-molecular-weight . xsd:integer)))
5) |_(small-organic-molecular-compound ⊆ (organic-molecular-compound ∩ small-molecular-compound))
6) |_(organic-molecular-compound ⊆ (∃contains . carbon))
7) |_(carbon = ((= 1 atomic-number) ∩ (∃atomic-number . xsd:integer) ∩ chemical))
8) (nonmetal ⊆ ¬ metal)
9) |_(metal = ((= 1 atomic-number) ∩ (∃atomic-number . xsd:integer) ∩ chemical))
10) (nonmetal = ((= 1 atomic-number) ∩ (∃atomic-number . xsd:integer) ∩ chemical))

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Superfluousness

Early solution: Strike-out feature in SWOOP

Axioms causing the inference

alpha-helix = owl:Nothing:

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2) |_(protein-secondary-structure ⊆ protein-structure)

3) |_(protein-structure = (~~biological-structure~~ ∩ (~~∀structure-of . macromolecular-compound~~) ∩ (∃structure-of . macromolecular-compound)))

4) |_(macromolecular-compound = ((~~∃has-length . residue-number~~) ∩ (~~∀polymer-of . small-organic-molecular-compound~~) ∩ (~~= 1 has-molecular-weight~~) ∩ (~~molecule ∩ compound~~) ∩ (~~= 1 has-length~~) ∩ (∃polymer-of . small-organic-molecular-compound) ∩ (~~∃has-molecular-weight . xsd:integer~~)))

5) |_(small-organic-molecular-compound ⊆ (organic-molecular-compound ∩ ~~small-molecular-compound~~))

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Superfluousness

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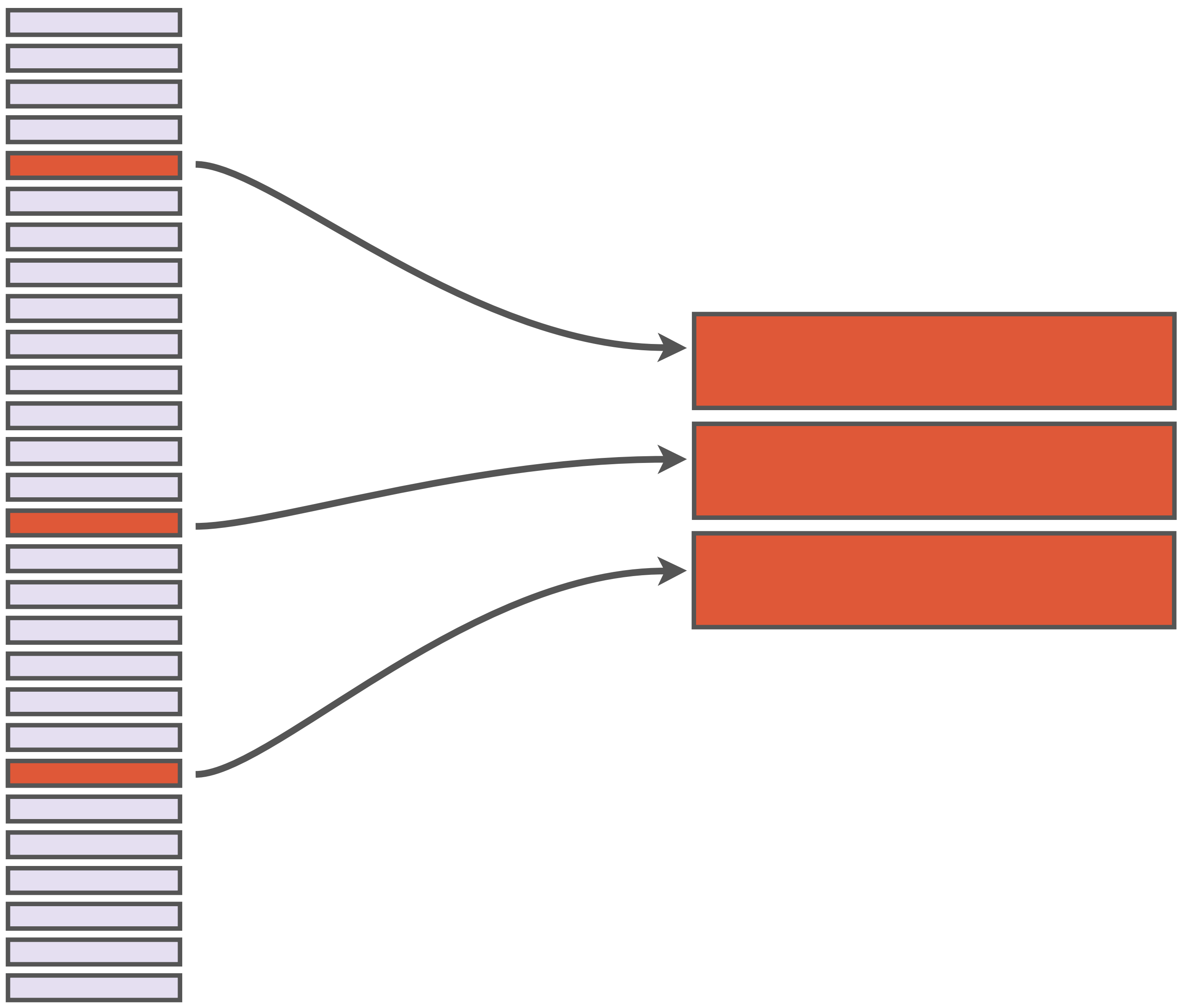

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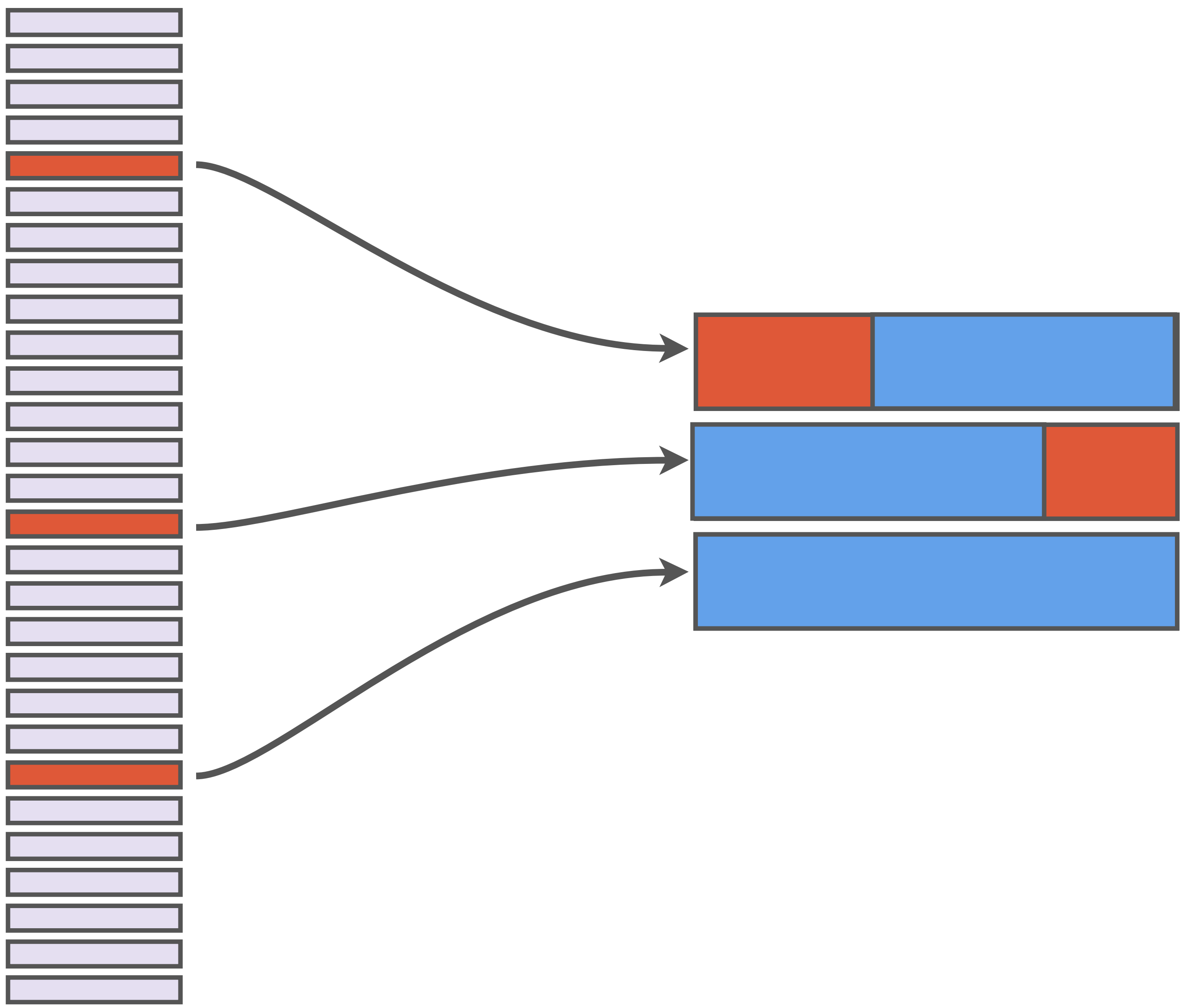

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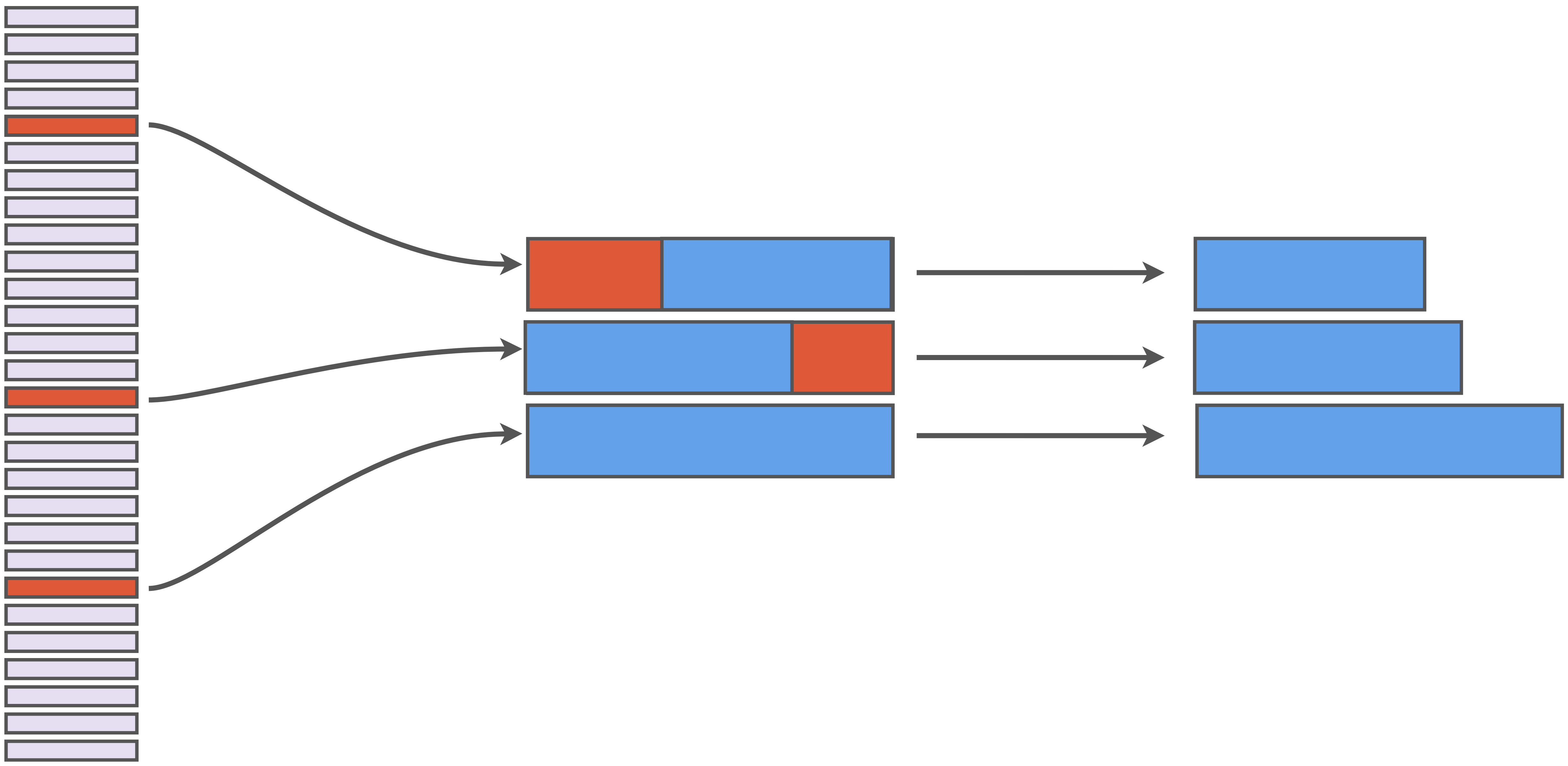

