COSE419: Software Verification

Lecture 11 – Static Analysis Overview

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2024 Spring

Principles of Static Analysis

$$30 \times 12 + 11 \times 9 = ?$$

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  - “positive integer”
  - “integer between 400 and 500”
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1. Choose abstract value (domain)

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  - "integer"
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1. Choose abstract value (domain)

2. "Execute" the program with abstract values

$$e \hat{\times} e \hat{+} o \hat{\times} o = o$$

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Strength of Static Analysis

- By contrast to testing, static analysis can prove the absence of bugs

```
void f (int x) {
    y = x * 12 + 9 * 11;
    assert (y % 2 == 1);
}
```

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T (don't know)

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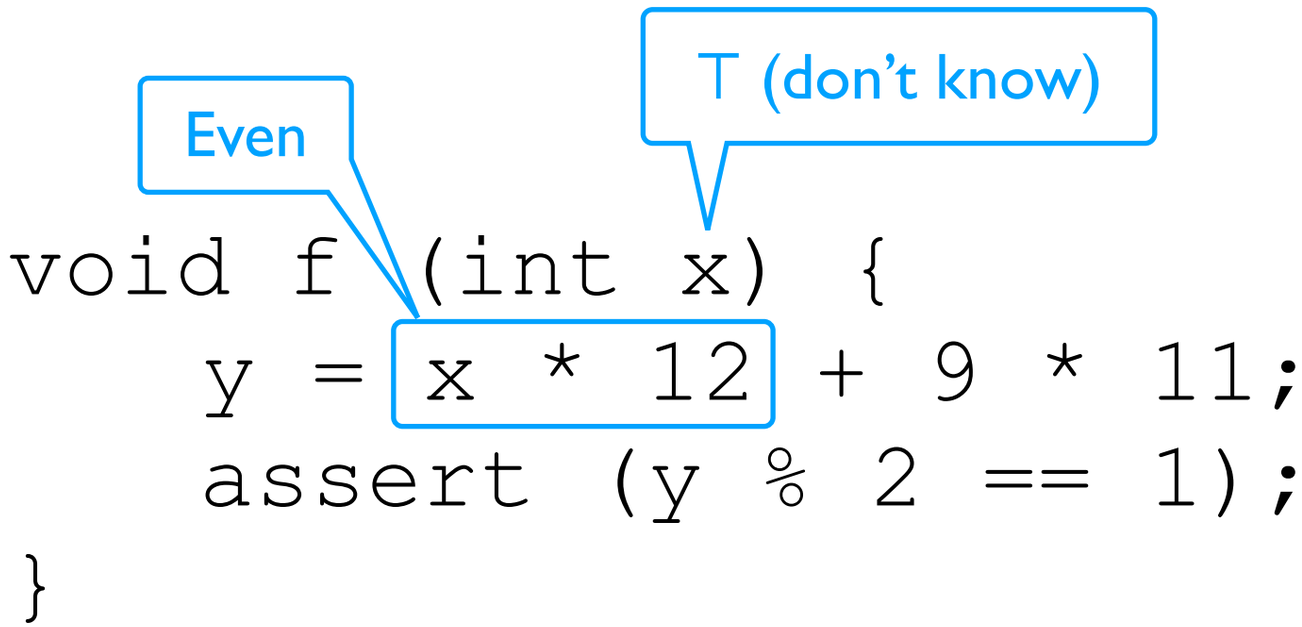

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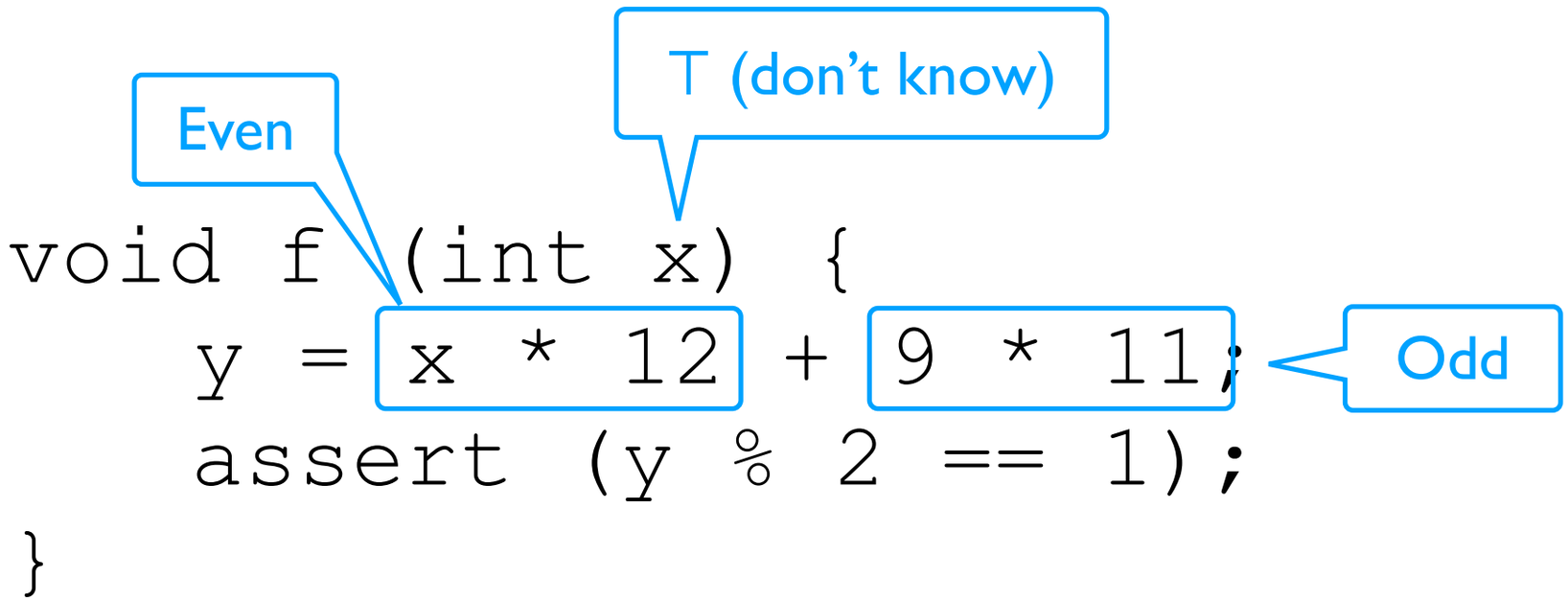

