

Shape Types for Ambients with Communication Dependencies

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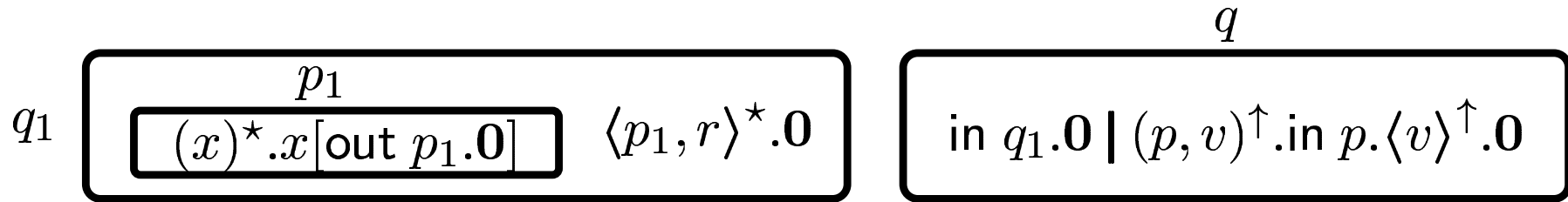
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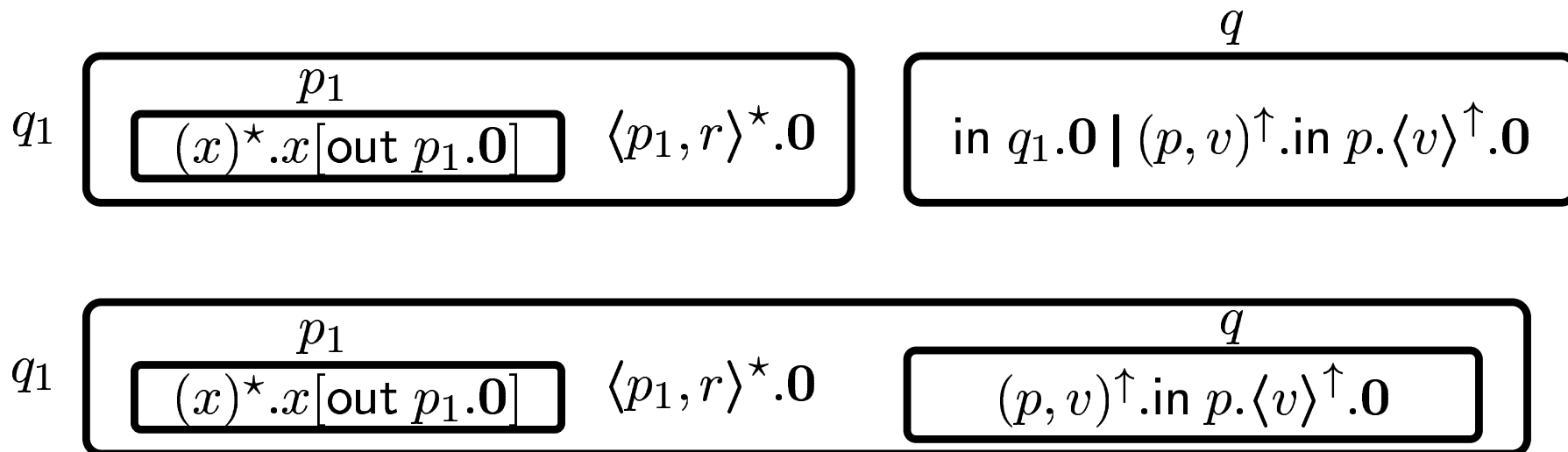
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- **Location:** All processes are located in *ambients* which can be nested, forming a tree.
- **Mobility:** Ambients can move, making the tree dynamic.
- **Communication:** Processes that are “*close*” to each other can exchange values.