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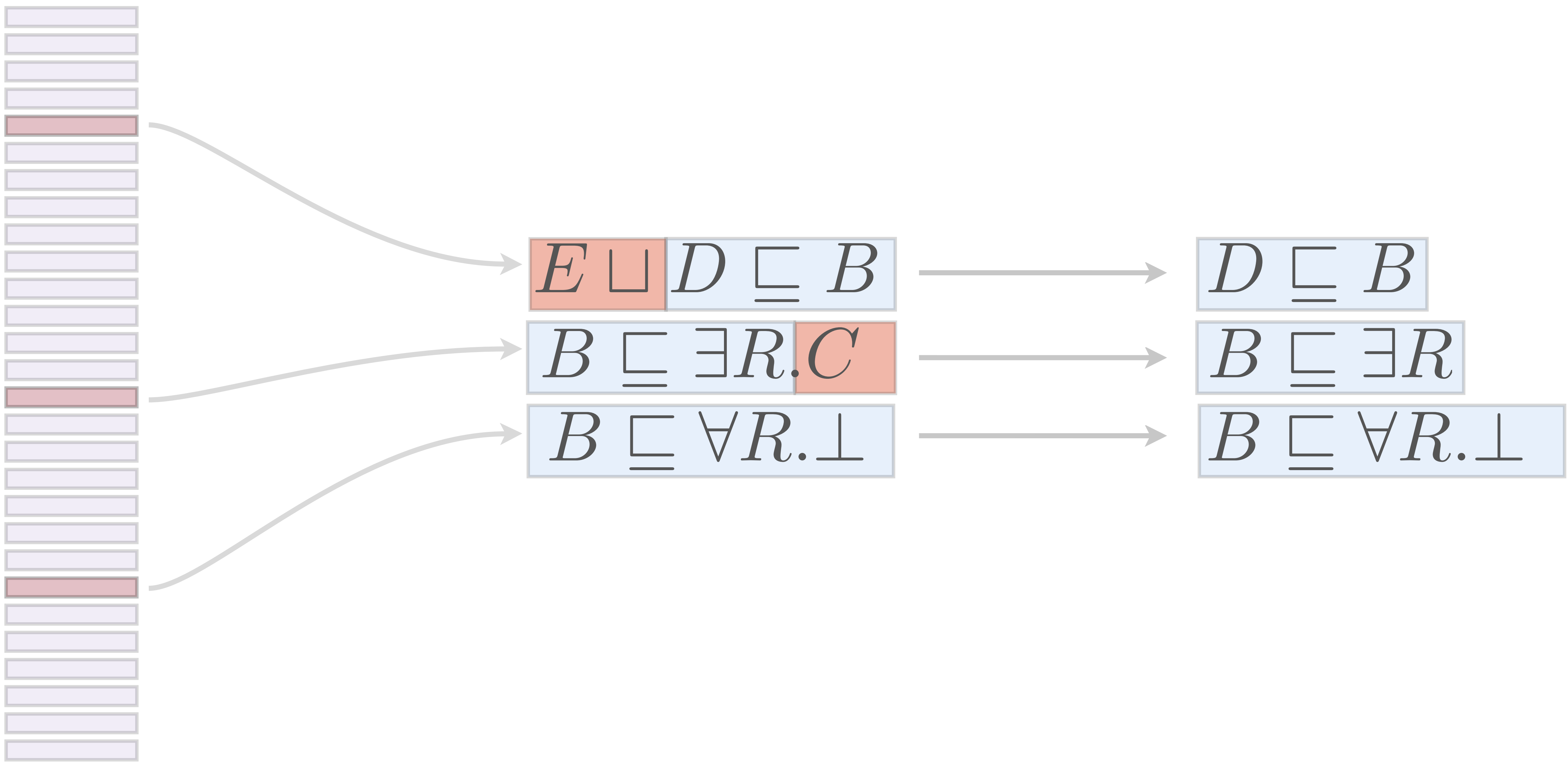

Superfluousness

$$(1) \quad A \sqsubseteq B \sqcap \exists R.C \sqcap D$$

$$(2) \quad D \sqsubseteq \forall R.\neg C$$

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B is irrelevant, distracting, and might lead to over-repair!

Internal Masking

$$\mathcal{O} = \{ \begin{array}{rcl} A & \sqsubseteq & B \sqcap \exists R.C \sqcap \forall R.C \\ F & \equiv & \exists R.C \end{array} \} \quad \models A \sqsubseteq F$$

Two reasons for the entailment, in the same justification:

Internal Masking

$$\mathcal{O} = \{ \begin{array}{lll} A & \sqsubseteq & B \sqcap \exists R.C \sqcap \forall R.C \\ F & \equiv & \exists R.C \end{array} \} \quad \models A \sqsubseteq F$$

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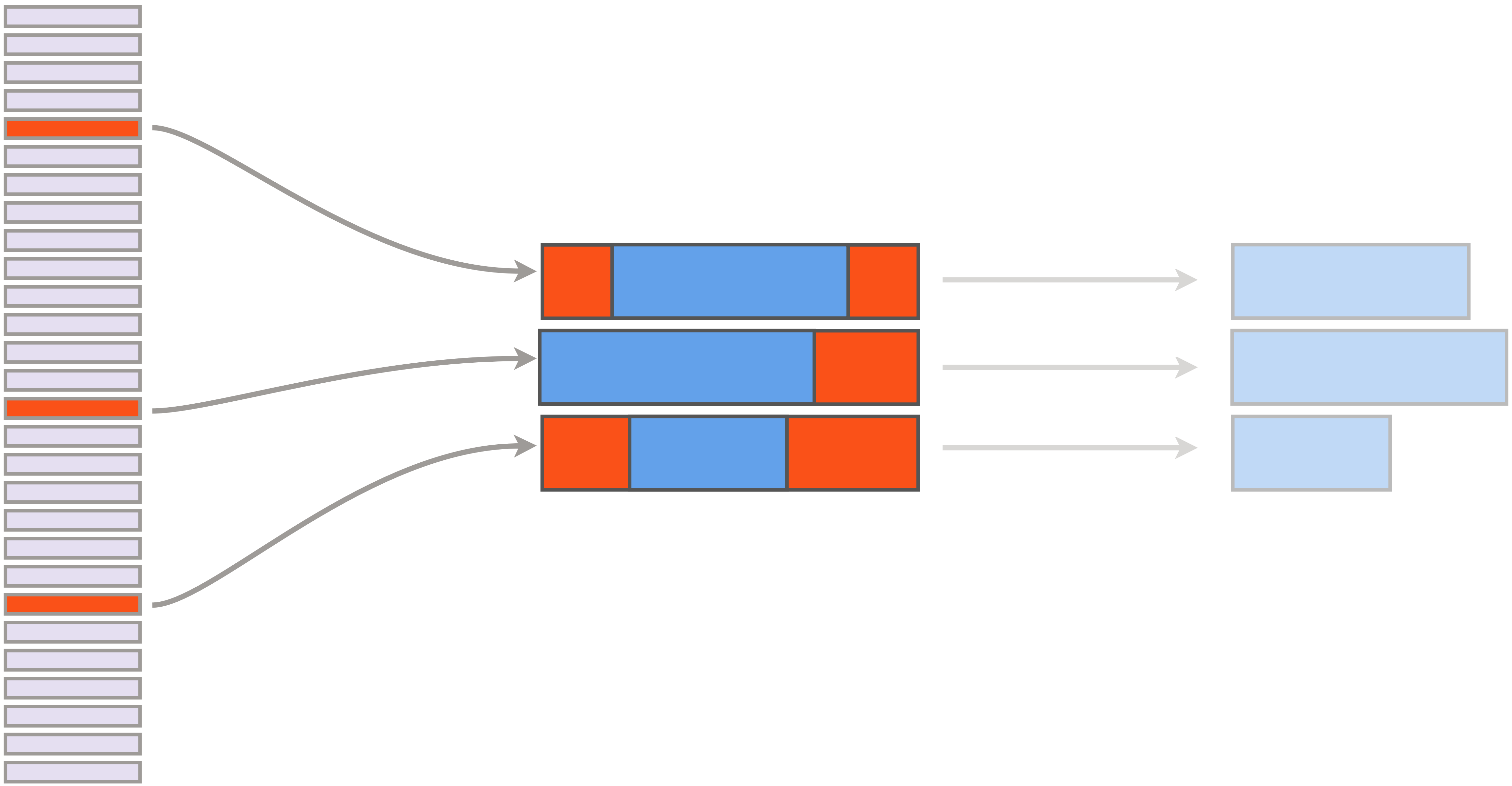
External Masking