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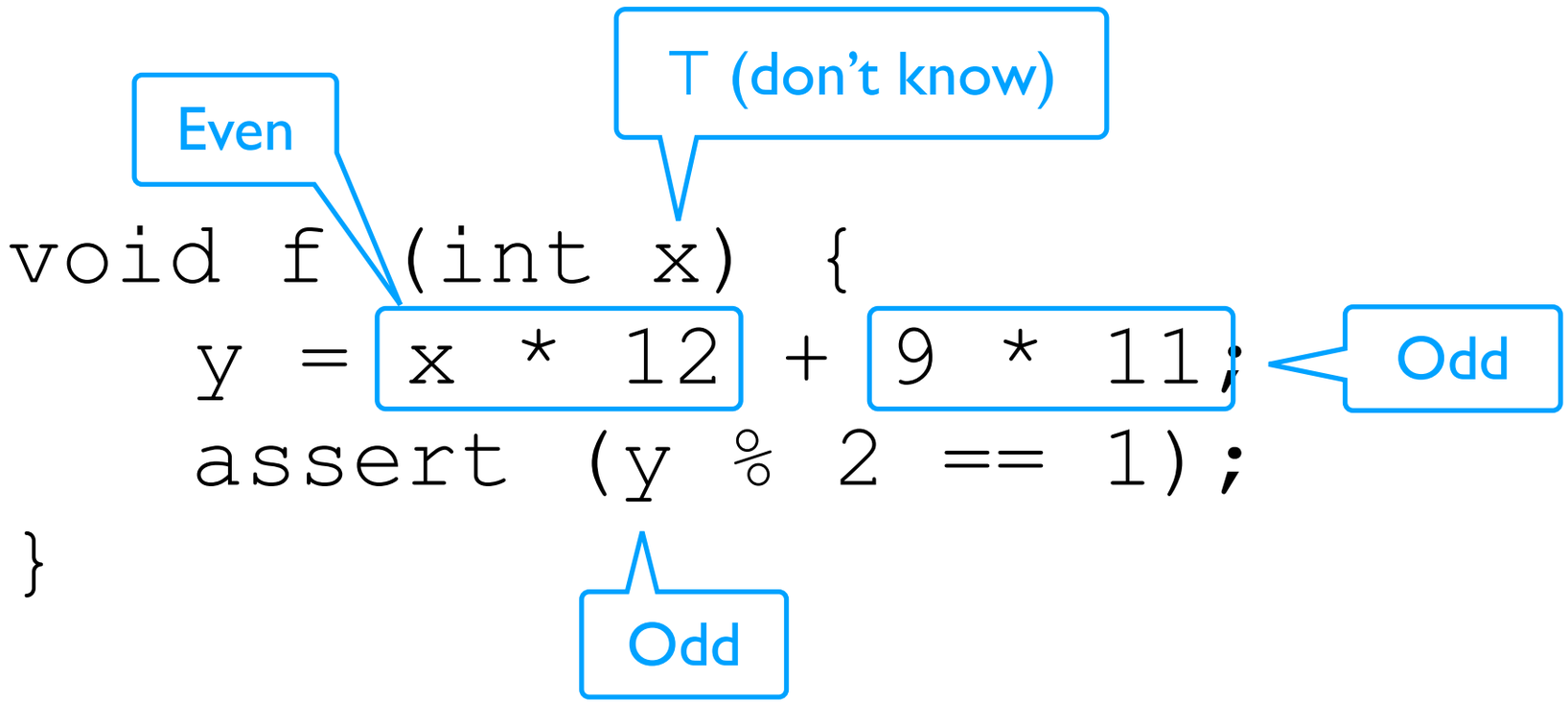

Strength of Static Analysis

- By contrast to program verification, static analysis can prove the absence of bugs automatically

```
@pre: n >= 0
@post: rv == n
int SimpleWhile (int n) {
   int i = 0;
   while
   @L: 0 <= i <= n
   (i < n) {
      i = i + 1;
   }
}
```

Weakness of Static Analysis

- Instead, static analysis may produce false alarms

```
void f (int x) {