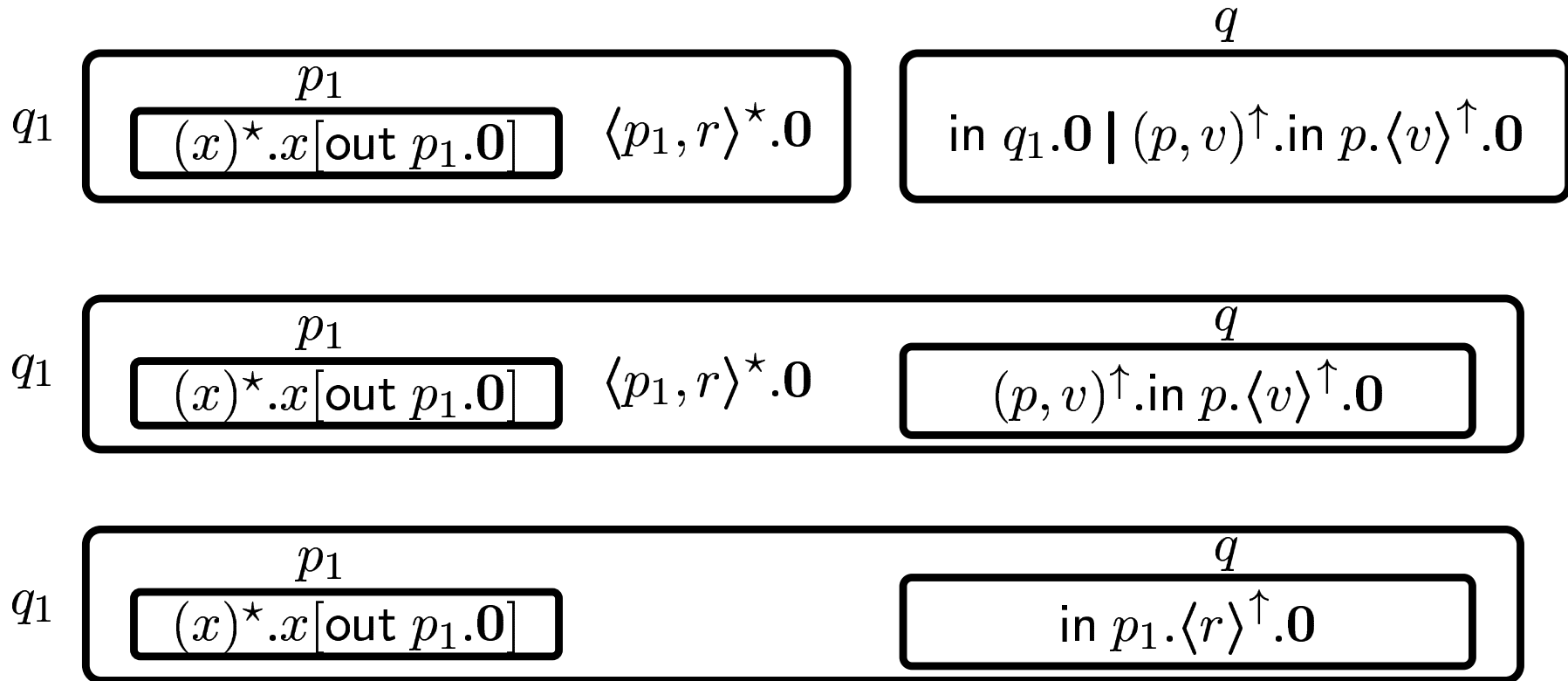
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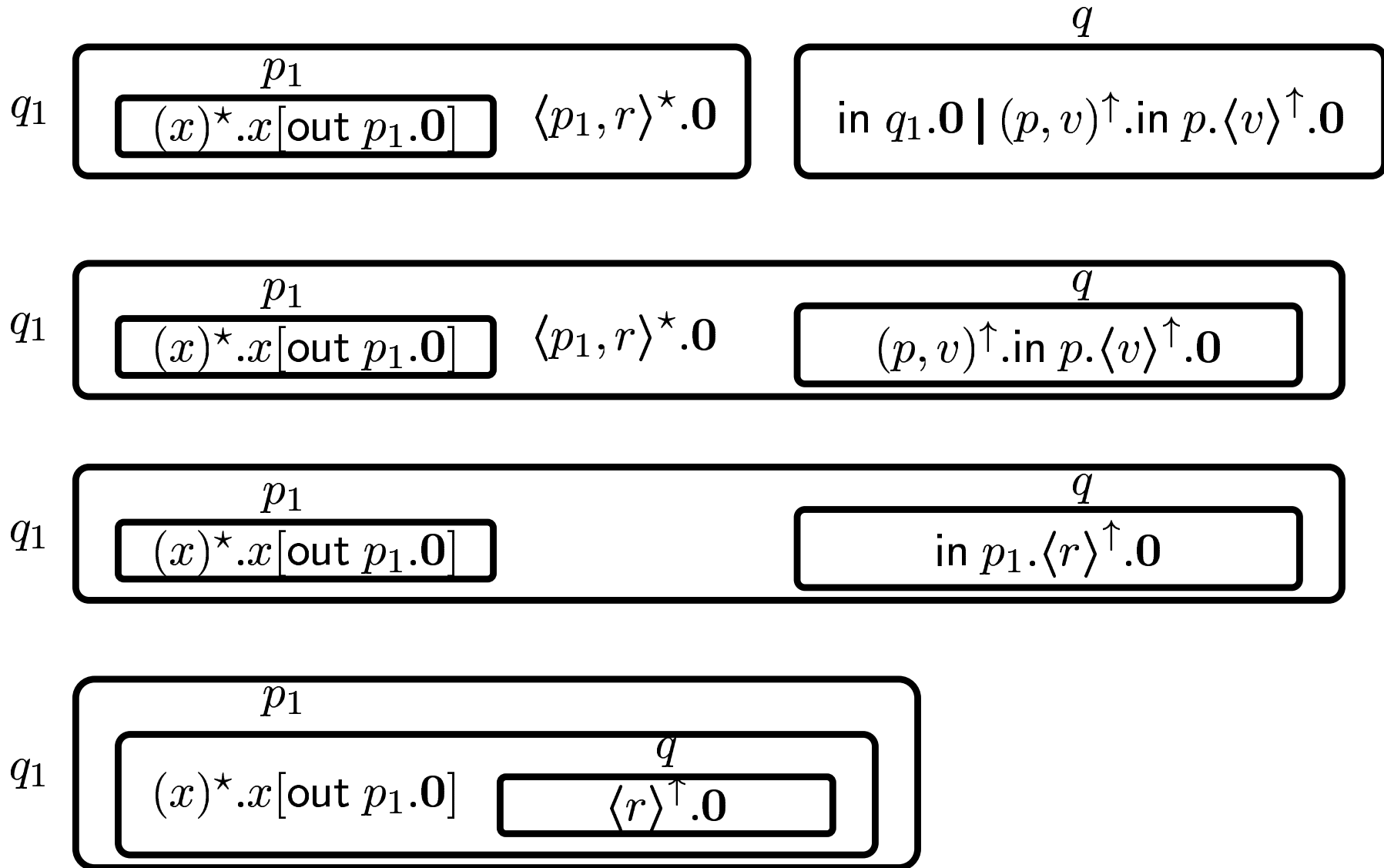