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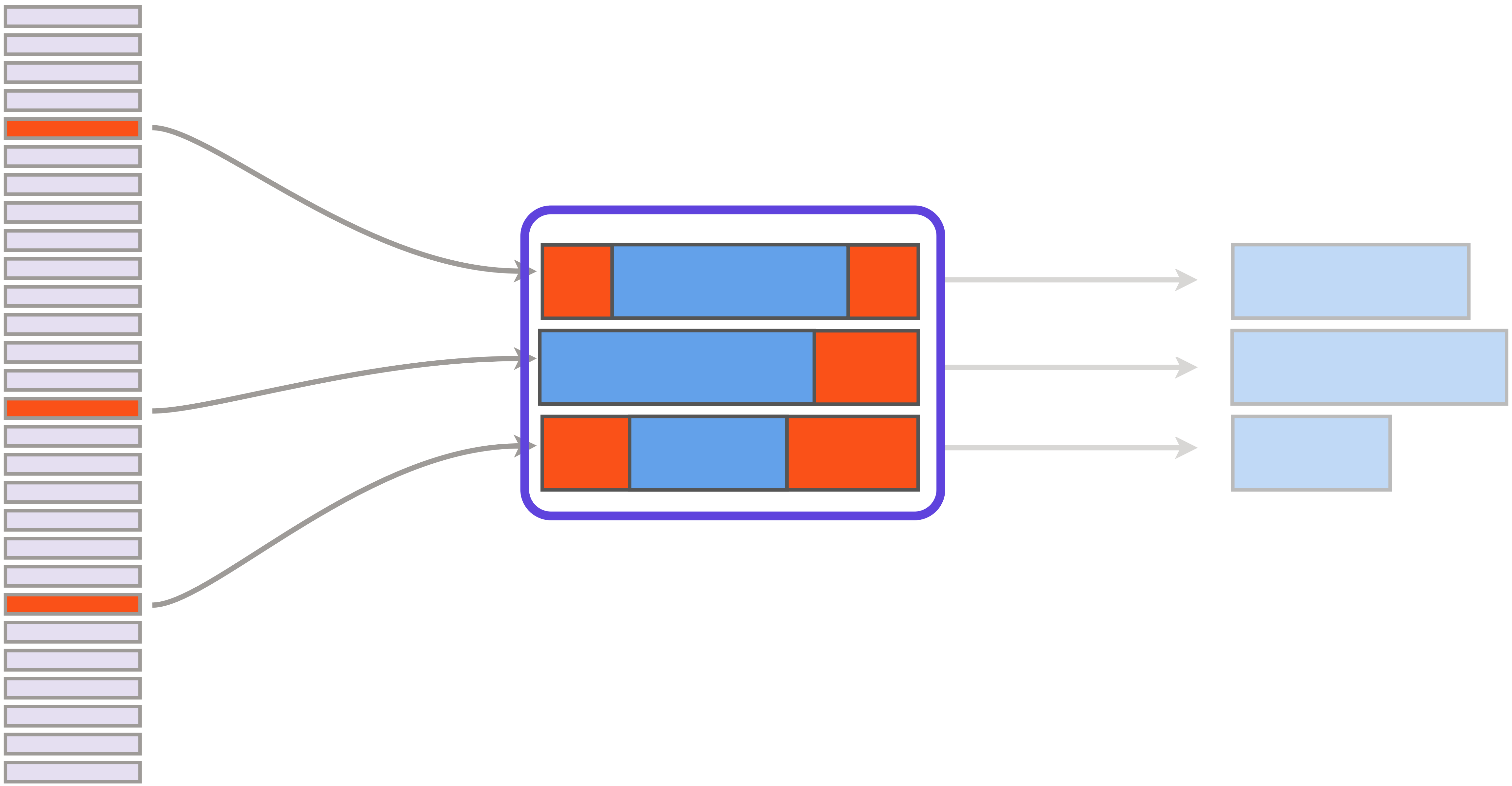

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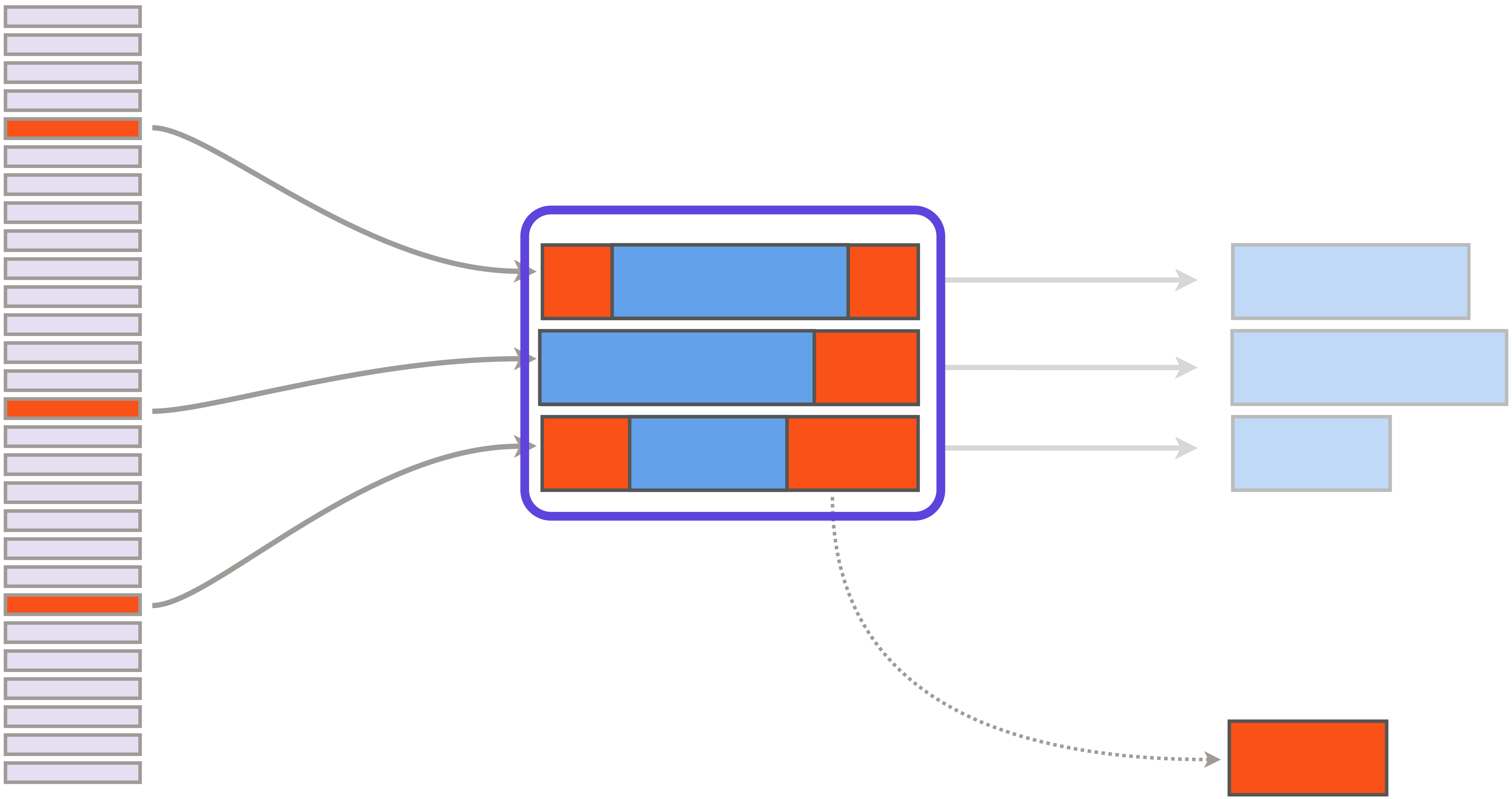

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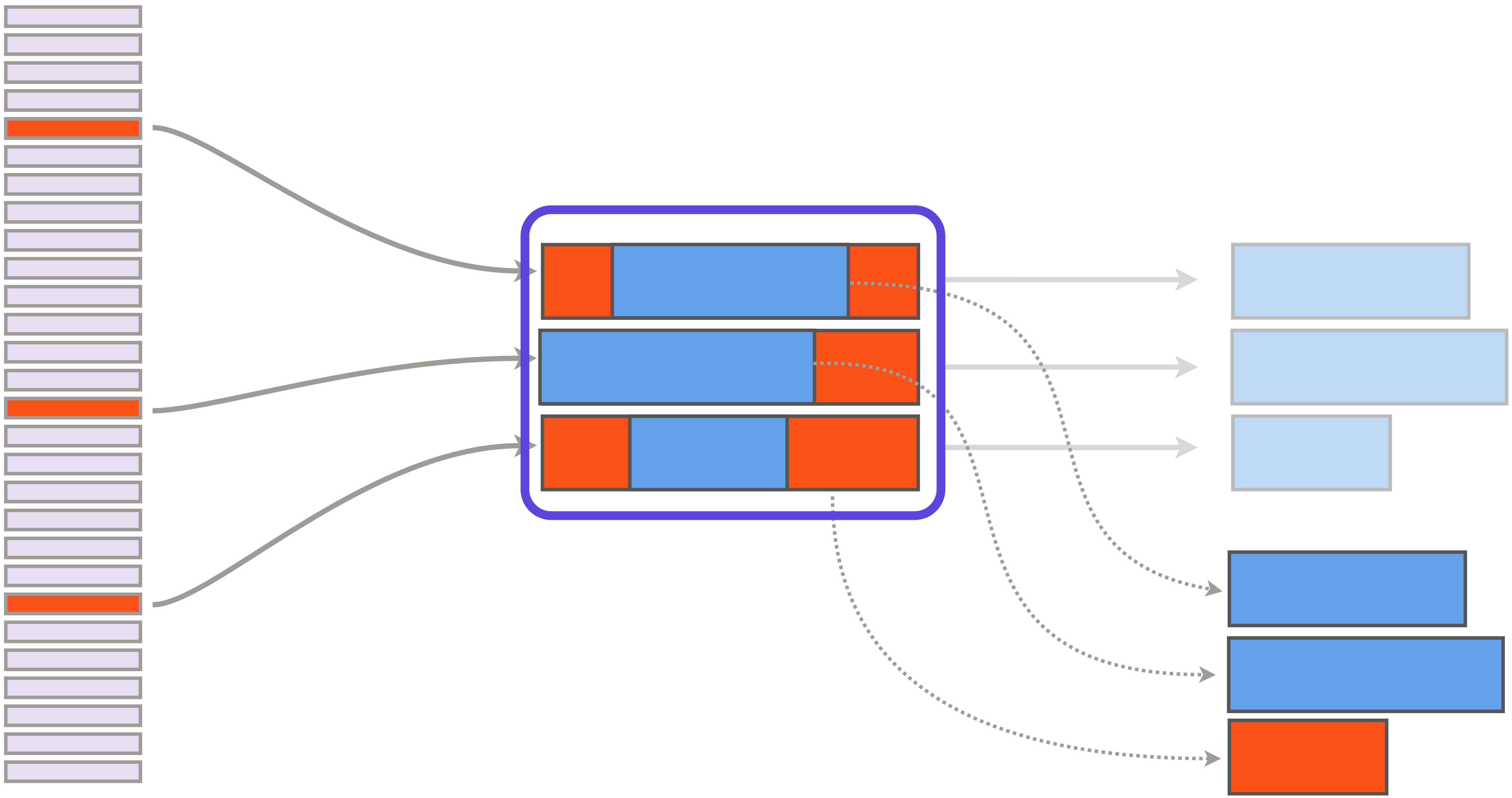