    y = x + x;
    assert (y % 2 == 0);
}
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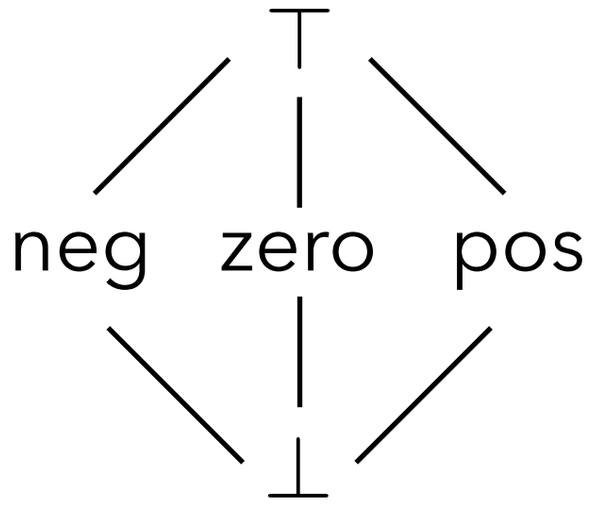
false alarm

A Simple Sign Domain

- Abstract values



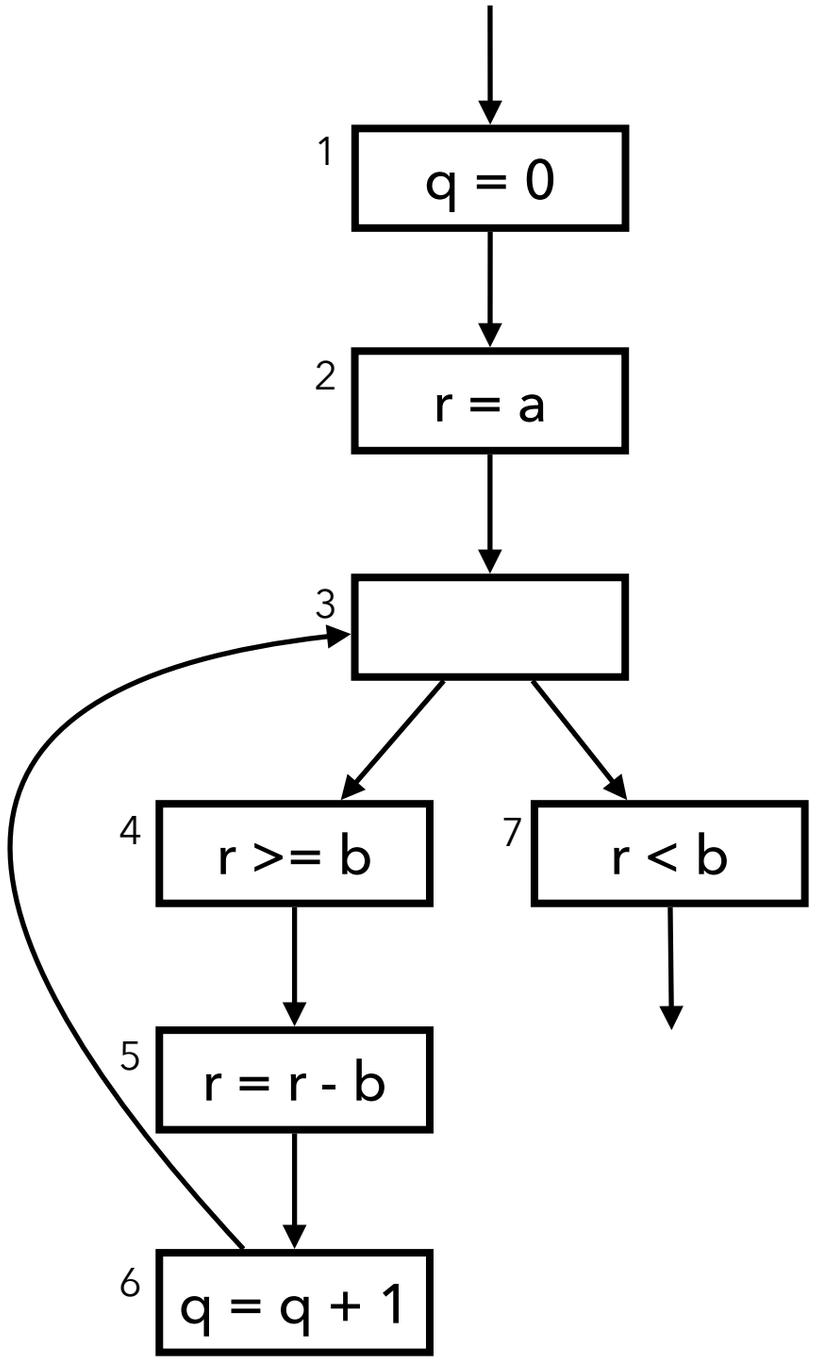
- Abstract operators

+/−	top	neg	zero	pos	bot
top					
neg					
zero					
pos					
bot					

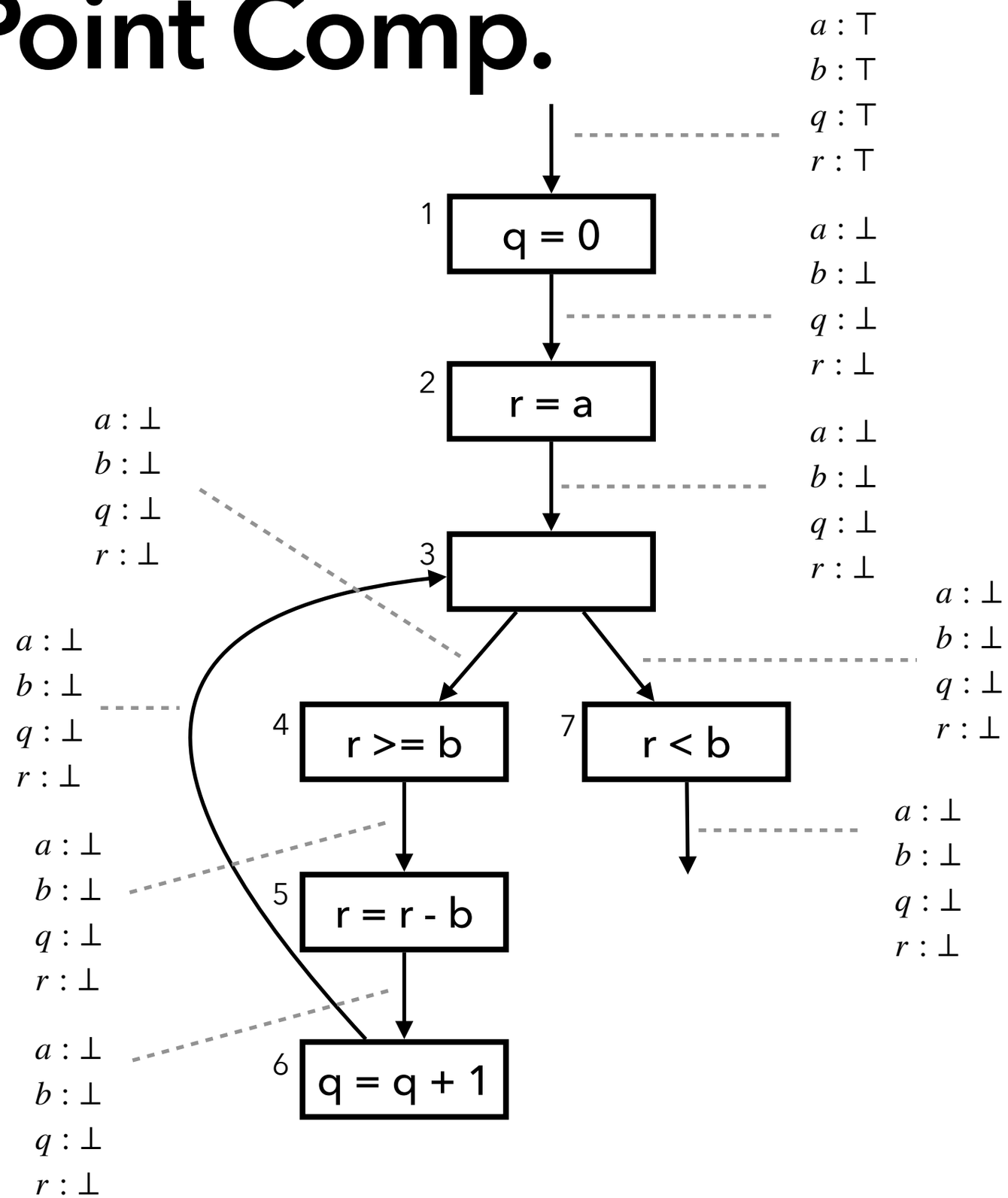
×	top	neg	zero	pos	bot
top					
neg					
zero					
pos					
bot					

Example Program