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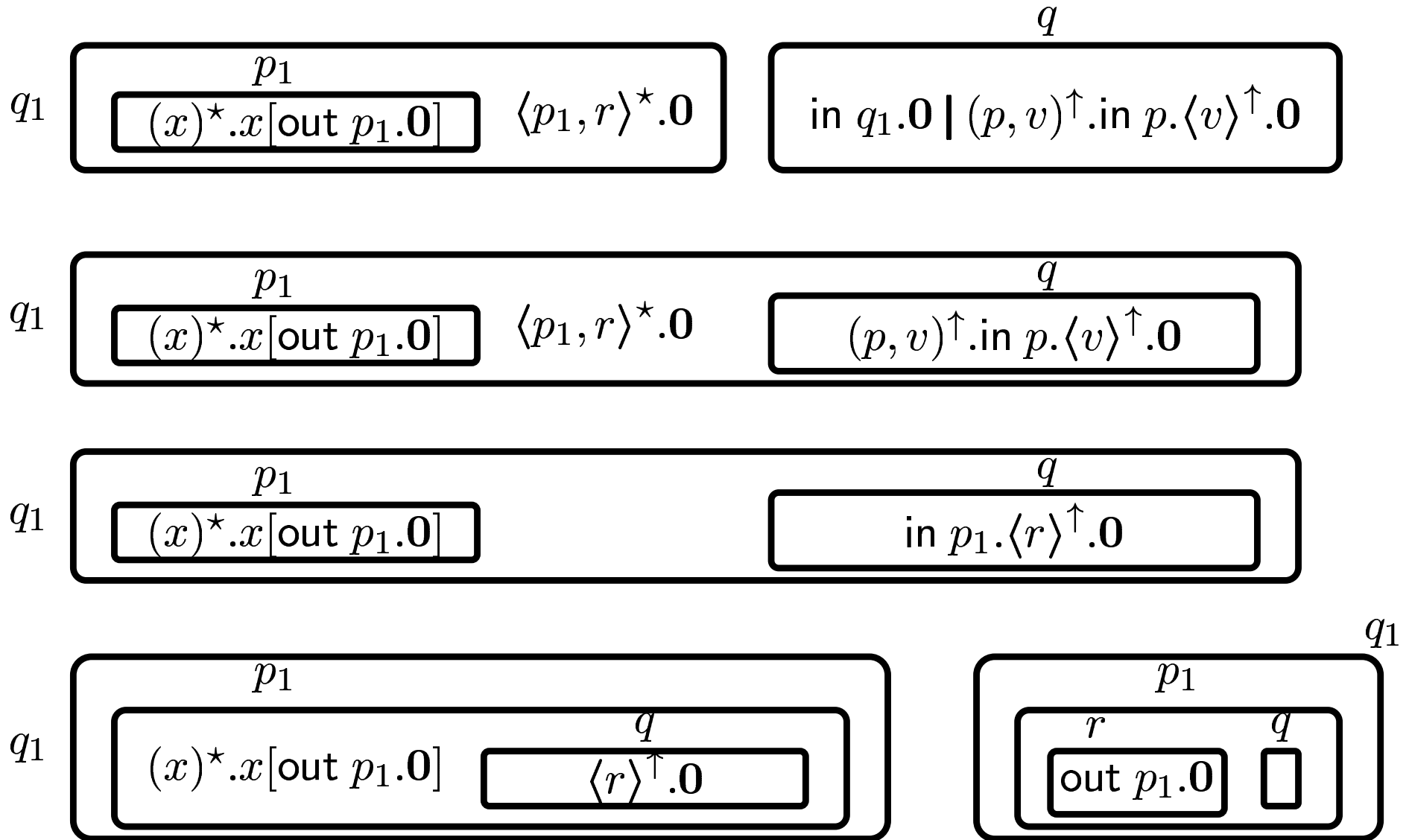