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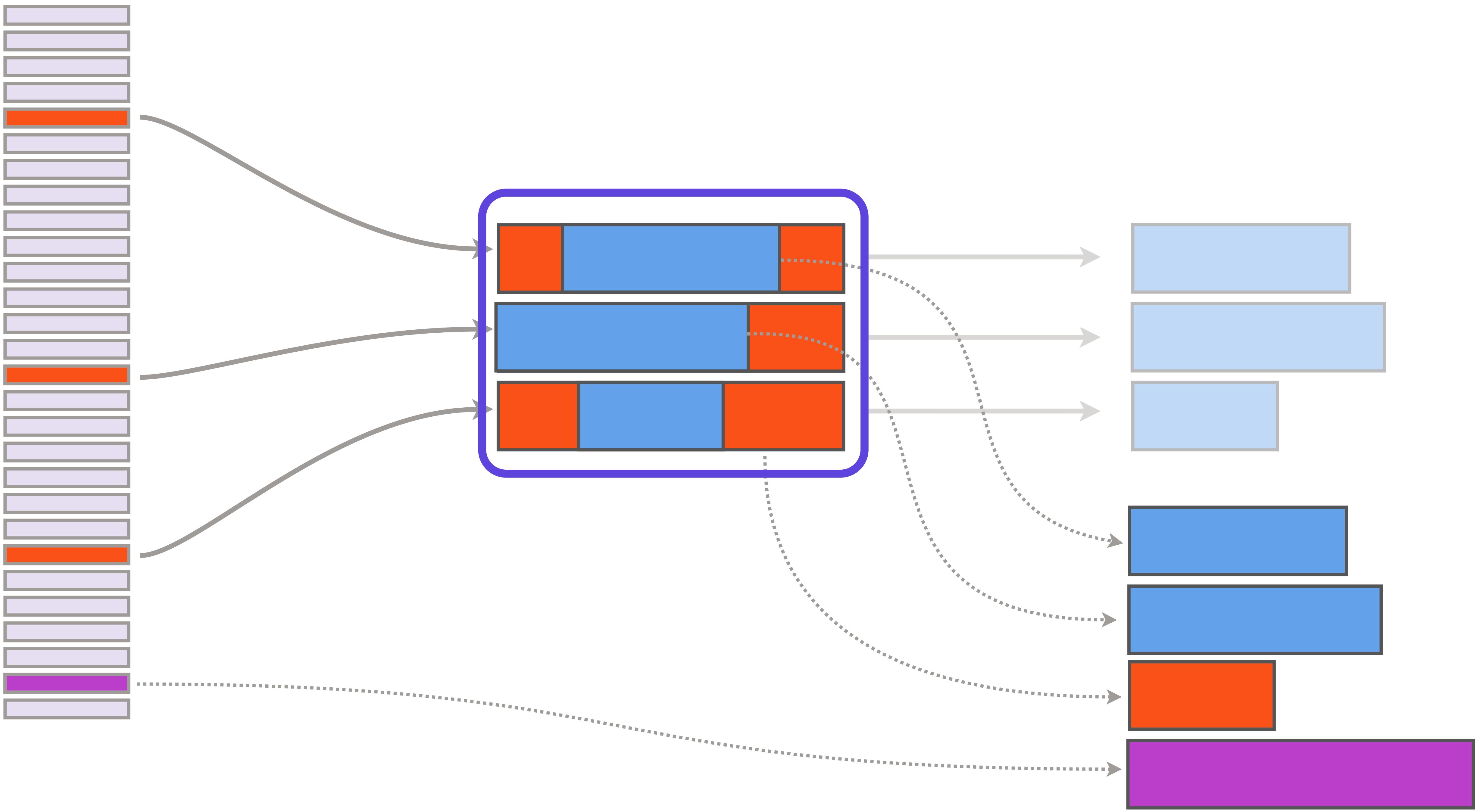

External Masking

$$\mathcal{O} = \left\{ \begin{array}{lll} A & \sqsubseteq & B \sqcap C \sqcap \neg C \\ A & \sqsubseteq & \neg B \end{array} \right\} \quad \models A \sqsubseteq \bot$$

Two reasons, but only one regular justification:

External Masking

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Two reasons, but only one regular justification:

$$(1) \quad A \sqsubseteq B \sqcap C \sqcap \neg C$$

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Two reasons, but only one regular justification:

(1) $A \sqsubseteq B \sqcap C \sqcap \neg C$

(2) $A \sqsubseteq B \sqcap C \sqcap \neg C$

$A \sqsubseteq \neg B$

Shared cores

$$\mathcal{O} = \{ \begin{array}{rcl} A \sqcup B & \sqsubseteq & C \sqcap D \\ A \sqcup E & \sqsubseteq & C \sqcap F \\ C & \sqsubseteq & G \sqcap \neg G \end{array} \} \models A \sqsubseteq \bot$$

Two regular justifications, but only one reason:

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Shared cores

$$\mathcal{O} = \{\ A \sqcup B \sqsubseteq C \sqcap D$$
$$A \sqcup E \sqsubseteq C \sqcap F$$
$$C \sqsubseteq G \sqcap \neg G\ \} \models A \sqsubseteq \bot$$

Two regular justifications, but only one reason:

(1) $A \sqcup B \sqsubseteq C \sqcap D$

$C \sqsubseteq G \sqcap \neg G$

Shared cores

$$\mathcal{O} = \{\ A \sqcup B \sqsubseteq C \sqcap D,\quad A \sqcup E \sqsubseteq C \sqcap F,\quad C \sqsubseteq G \sqcap \neg G\ \} \models A \sqsubseteq \bot$$

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Problems

	Understanding	Repair
Superfluous parts	Wasted effort	Possibility of over-repair
Internal masking	Not obvious that there is >1 explanation	Lack of understanding ~> over-repair possible
External masking	Further explanations can be overlooked	Not all info for repair available; over-repair poss.
Shared cores	Looks like there are more reasons than there are	Repair design is time consuming; over-repair poss.

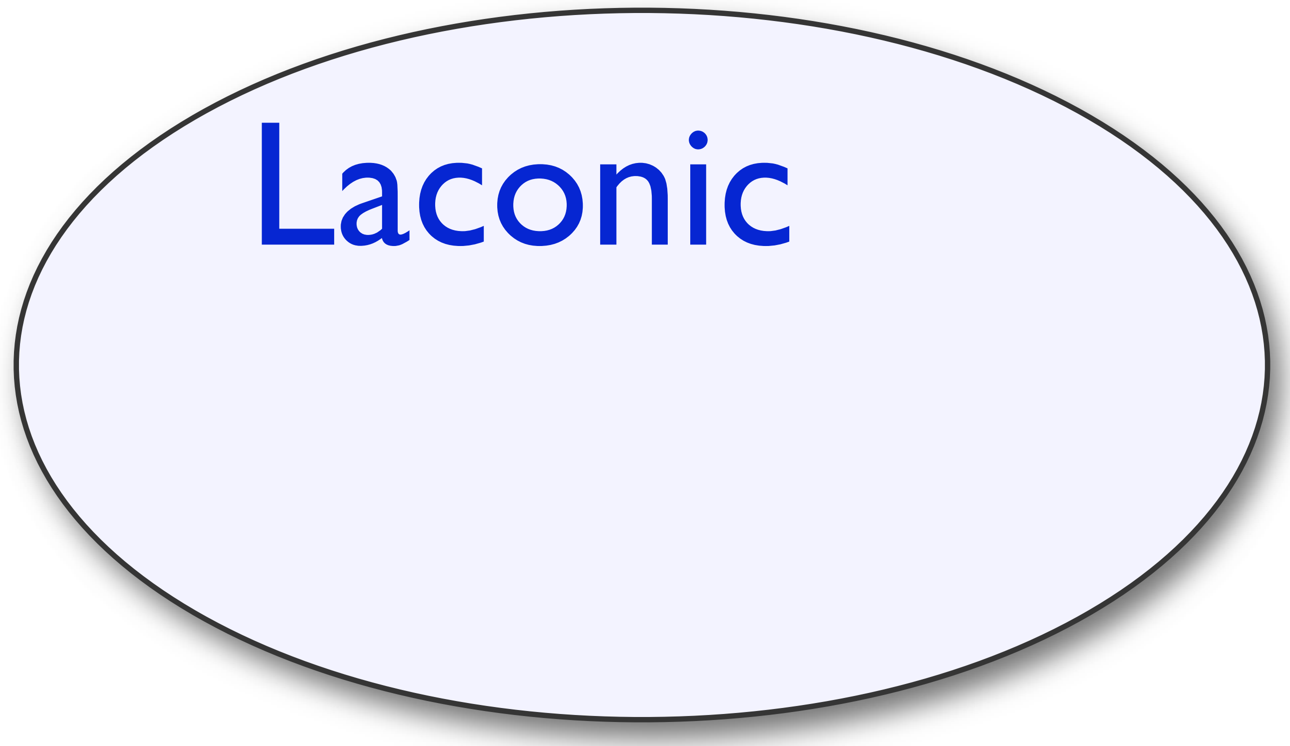
Fine-grained Justifications

Intuitions:

- Show me only parts of axioms!
  But what is a part? How far to split?
- Do a minimal repair!