```
// a >= 0, b >= 0
q = 0;
r = a;
while (r >= b) {
  r = r - b;
  q = q + 1;
}
assert(q >= 0);
assert(r >= 0);
```

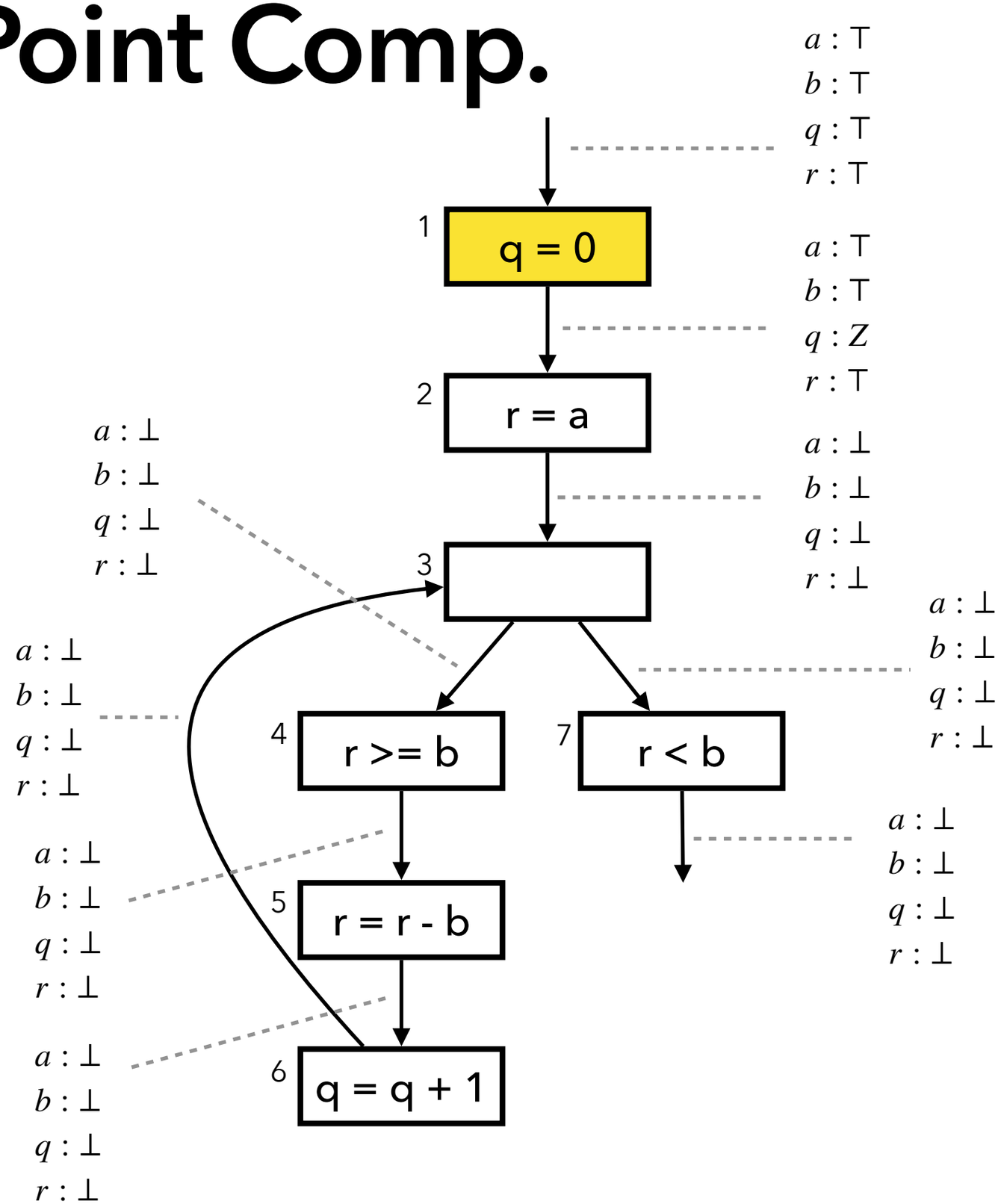


Fixed Point Comp.



W = { 1, 2, 3, 4, 5, 6, 7 }

Fixed Point Comp.



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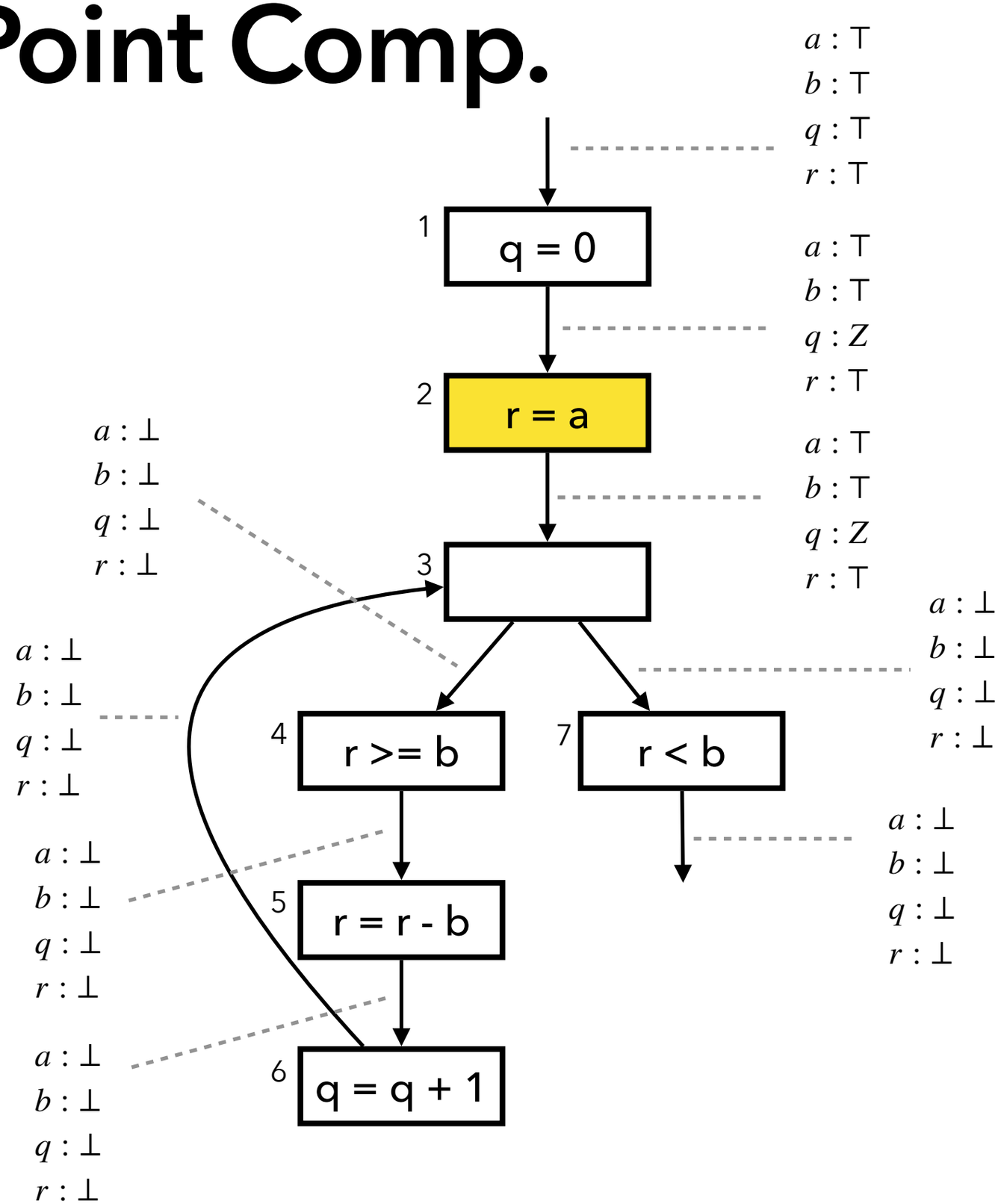