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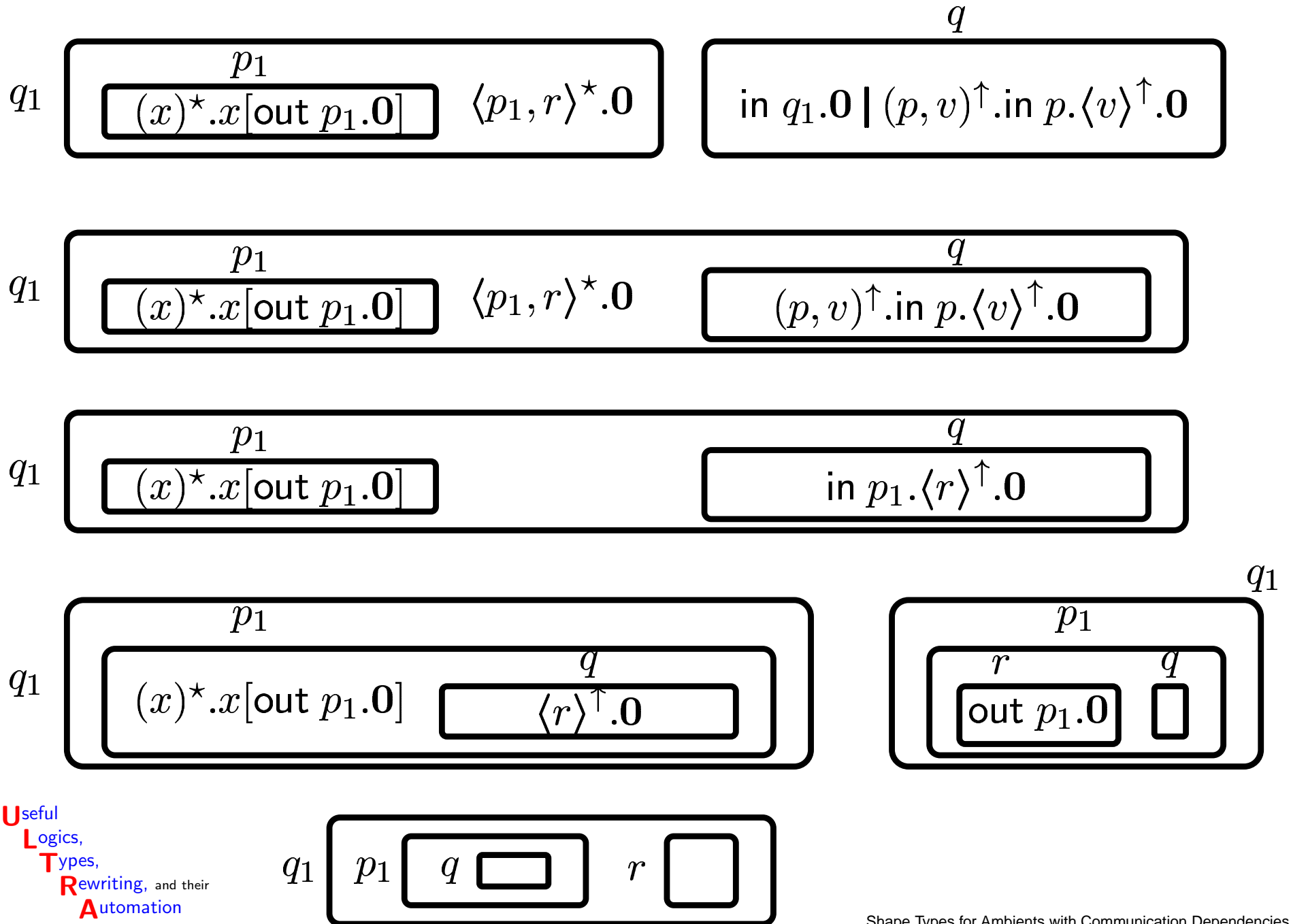
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