Fine-grained Justifications

Fine-grained Justifications



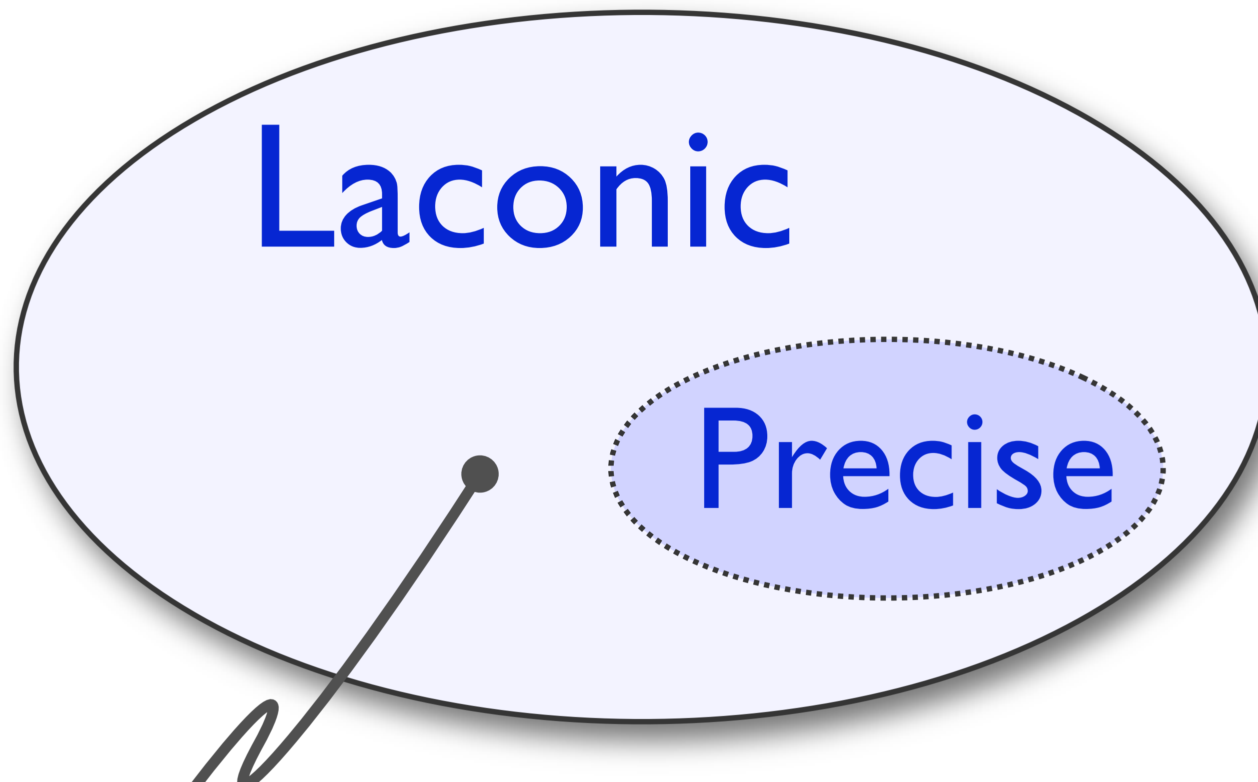
Fine-grained Justifications

Laconic

No superfluous parts

All parts as weak as possible

Fine-grained Justifications



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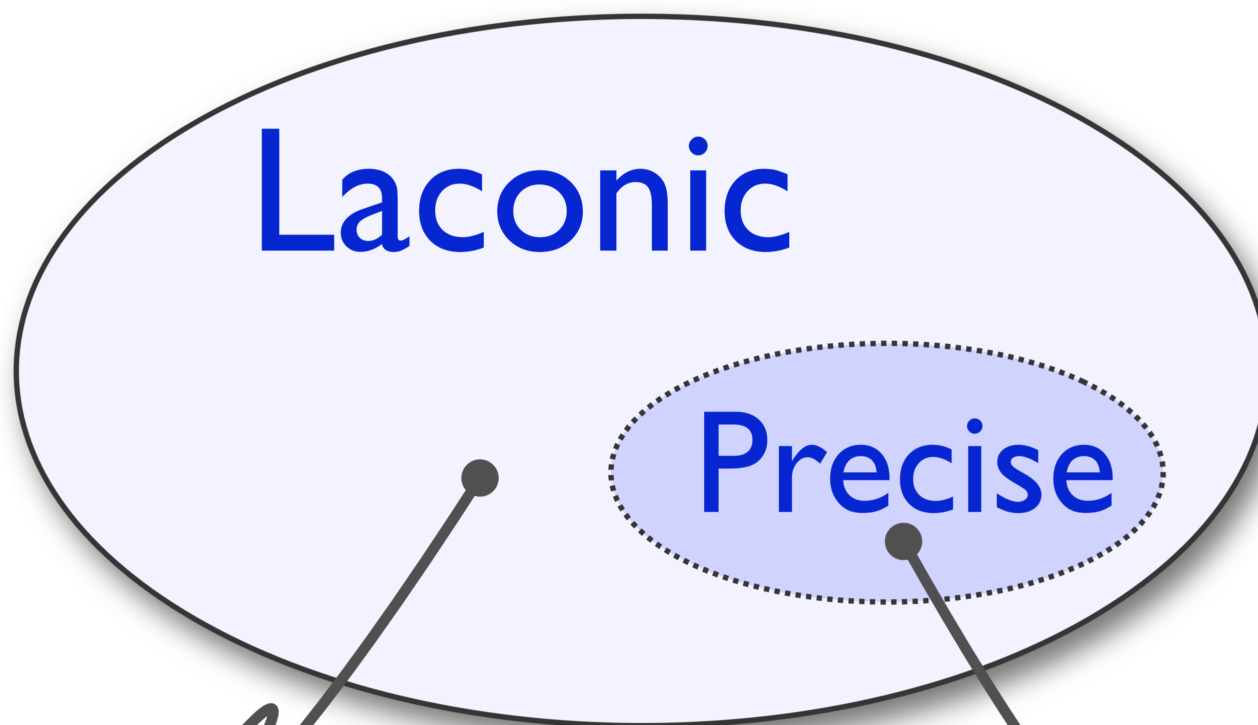
Fine-grained Justifications



No superfluous parts
All parts as weak as possible

Primarily geared towards repair
Each axiom is a minimal repair

Laconic and precise justifications

Laconic Justifications

Intuitions:

- Instead of whole axioms, use *parts* thereof
- Get parts from *deductive closure O** of ont. *O*:
  *O** = *O* “plus” all its entailments
- Use axioms from *O** to construct explanations
  ~> Get rid of superfluous parts

Example

$$\mathcal{O} = \left\{ \begin{array}{rcl} A & \sqsubseteq & D \sqcap {=}1R.C \sqcap B \\ D & \sqsubseteq & \forall R.C \sqcap F \\ E & \equiv & \exists R.C \sqcap \forall R.C \end{array} \right\} \models A \sqsubseteq E$$

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$$\left\{ \begin{array}{rcl} A & \sqsubseteq & D \sqcap \geqslant 1R.\top \\ D & \sqsubseteq & \forall R.C \\ \exists R.C \sqcap \forall R.C & \sqsubseteq & E \end{array} \right\} \quad \models A \sqsubseteq E$$

Example

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How to weaken axioms?

- In previous example, we
  - ➡ Left out conjuncts
  - ➡ weakened exact-cardinality restriction
  - ➡ weakened equivalence
- How to do this systematically?
- We need to flatten nested class descriptions using a *Structural Transformation*

Structural Transformation

- Motivation: flatten nested class expressions
- ST preserves structure
- ST helps identify parts of class expressions and to work with them
- We'll use an ST that has been widely used

Structural Transformation

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$$C \sqcup D \sqsubseteq A \sqcap \exists R.(F \sqcap \exists R.F)$$

Structural Transformation

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$$\boxed{\boxed{C} \sqcup \boxed{D}} \sqsubseteq \boxed{\boxed{A} \sqcap \boxed{\boxed{\exists R}.(\boxed{\boxed{F} \sqcap \boxed{\boxed{\exists R}.\boxed{F}}})}}$$

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Structural Transformation

Example: see blackboard

Definition: see paper [1]

[1] M. Horridge, B. Parsia, U. Sattler:
Laconic and Precise Justifications in OWL. ISWC '08.

http://owl.cs.manchester.ac.uk/2009/esslli-explanation/HoPaSa08.pdf

Laconic Justifications

Given $\mathcal{O} \models \eta$,

$\mathcal{J}$ is a laconic justification for η over $\mathcal{O}$:

1. $\mathcal{J}$ is a justification for η in $\mathcal{O}^*$

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Laconic Justifications

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Laconic Justifications

Given $\mathcal{O} \models \eta$,

$\mathcal{J}$ is a laconic justification for η over $\mathcal{O}$:

1. $\mathcal{J}$ is a justification for η in $\mathcal{O}^*$
2. $\delta(\mathcal{J})$ is a justification for η in $\delta(\mathcal{O}^*)$
3. For each $\alpha \in \delta(\mathcal{J})$ there is no α' such that
   (a) α' is weaker than α: $\alpha \models \alpha'$ and $\alpha' \not\models \alpha$
   (b) α' is no longer than α: $|\alpha'| \leqslant |\alpha|$
   (c) $(\delta(\mathcal{J}) \setminus \{\alpha\}) \cup \delta(\alpha')$ is a justification for η in $\delta(\mathcal{O}^*)$

Laconic Justifications

Example: see blackboard

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Precise Justifications

Given a justification $\mathcal{J}$ for $\mathcal{O} \models \eta$

Let $\mathcal{J}' = \delta(\mathcal{J})$

Then $\mathcal{J}'$ is a precise justification with respect to $\mathcal{J}$ if $\mathcal{J}$ is a laconic justification for $\mathcal{O} \models \eta$

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Example

$$\mathcal{O} = \{ \begin{array}{rcl} A & \sqsubseteq & D \sqcap {=}1R.C \sqcap B \\ D & \sqsubseteq & \forall R.C \sqcap F \\ E & \equiv & \exists R.C \sqcap \forall R.C \end{array} \}$$

$$\models A \sqsubseteq E$$

Example

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$$\models A \sqsubseteq E$$

$$\begin{array}{rcl}
\top & \sqsubseteq & X_0 \sqcup X_1 \\
X_0 & \sqsubseteq & \neg D \\
X_1 & \sqsubseteq & =1R.X_2 \\
X_2 & \sqsubseteq & C \\
X_1 & \sqsubseteq & B \\
\top & \sqsubseteq & X_3 \sqcup X_4 \\
X_3 & \sqsubseteq & \neg D \\
X_4 & \sqsubseteq & \forall R.X_5 \\
X_5 & \sqsubseteq & C \\
X_4 & \sqsubseteq & F \\
\top & \sqsubseteq & X_6 \sqcup X_7 \\
X_6 & \sqsubseteq & \neg E \\
X_7 & \sqsubseteq & \exists R.X_8 \\
X_8 & \sqsubseteq & C \\
X_7 & \sqsubseteq & \forall R.X_9 \\
X_9 & \sqsubseteq & C \\
\top & \sqsubseteq & X_{10} \sqcup X_{11} \\
X_{10} & \sqsubseteq & E \\
X_{11} & \sqsubseteq & X_{12} \sqcup X_{13} \\
X_{12} & \sqsubseteq & \forall R.X_{14} \\
X_{14} & \sqsubseteq & \neg C \\
X_{13} & \sqsubseteq & \exists R.X_{15} \\
X_{15} & \sqsubseteq & \neg C
\end{array}$$

Problems

- Contains many more axioms
- Contains new vocabulary
- Is in negation normal form

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- Contains many more axioms
- Contains new vocabulary
- Is in negation normal form