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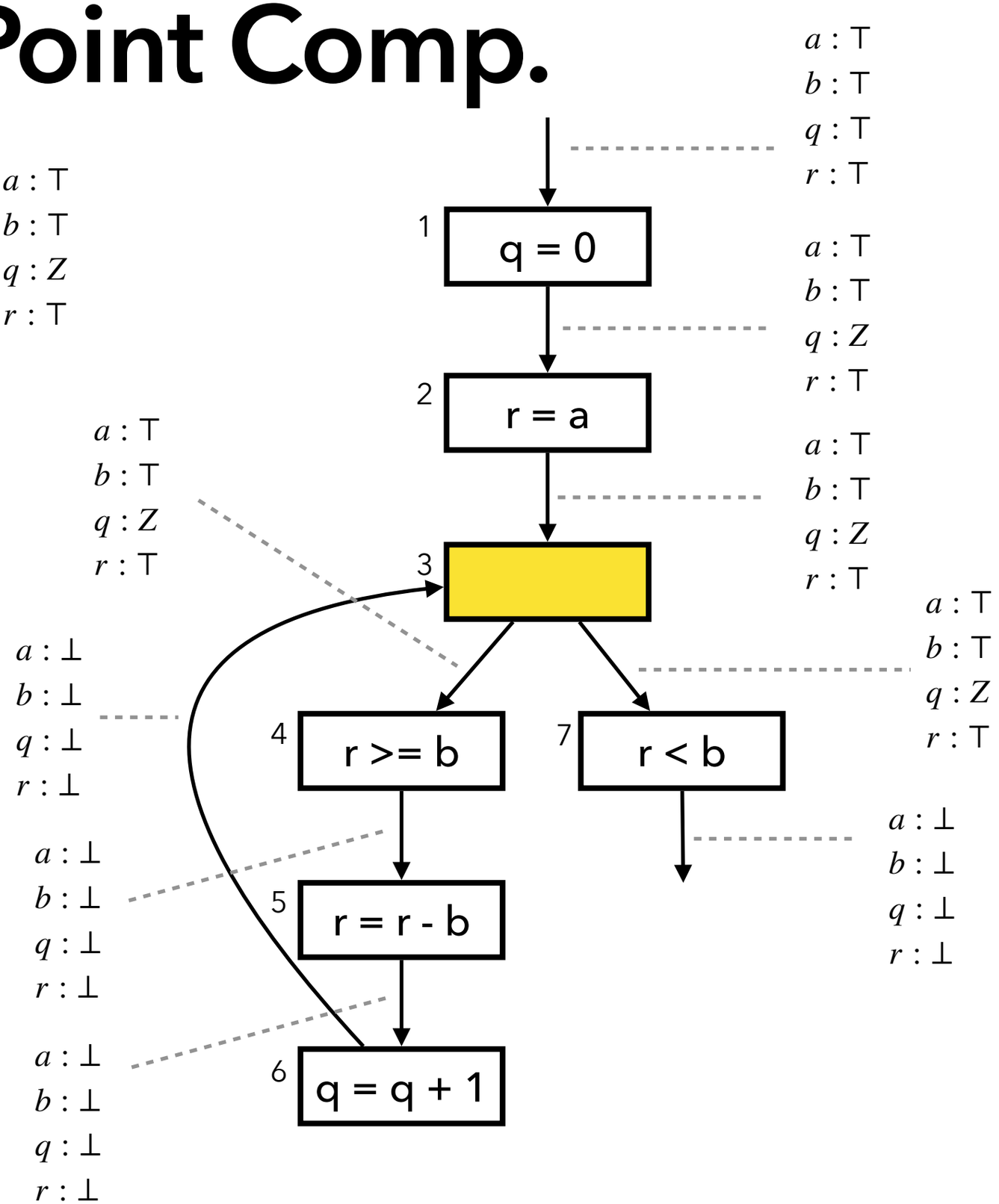
Fixed Point Comp.

$$\begin{matrix} a:\top \\ b:\top \\ q:Z \\ r:\top \end{matrix} \sqcup \begin{matrix} a:\bot \\ b:\bot \\ q:\bot \\ r:\bot \end{matrix} = \begin{matrix} a:\top \\ b:\top \\ q:Z \\ r:\top \end{matrix}$$