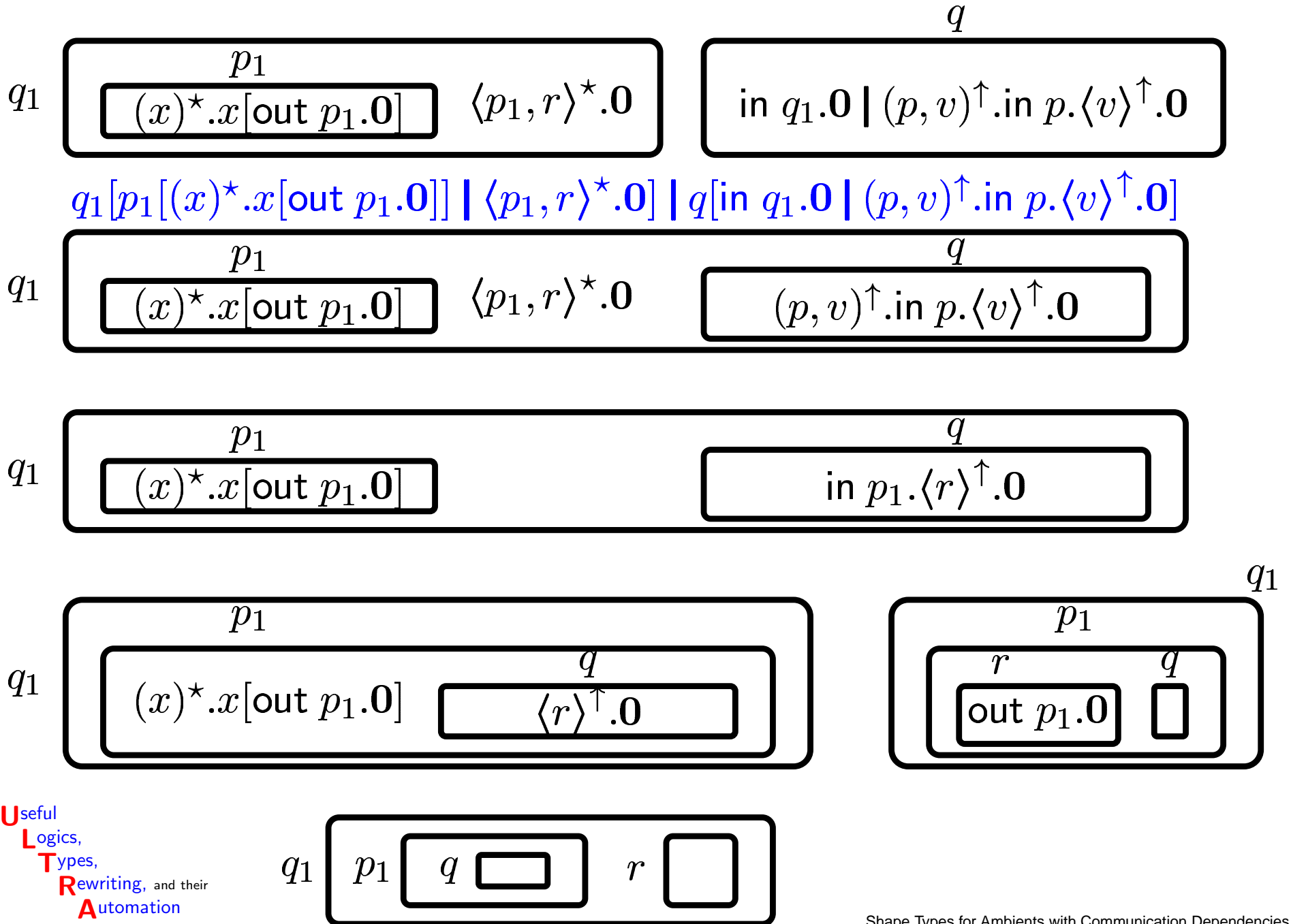
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The Language Formalism