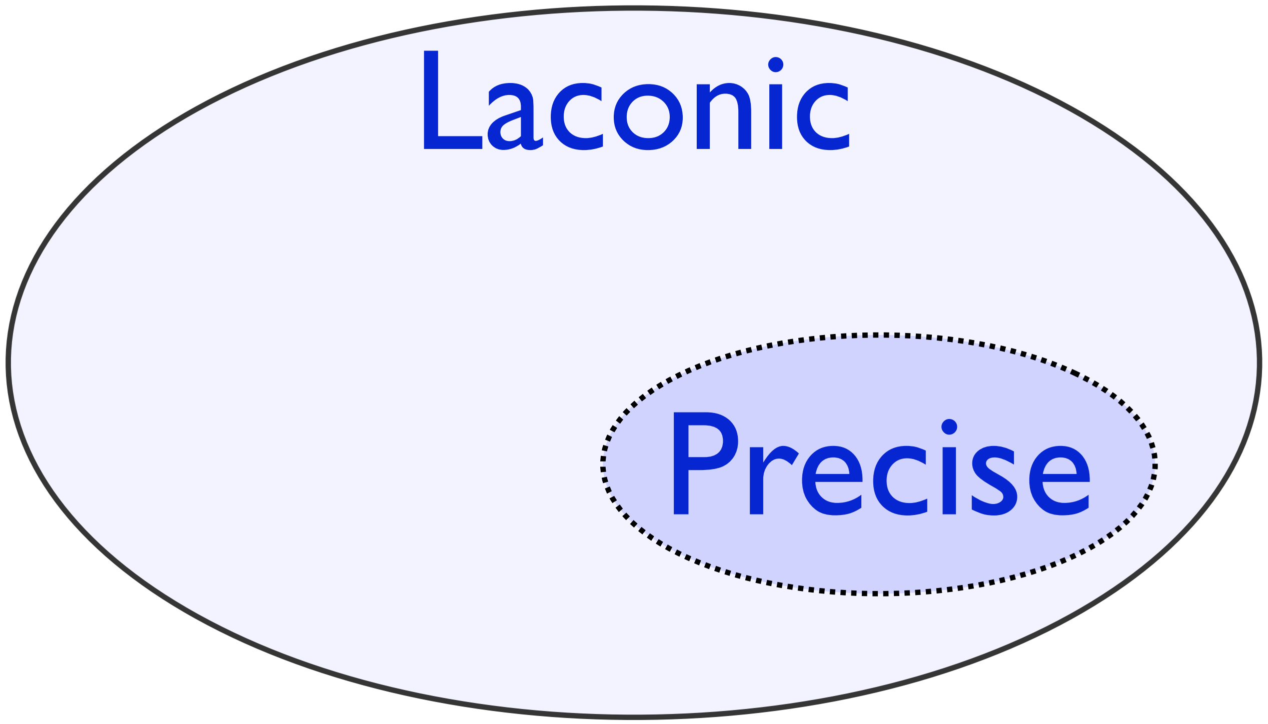
➡ Looks horrible

➡ Difficult to understand
and to relate back to the original ontology

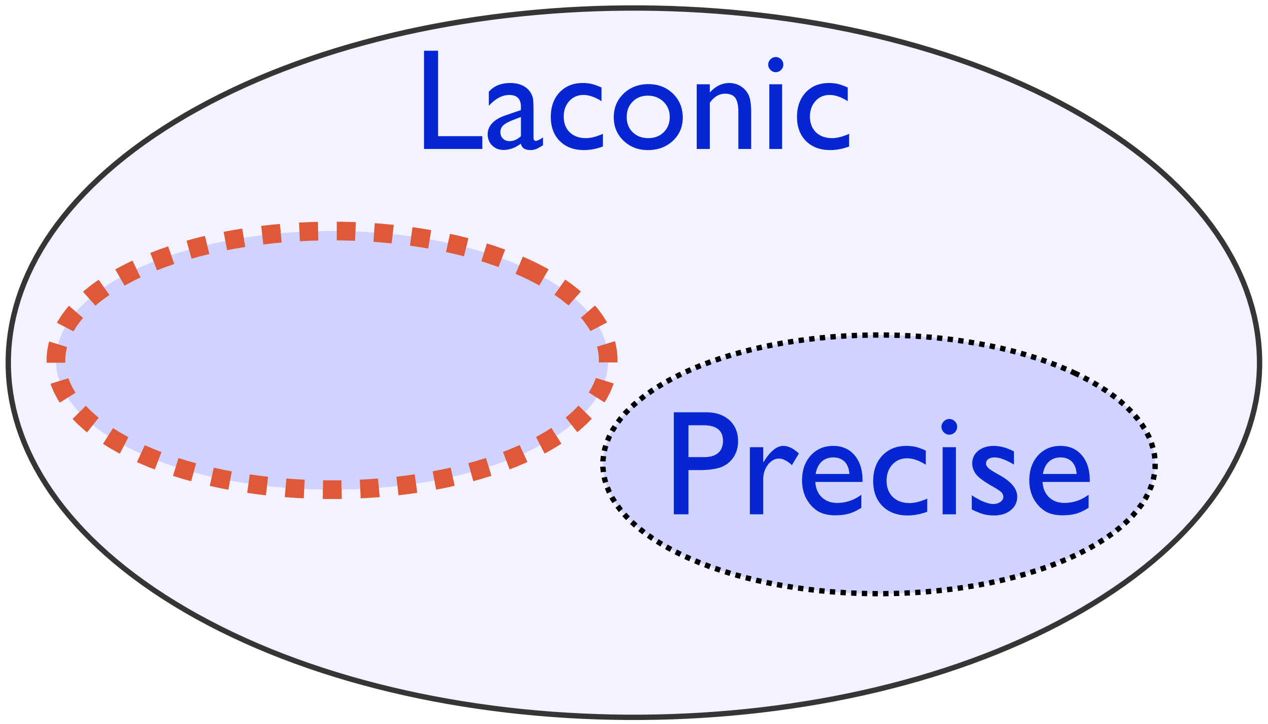
Preferred Laconic Justifications

- Precise justifications don't work as expected
- In the context of an ontology, not all remaining laconic justifications will be easy to understand
- Some weakenings can be confusing:
  - ≥ 1 instead of $= 1$
  - GCI instead of domain axiom
- We need to filter laconic justifications!
- Use those LJ whose axioms have a syntactic resemblance to the asserted axioms in the ontology.

Preferred Laconic Justifications



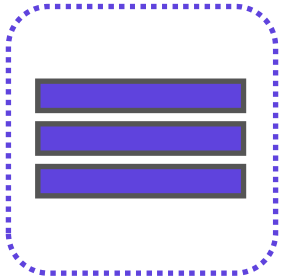
Preferred Laconic Justifications



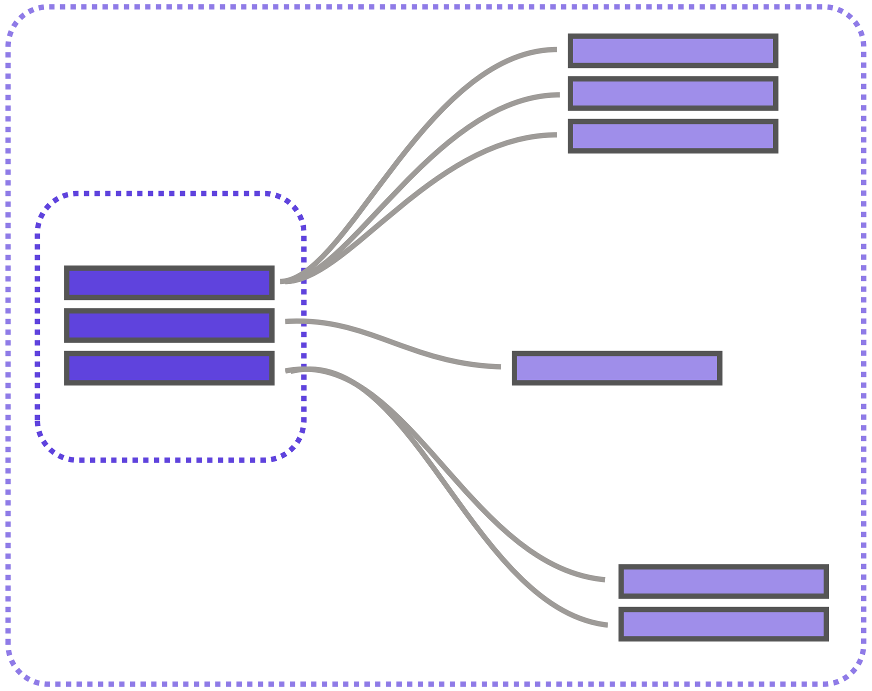
Filter: $\mathcal{O}^+$

- LJs defined with respect to the deductive closure
- There could be many LJs for an entailment
- Need to filter the LJs we are interested in
- ~> *O*+
- *O*+ ensures that LJs have a syntactic resemblance to the original ontology *O*
- Essentially, *O*+ contains systematically weakened axioms from *O*

Filter: $\mathcal{O}^+$



Filter: $\mathcal{O}^{+}$



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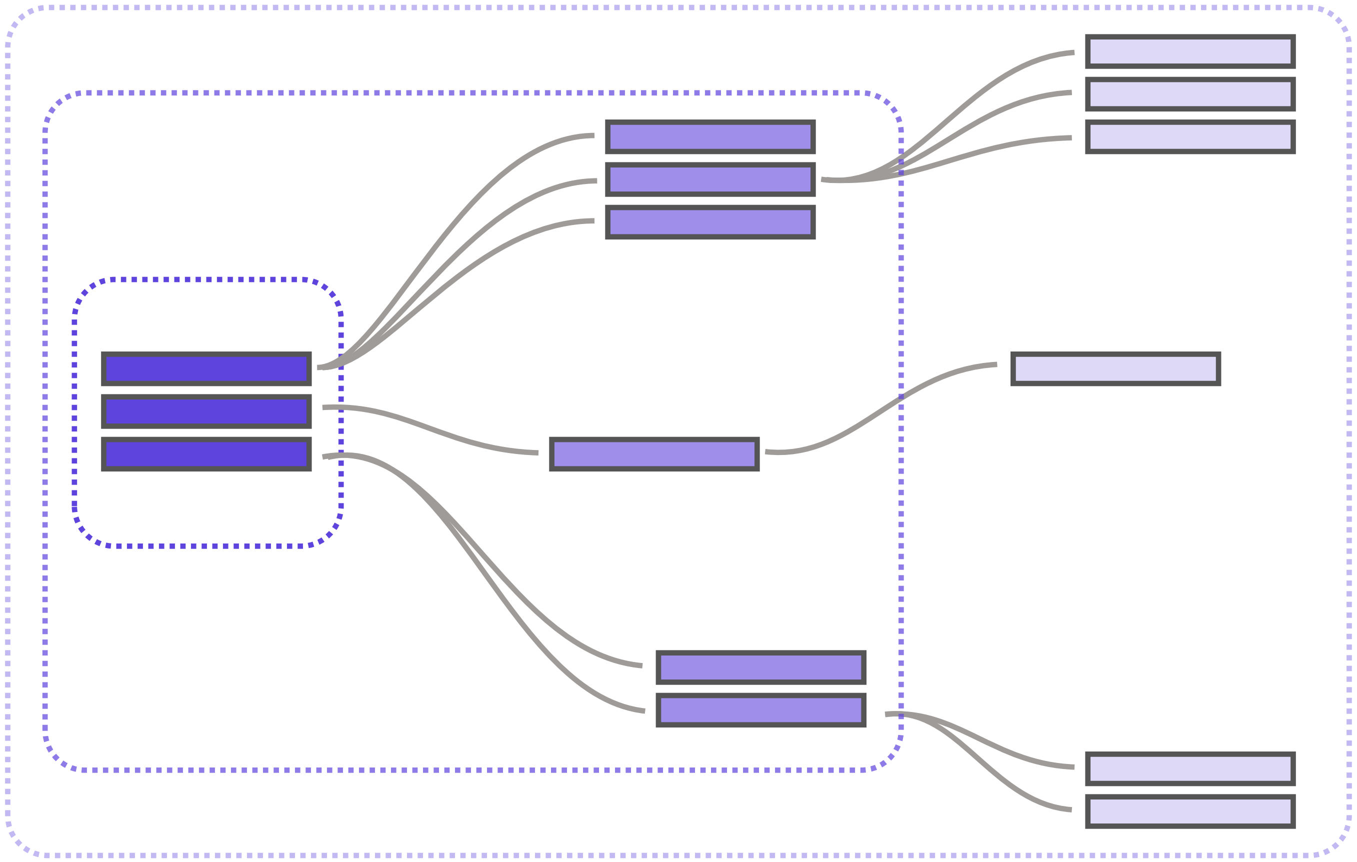

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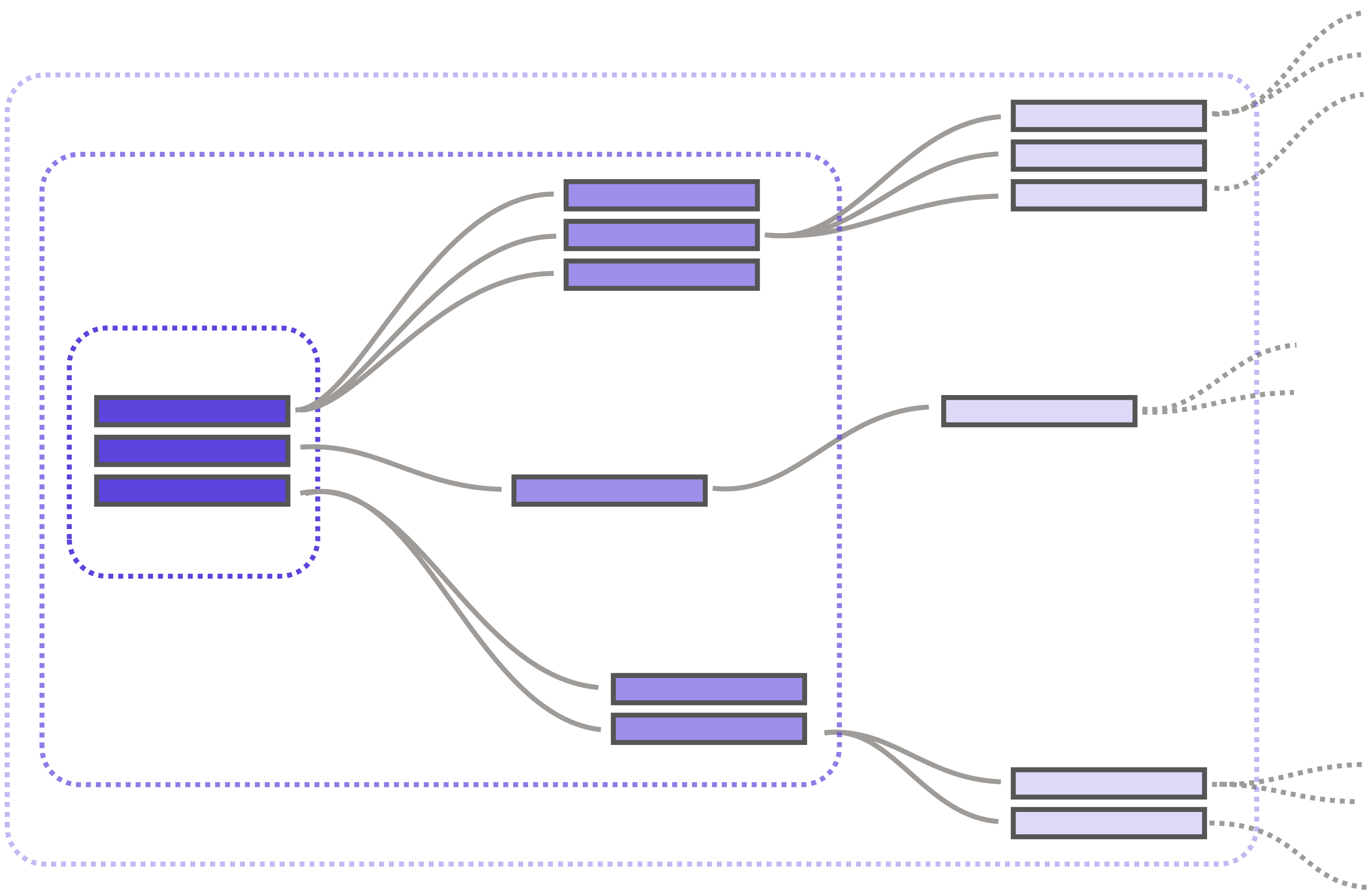