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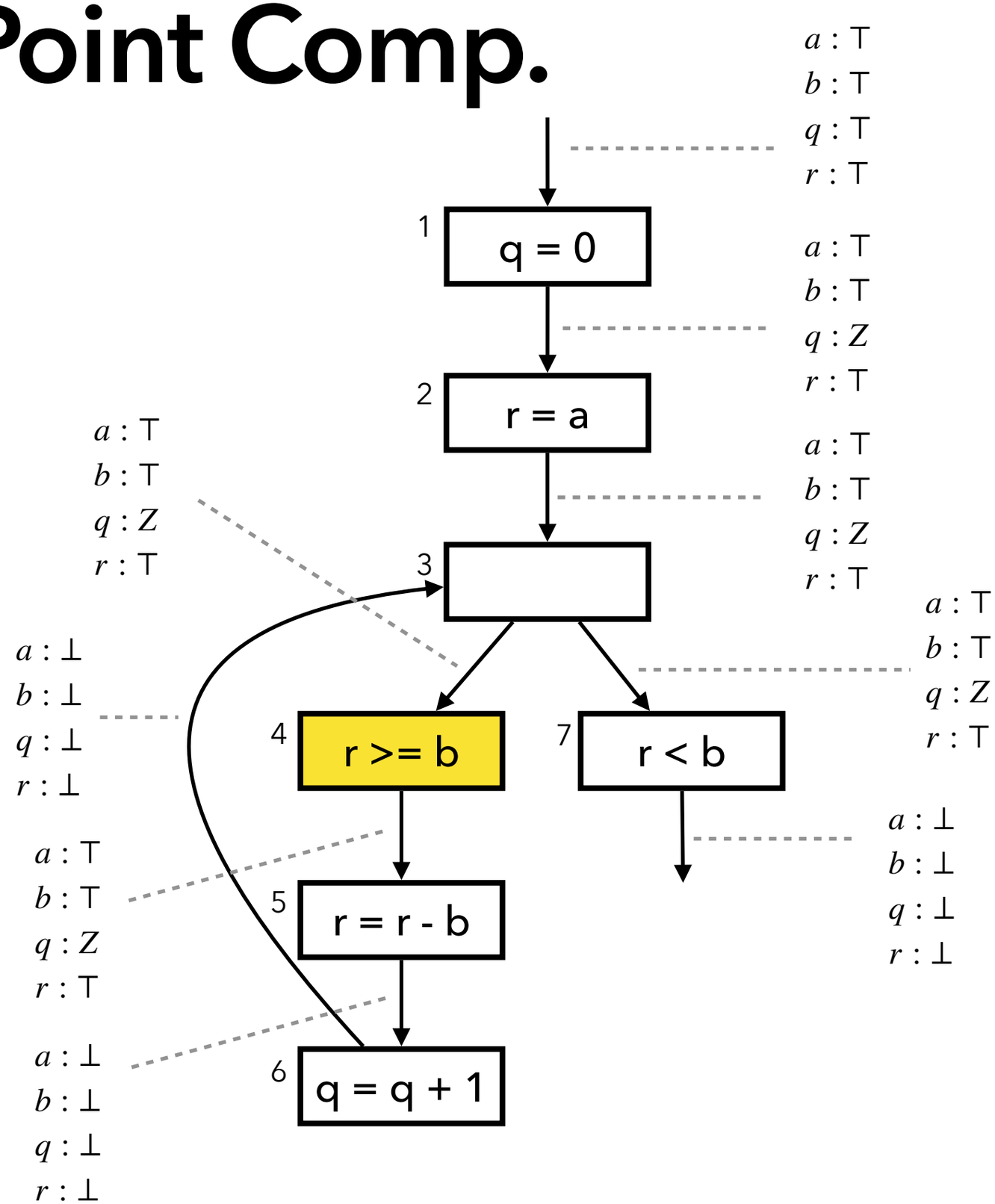

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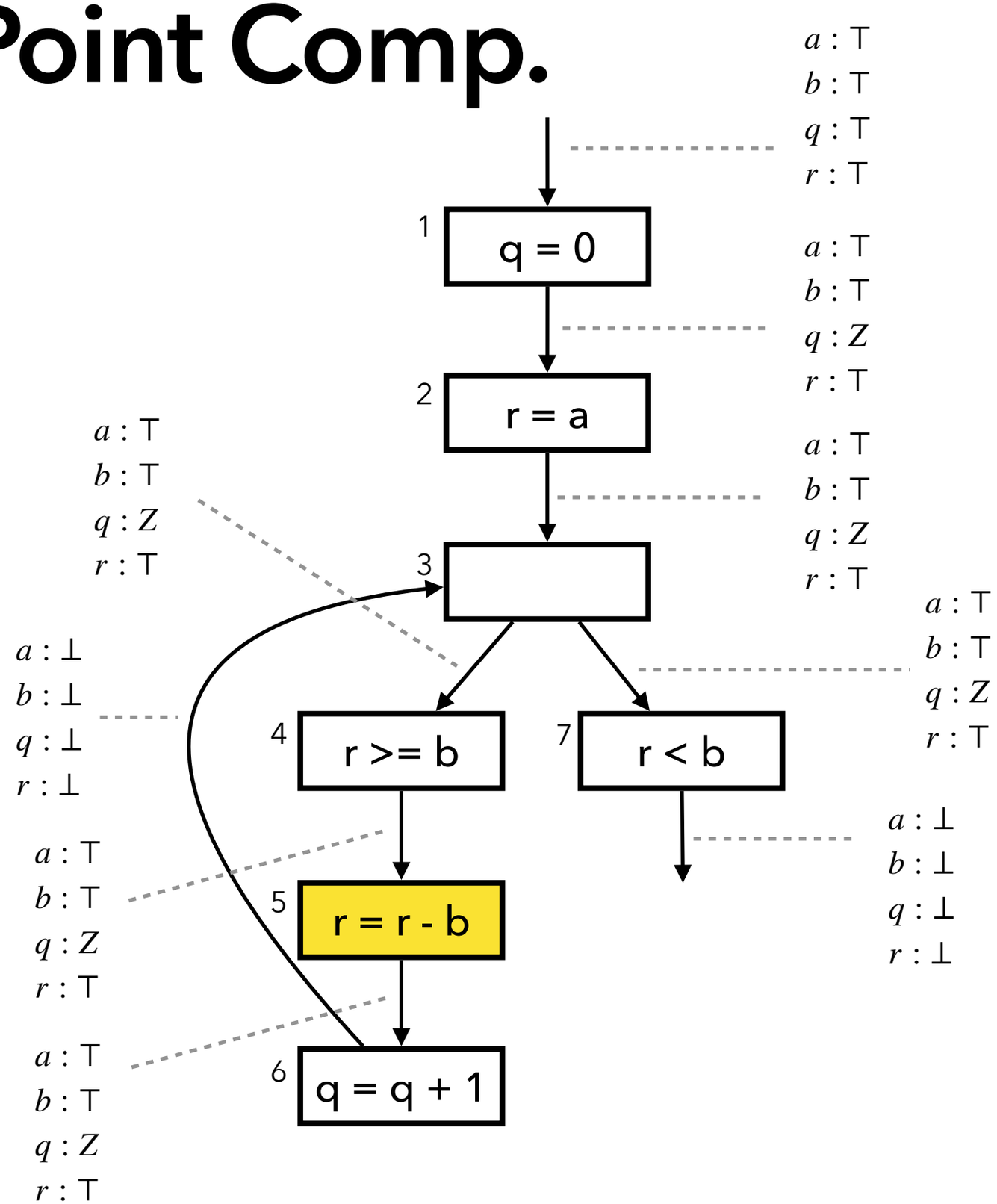

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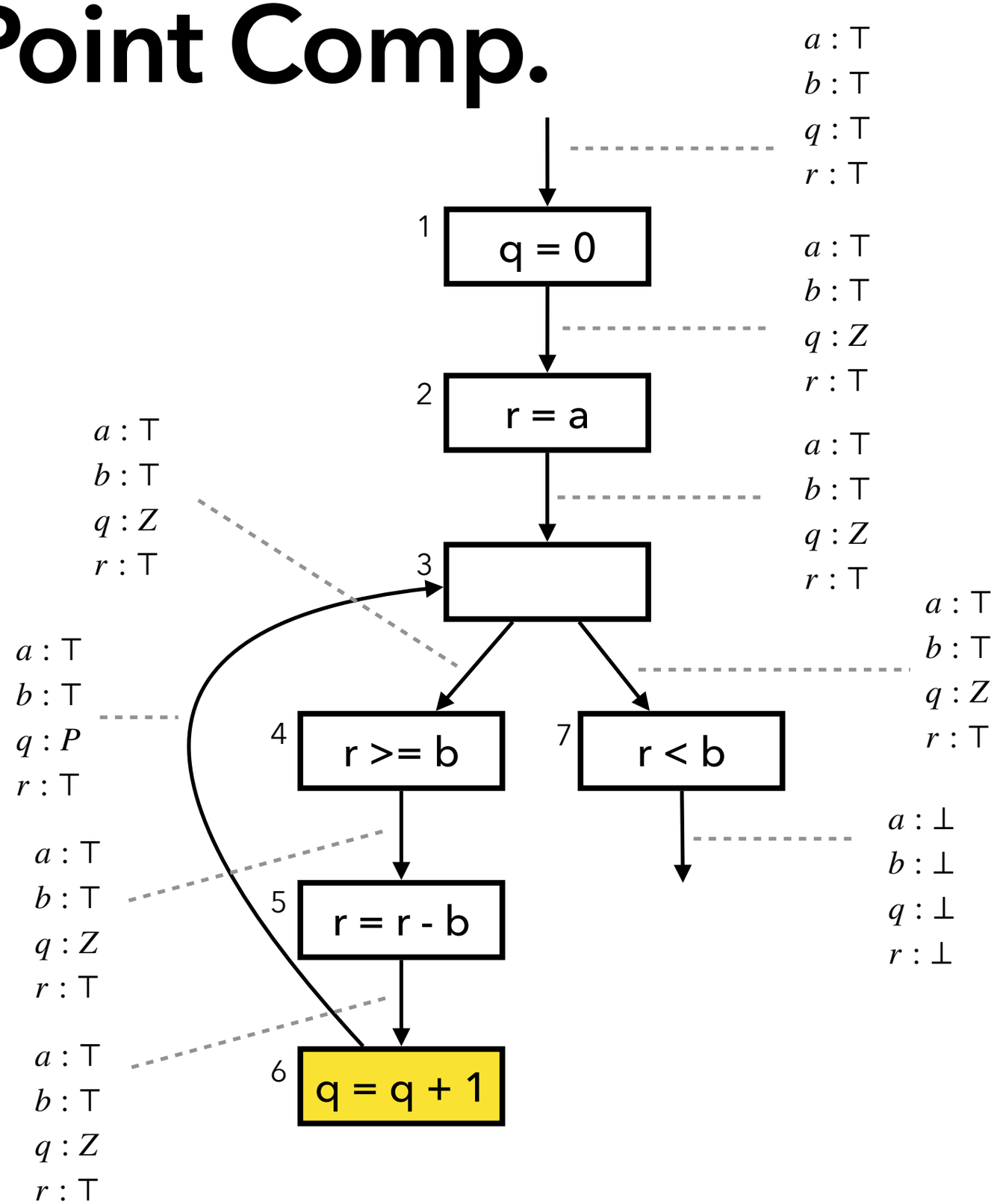