We use the extension of Boxed Ambients with open.

$$\lambda \in \text{Locs} ::= \star \mid \uparrow \mid \downarrow a$$
$$M \in \text{Exp} ::= a \mid c \mid \text{in } a \mid \text{out } a \mid \text{open } a \mid \epsilon \mid M_1.M_2$$
$$P, Q, R \in \text{Proc} ::= \mathbf{0} \mid P_1 \mid P_2 \mid !P \mid (\nu a).P$$
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The semantics are defined by rewrite rules such as:

$$b[(\vec{a})^\uparrow.P \mid R] \mid \langle \vec{M} \rangle^\star.Q \longrightarrow b[P[\vec{a} := \vec{M}] \mid R] \mid Q$$

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A type system should ensure at least well-definedness.

Previous Type Systems

Remember our example:

$$\begin{aligned} & q_1[\langle p_1, r \rangle^* . \mathbf{0} \mid p_1[(x)^* . x[\text{out } p_1 . \mathbf{0}]]] \\ & \mid q[\text{in } q_1 . \mathbf{0} \mid (p, v)^\uparrow . \text{in } p . \langle v \rangle^\uparrow . \mathbf{0}] \end{aligned}$$

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This can be typed by the system for Boxed Ambients (in the spirit of Cardelli & Gordon’s original) because in each ambient the “topic of conversation” is well-defined (for each arity and direction):

$$\begin{aligned} \text{type of } v, x : T_1 &= \text{Amb}[\text{shh}, \text{shh}] \\ \text{type of } p, p_1 : T_2 &= \text{Amb}[T_1, \text{shh}] \\ \text{type of } q : T &= \text{Amb}[\text{shh}, T_1 \cup (T_2 \times T_1)] \end{aligned}$$

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Note: It is unclear what such type assumptions really *mean*.