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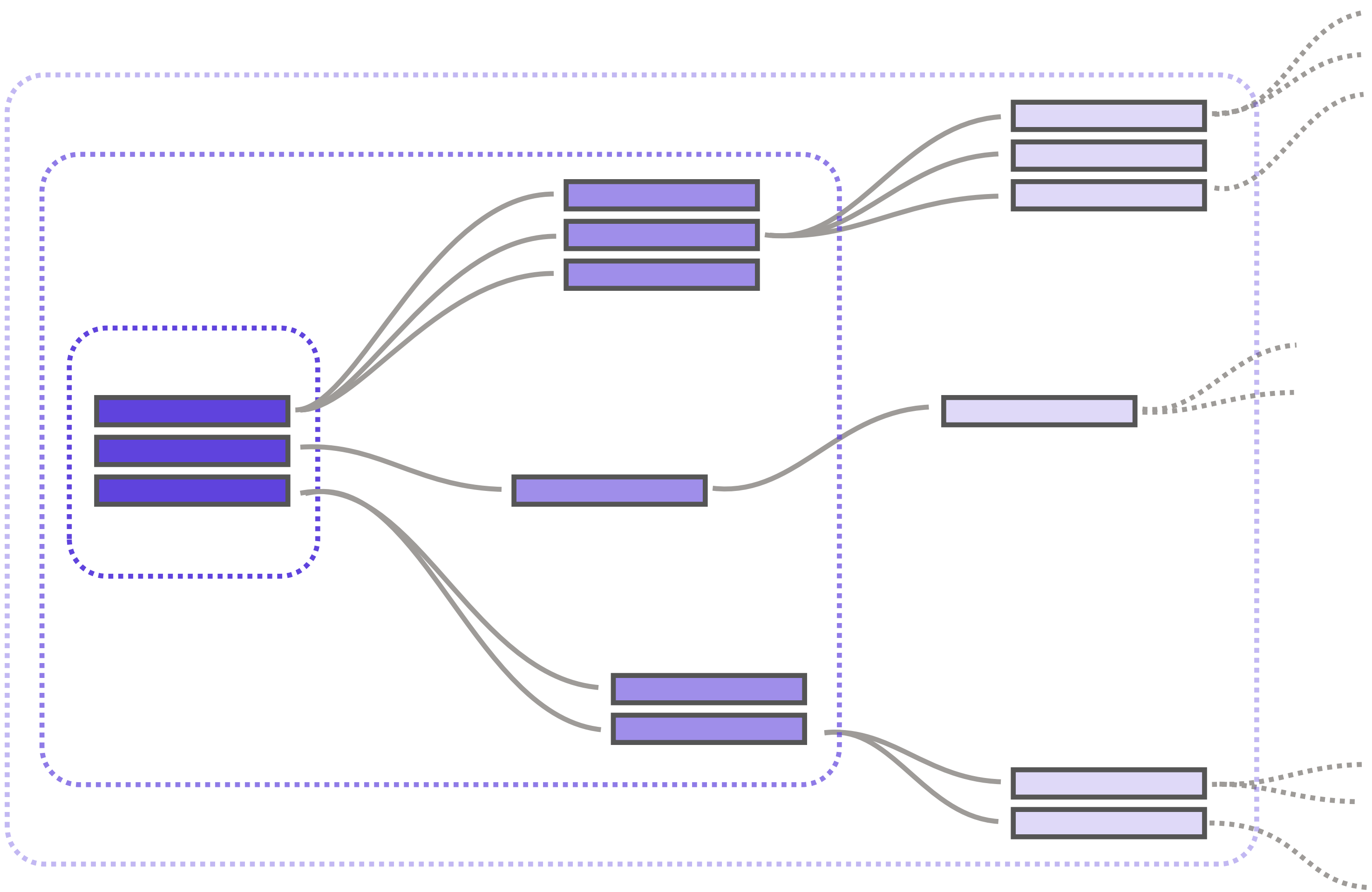
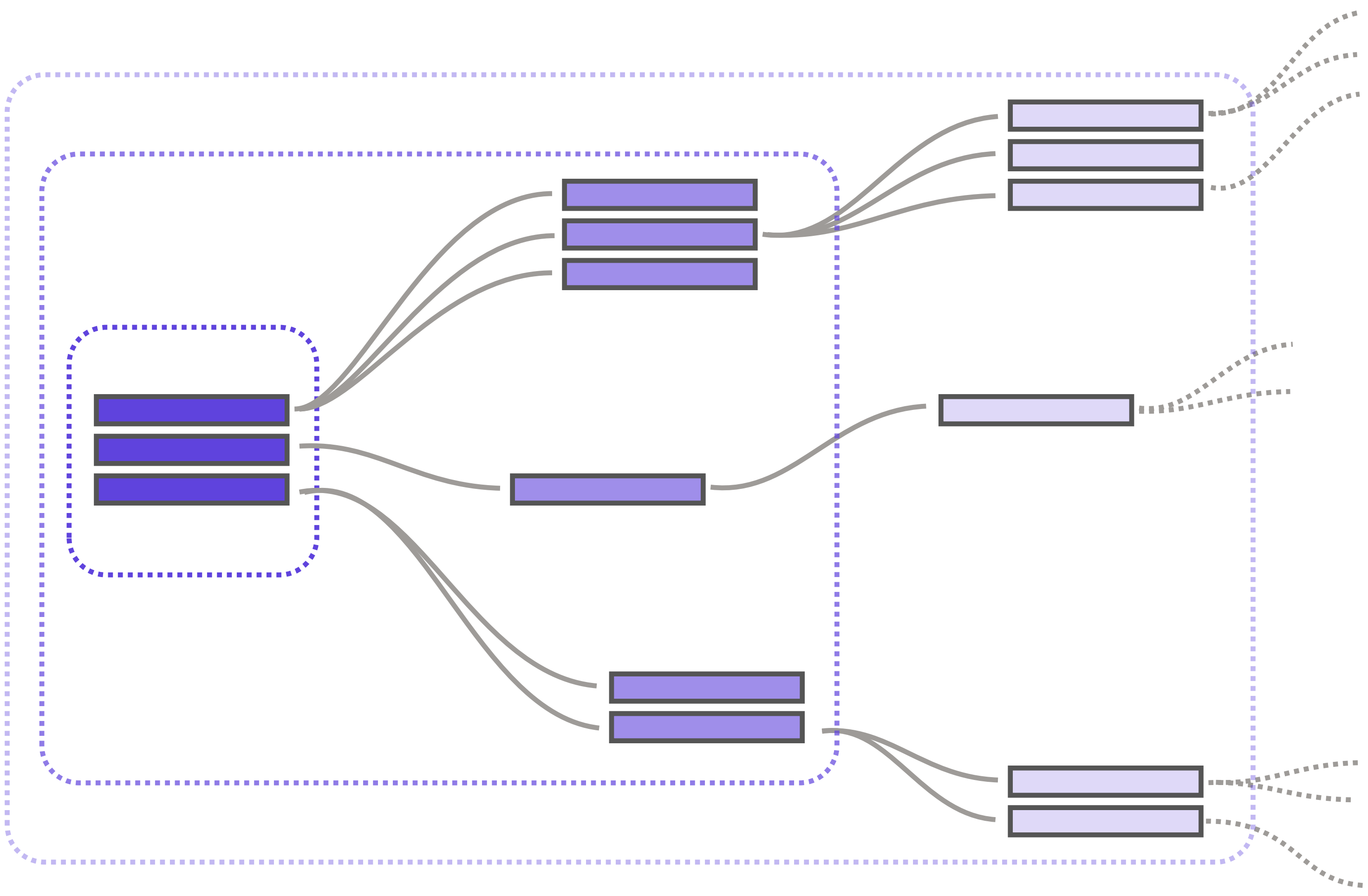