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Fixed Point Comp.

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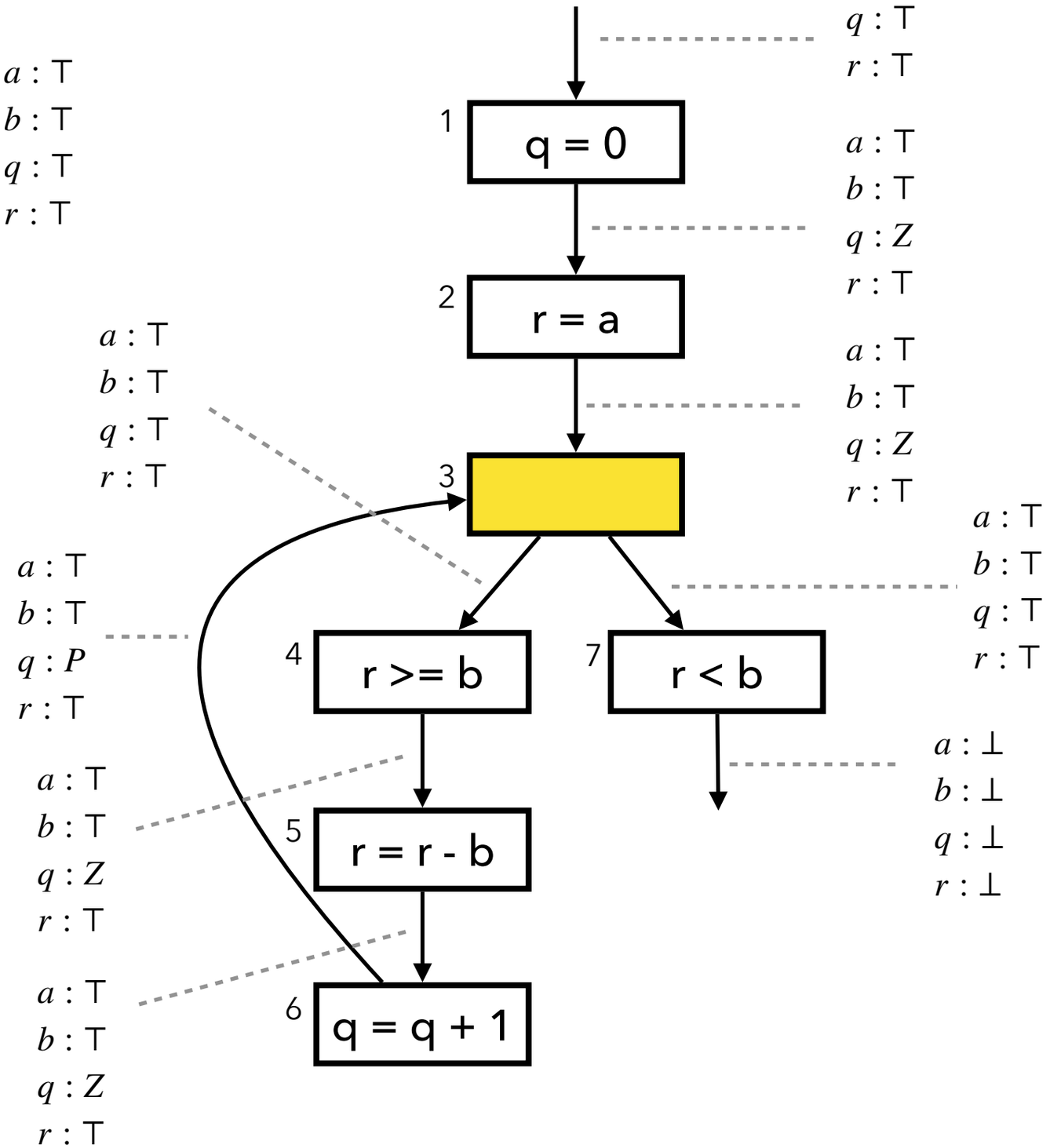

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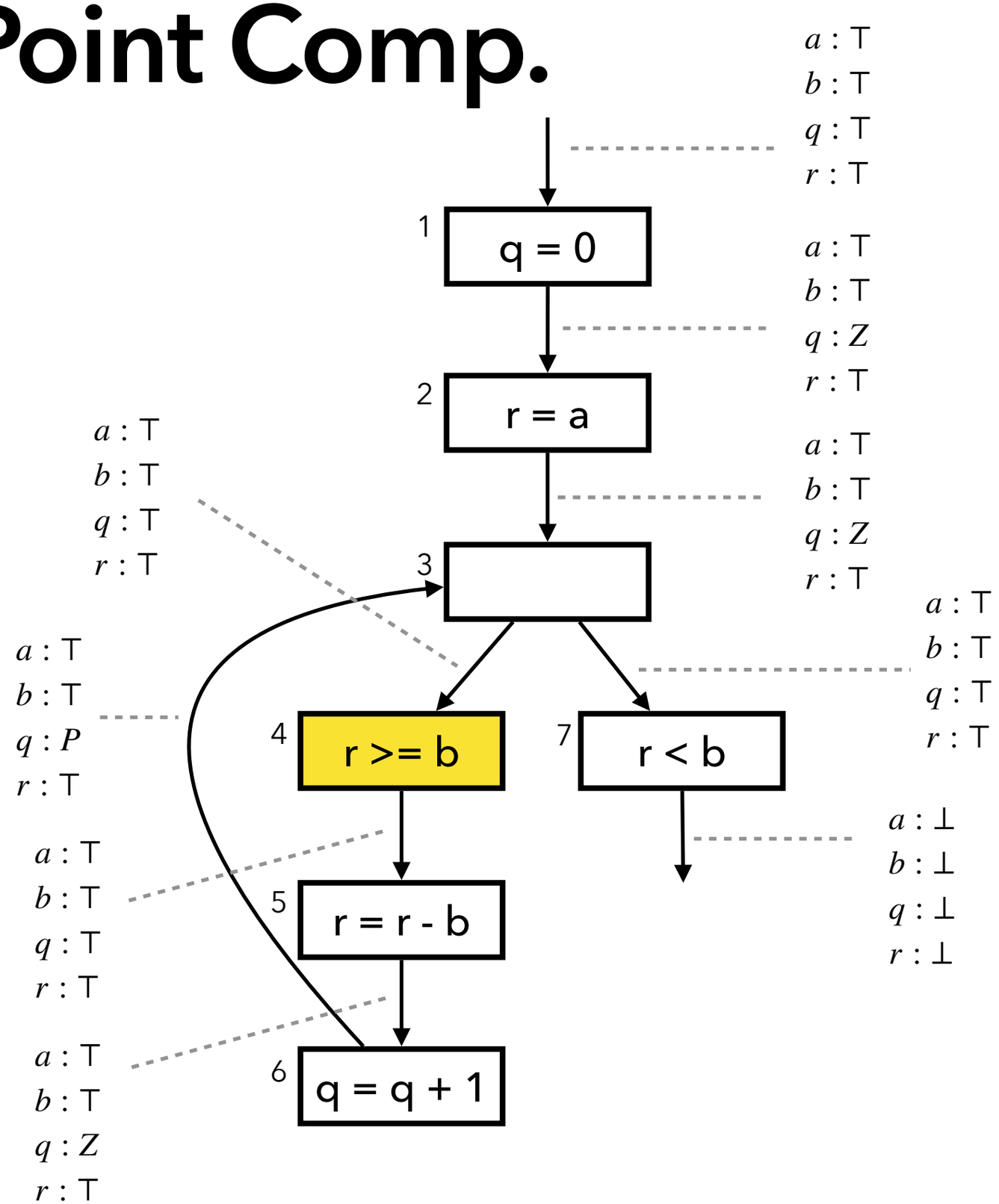