Example Needing Poly-morphism/variance

We extend the previous example process to have *two* possible execution paths:

$q_1[\langle p_1, r \rangle^*. \mathbf{0} \mid p_1[(x)^*. x[\text{out } p_1. \mathbf{0}]]]$ (*x must be a name*)

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To overcome some of the weaknesses of previous type systems for ambient calculi, we will now present a new type system.

The New Type System (1)

- The types represent upper bounds on the possible ambient nesting tree into which a process can evolve, e.g.:

$$\left(a[\text{in } b.\mathbf{0}] \mid b[\mathbf{0}] \right) \quad : \quad \left(a[\text{in } b] \mid b[a[\text{in } b]] \right)$$

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- The types say nothing about the number of copies of a feature at a location.

The New Type System (2)

- There are singleton types of ambient names and explicit dependencies on communication, e.g.:

$$\left((x)^* . x[\mathbf{0}] \mid \langle a \rangle^* . \mathbf{0} \right) \quad : \quad \left(((x)^* \rightarrow x[\mathbf{0}]) \mid \langle a \rangle^* \mid a[\mathbf{0}] \right)$$

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- The types merge distinct ambients at a location with the same name:

$$a[T_1] \mid a[T_2] \doteq a[T_1 \mid T_2]$$

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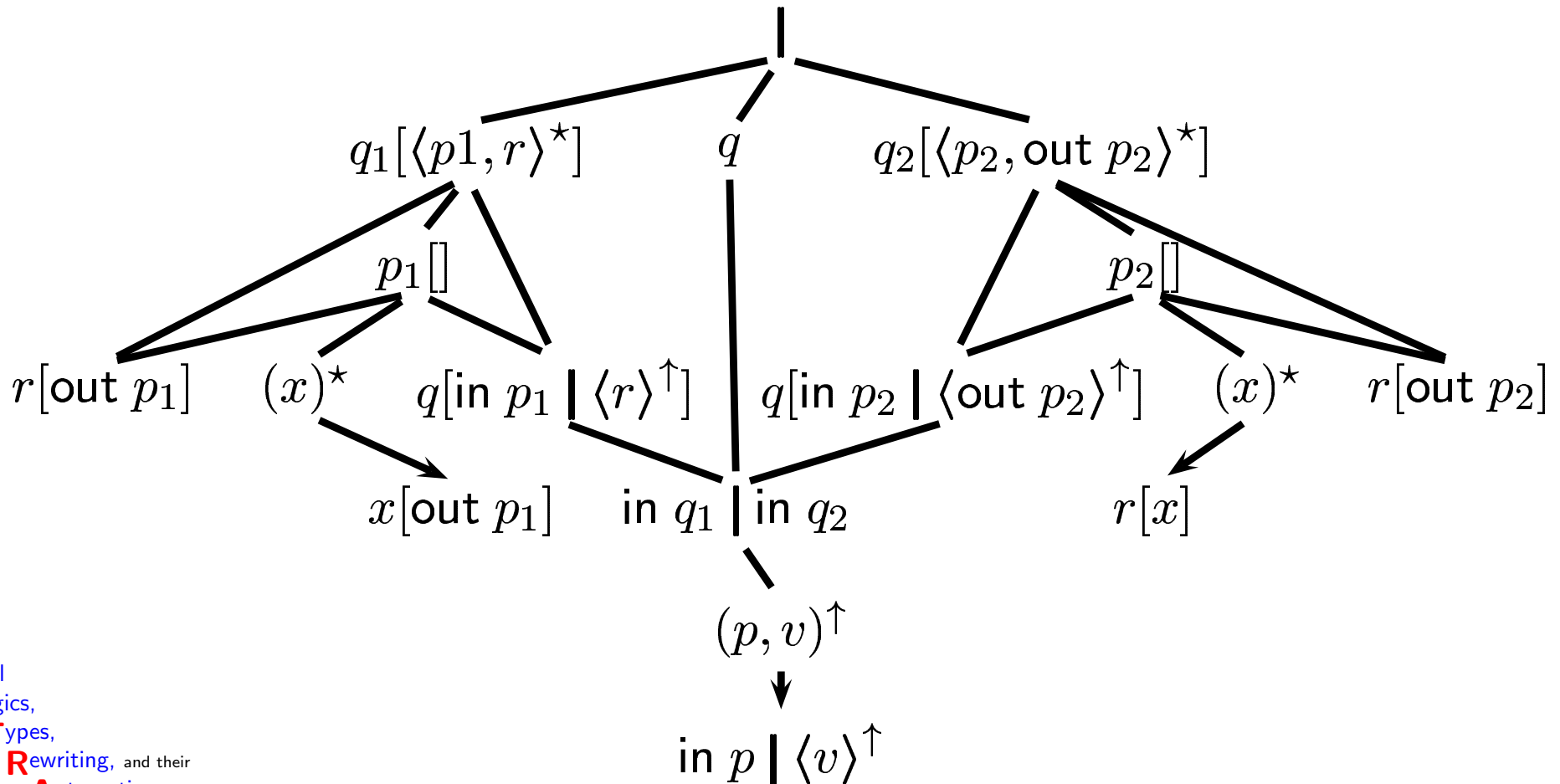
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- For our convenience, there is only one sort of types which is used for both messages (a.k.a. expressions) and processes.