$$A \sqsubseteq B \sqcap \exists R.C$$

Filter: $\mathcal{O}^+$



$A \sqsubseteq \exists R.C$

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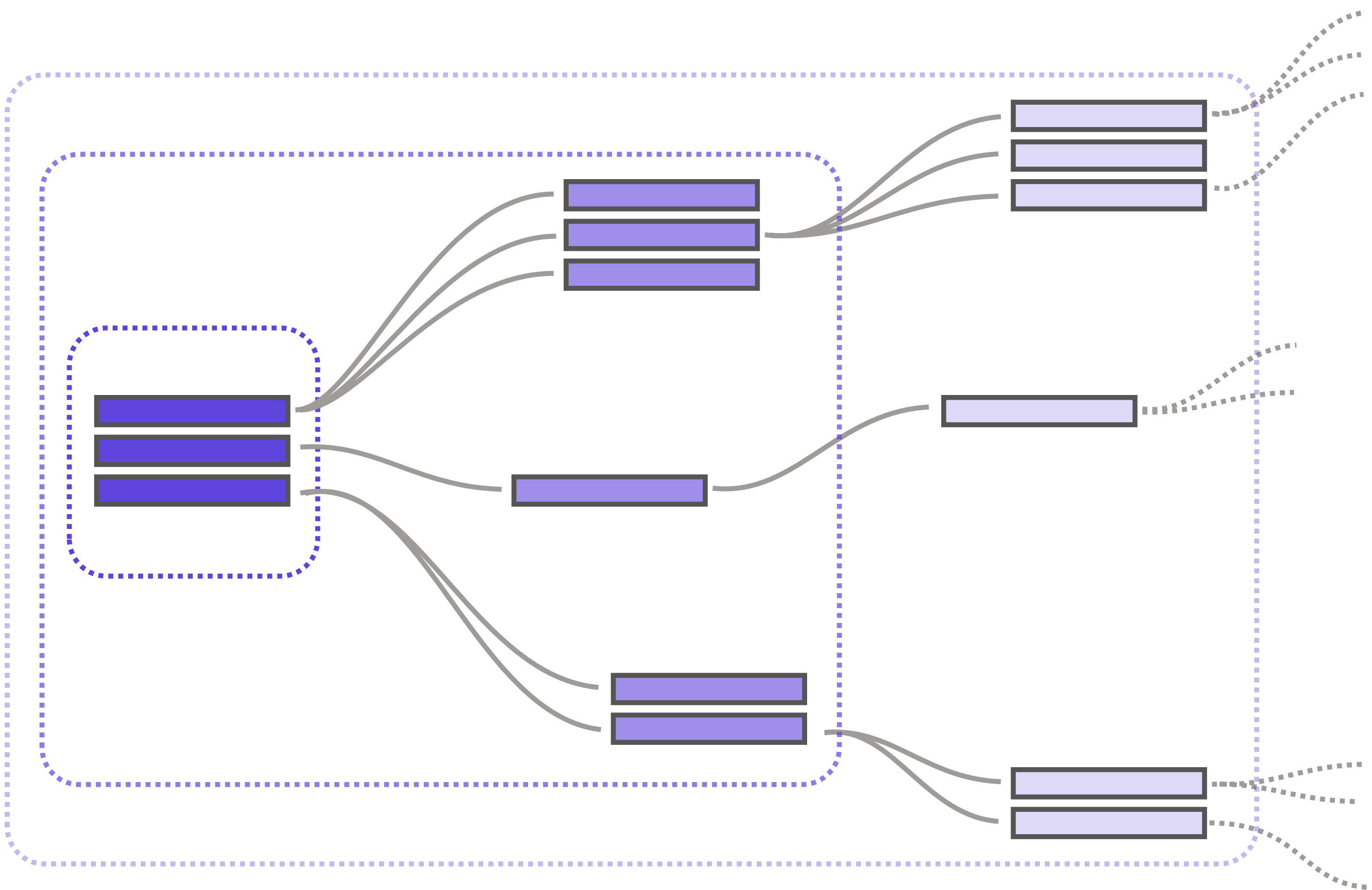
Filter: $\mathcal{O}^+$

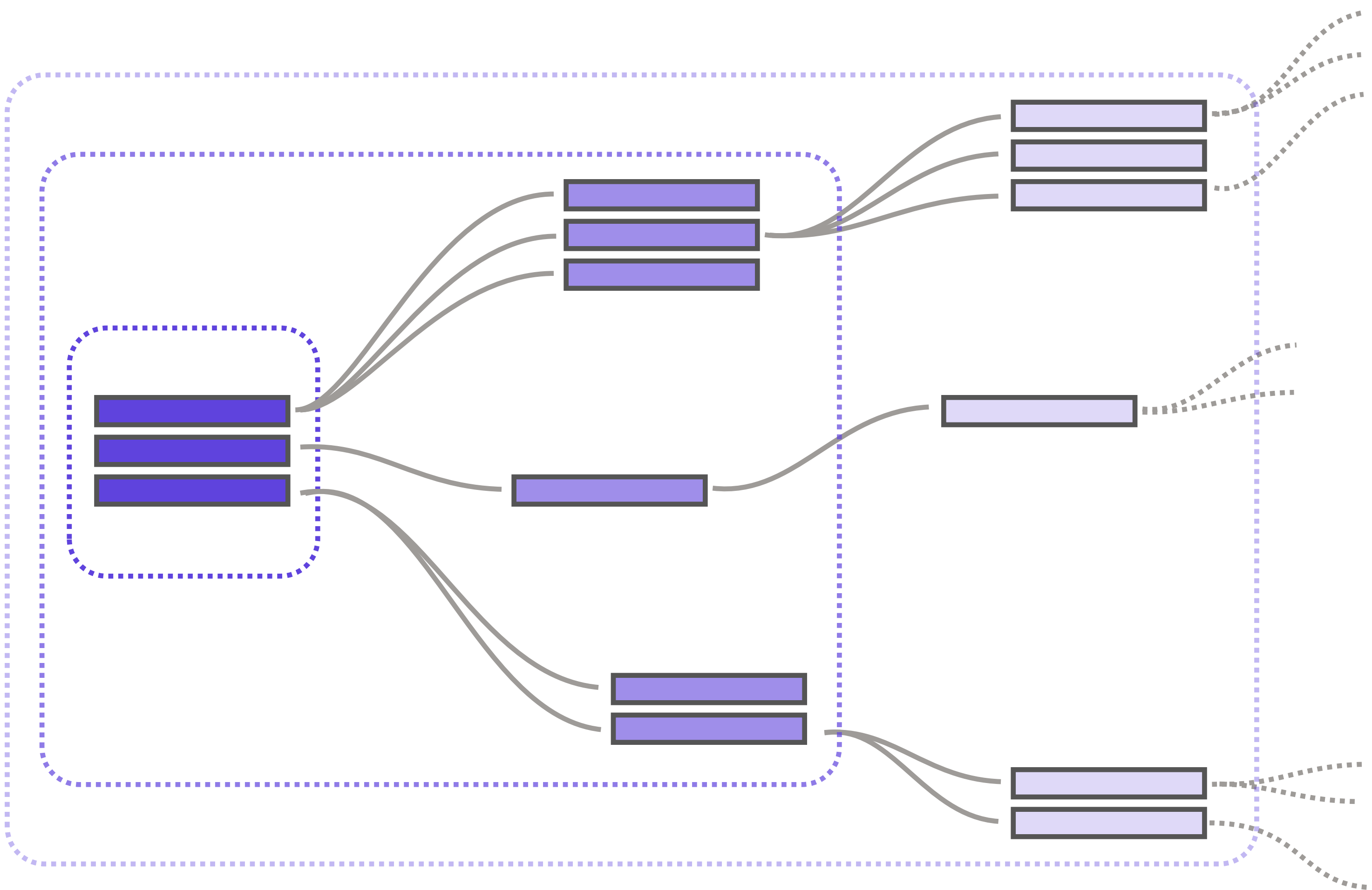


$$A \sqsubseteq B \sqcap \exists R.C$$

$$A \sqsubseteq \exists R.C$$

$$A \sqsubseteq B \sqcap \exists R.\top$$

Filter: $\mathcal{O}^+$



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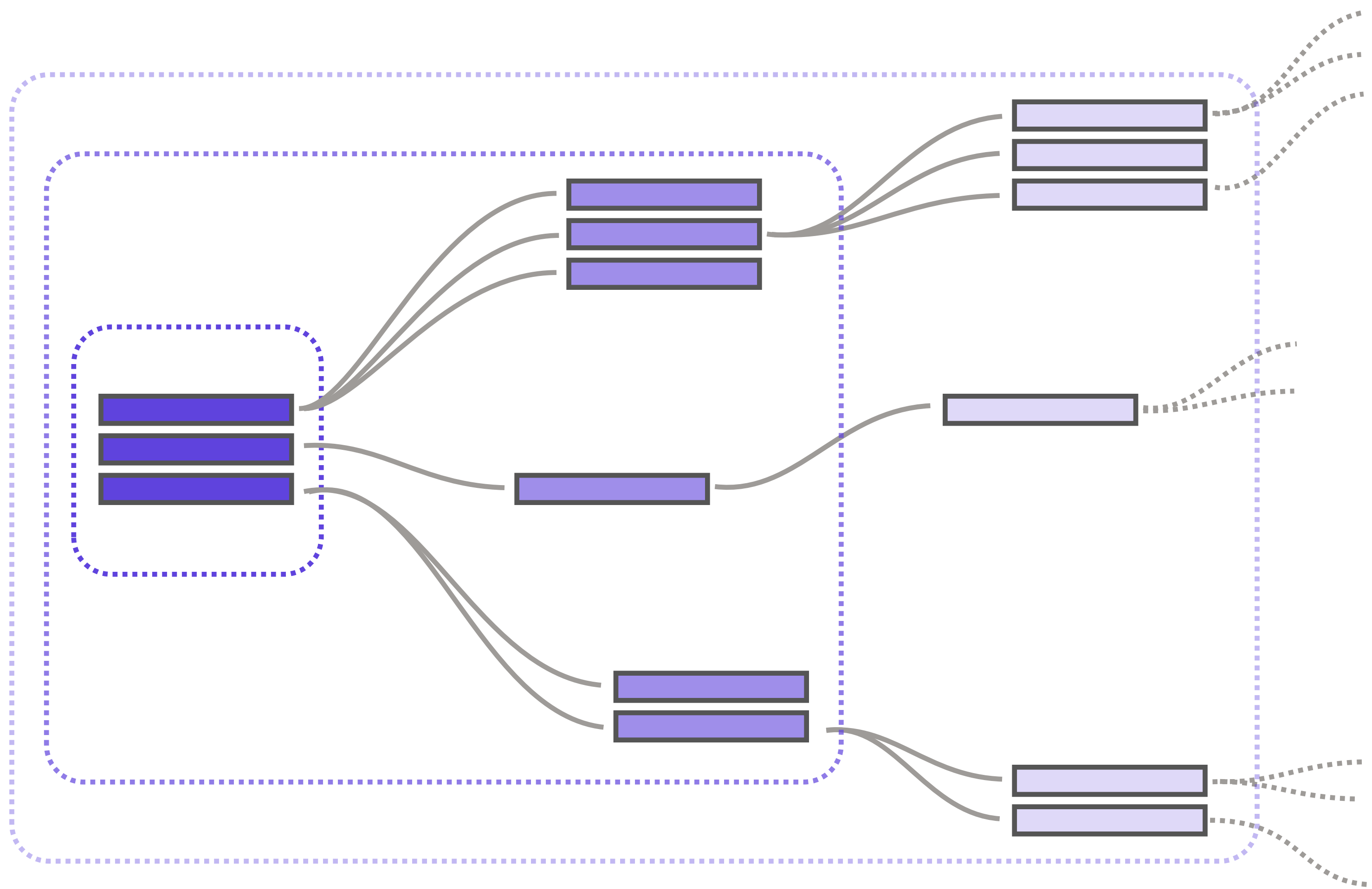
$$A \sqsubseteq B \sqcap \exists R.\top$$

$$A \sqsubseteq B$$

Filter: $\mathcal{O}^+$



$A \sqsubseteq B \sqcap \exists R.C$

$A \sqsubseteq \exists R.C$

$A \sqsubseteq B \sqcap \exists R.\top$

$A \sqsubseteq B$

$A \sqsubseteq \exists R.\top$

Filter: $\mathcal{O}^+$

- O+ is not uniquely determined
- Details depend on how LJs are used:

$$\mathcal{O} = \{C \sqsubseteq D \sqcap \neg D \sqcap E\} \qquad \models C \sqsubseteq \bot$$

$$\mathcal{J}_1 = \{C \sqsubseteq D \sqcap \neg D\}$$

$$\mathcal{J}_2 = \{C \sqsubseteq D,\ C \sqsubseteq \neg D\}$$

For presentation: prefer $\mathcal{J}_1$
For repair: prefer $\mathcal{J}_2$

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Filter: $\mathcal{O}^+$

- Has been devised for DL *SHOIQ*, see paper [1]
- $\mathcal{O} \subseteq \mathcal{O}^+ \subseteq \mathcal{O}^*$
- $\mathcal{O}^+$ is usually finite, but exponentially large, i.e., $|\mathcal{O}^+| \approx 2^{|\mathcal{O}|}$
- Don't need to compute whole $\mathcal{O}^+$!

[1] M. Horridge, B. Parsia, U. Sattler:
Laconic and Precise Justifications in OWL. ISWC '08.

http://owl.cs.manchester.ac.uk/2009/esslli-explanation/HoPaSa08.pdf