Typing for Example Program

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We demand that types are closed under certain rules that simulate rewriting, such as:

$$a[T_1] \mid b[T_2] \leq T \text{ and } (\text{in } b) \leq T_1 \Rightarrow b[a[T_1] \mid T_2] \leq T$$

$$(\vec{a})^* \rightarrow T' \leq T \text{ and } \langle \vec{T} \rangle^* \leq T \Rightarrow T'[\vec{a} := \vec{T}] \leq T$$

(implying LHS well-defined)

To compute the closure, approximations are needed.

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- **Subject reduction:** If $P \longrightarrow Q$ and $P : T$ (thus T closed), then $Q : T$.
- **Safety:** If $P : T$ (thus T closed), then execution of P will never give rise to an ill-defined substitution.

Anomaly with open

Consider this term:

$$a[\text{in } b.\mathbf{0}] \mid b[\text{open } a.\mathbf{0}]$$

Ignoring the closedness requirement, we could give it this type:

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This repeats forever. To close the type requires a recursive type:

$$a[\text{in } b] \mid \text{letrec } X = b[a[\text{in } b] \mid \text{open } a \mid \text{in } b \mid X] \text{ in } X$$

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- **Multiplicities.** Counting is not enough because the types “confuse the past with the future”, e.g., the count z must be ω to make this type closed:

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- **Union types.** Together with multiplicities, union types could work theoretically, but they are not feasible because each point in the possible future state space would likely become a separate type.

Embedding Cardelli & Gordon (POPL '99)

At least for ν -free programs, we can translate a typing.

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A mechanical translation converts the above into this type:

$$\begin{aligned} \text{letrec } X_C &= \text{in } \{a, b, c, y\} \mid \text{out } \{a, b, c, y\} \mid \text{action} \\ X_A &= a[X_1] \mid b[X_1] \mid c[X_0] \\ X_0 &= X_A \mid X_C \mid \text{open } \{c, y\} \\ X_1 &= X_A \mid X_C \mid \text{open } \{a, b\} \mid \langle c \rangle^* \mid \langle y \rangle^* \mid (y)^* \rightarrow X_1 \\ \text{in } X_0 \end{aligned}$$

Embedding Cardelli & Gordon (POPL '99)

At least for ν -free programs, we can translate a typing.

$$a[\text{open } b.(y)^*. \text{in } y.0 \mid b[\langle c \rangle^*.0]] \mid c[0]$$

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This can probably be extended to Mobility Types
(Cardelli & Ghelli & Gordon).

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Very precise, but potentially also very expensive.

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None of the above-listed work handles communication, so none can show our example is safe.

Conclusion

We presented a type system for a variant ambient calculus that:

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- Evaluating practical usefulness and feasibility.