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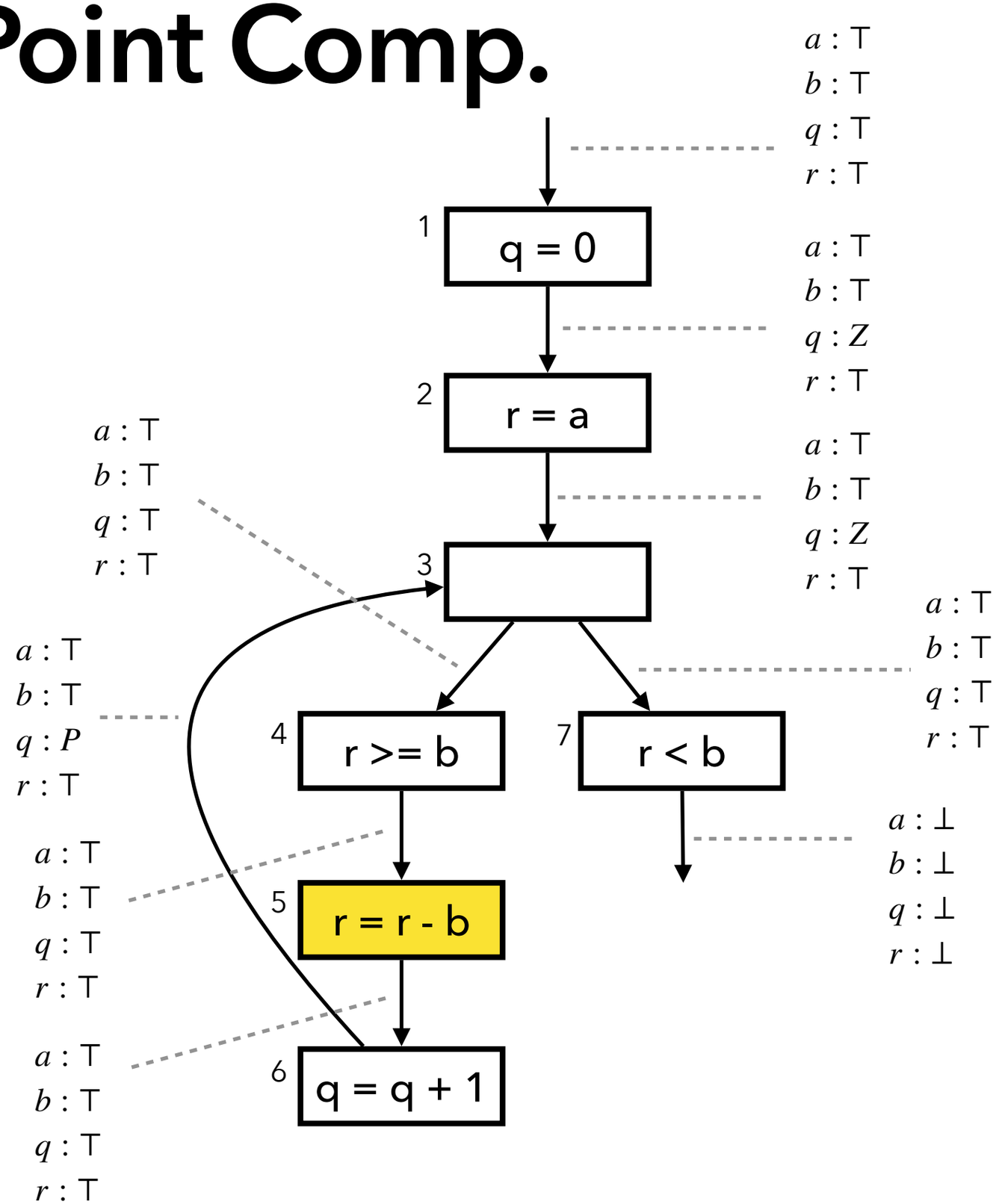

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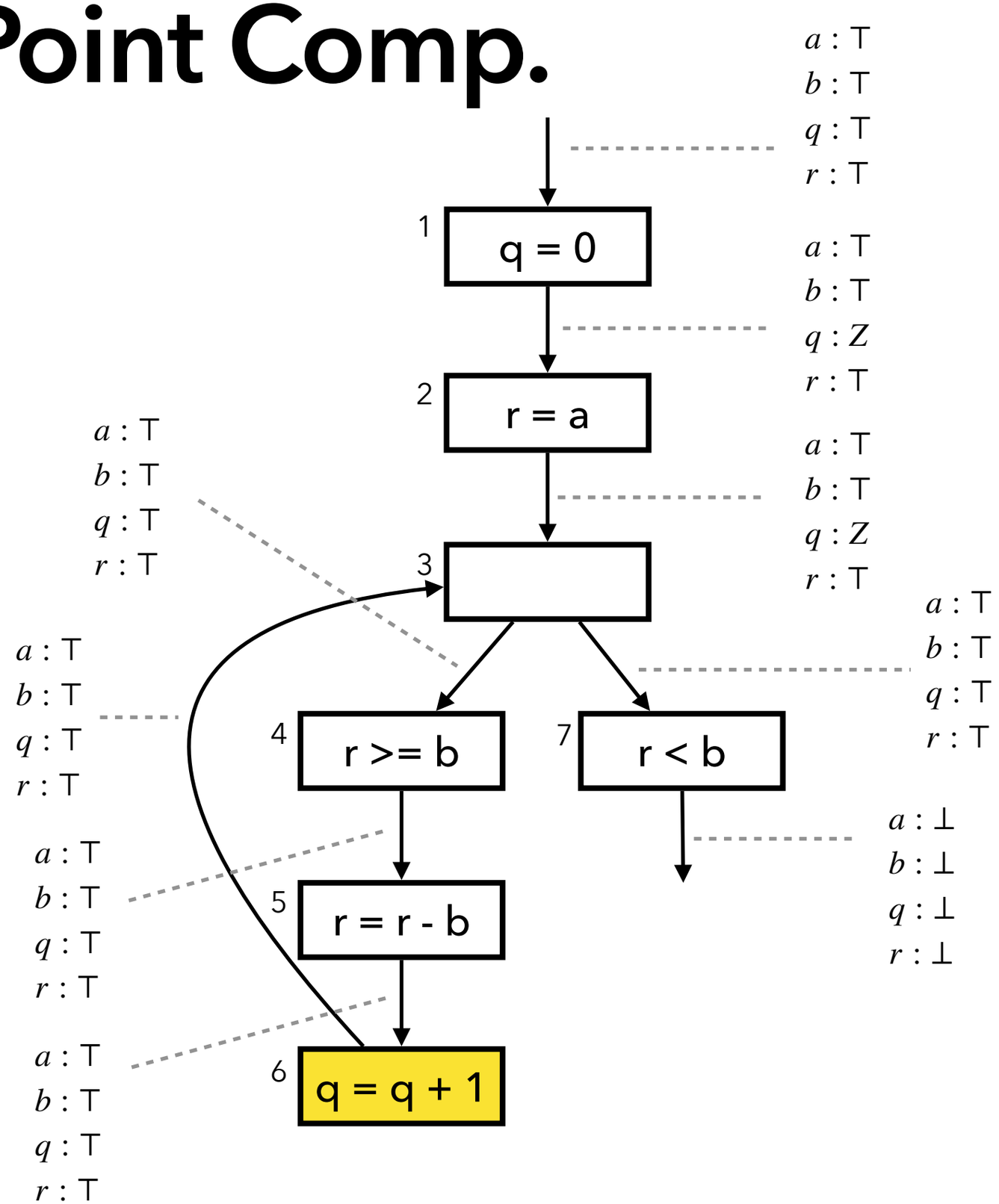

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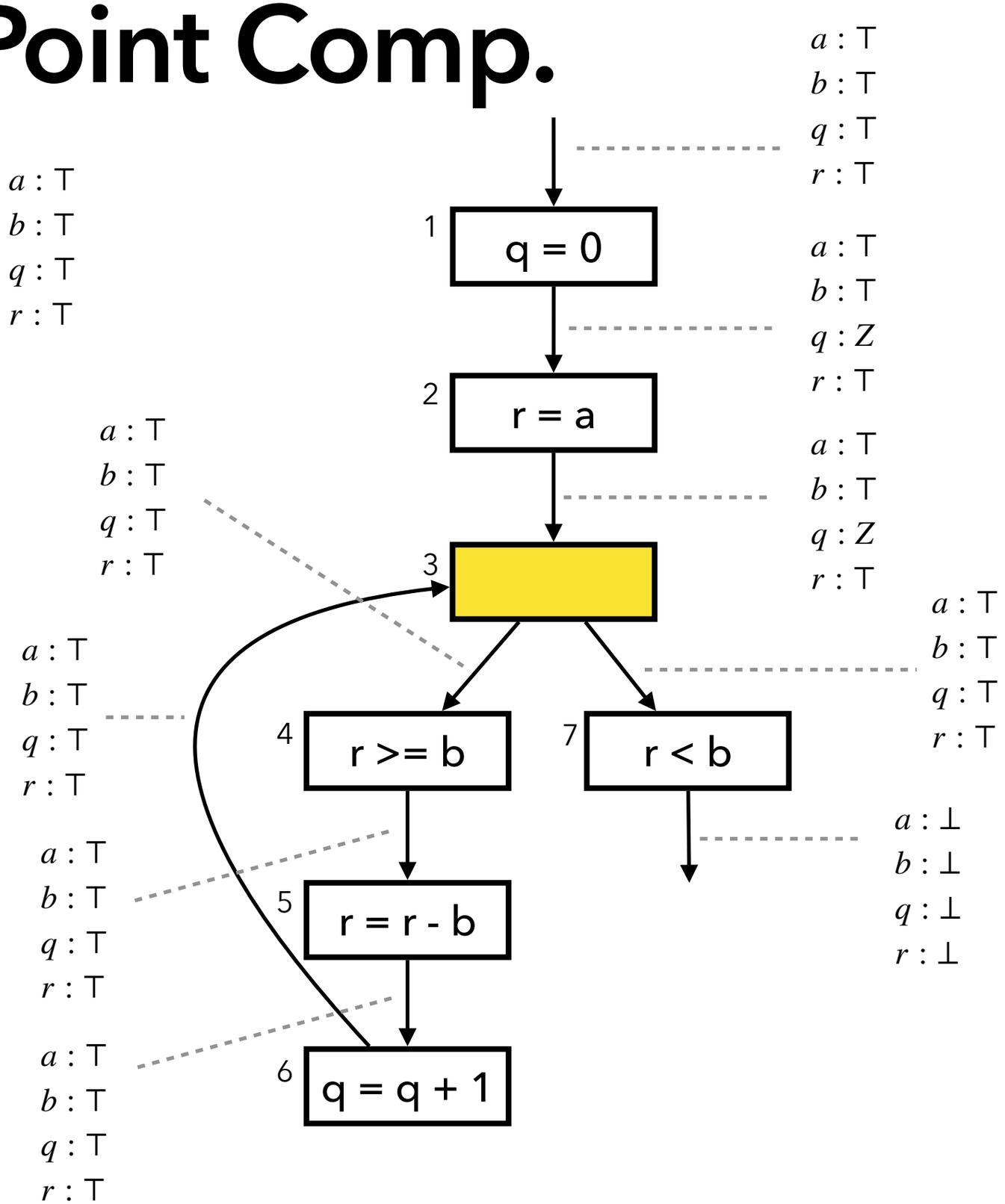
(fixed point)



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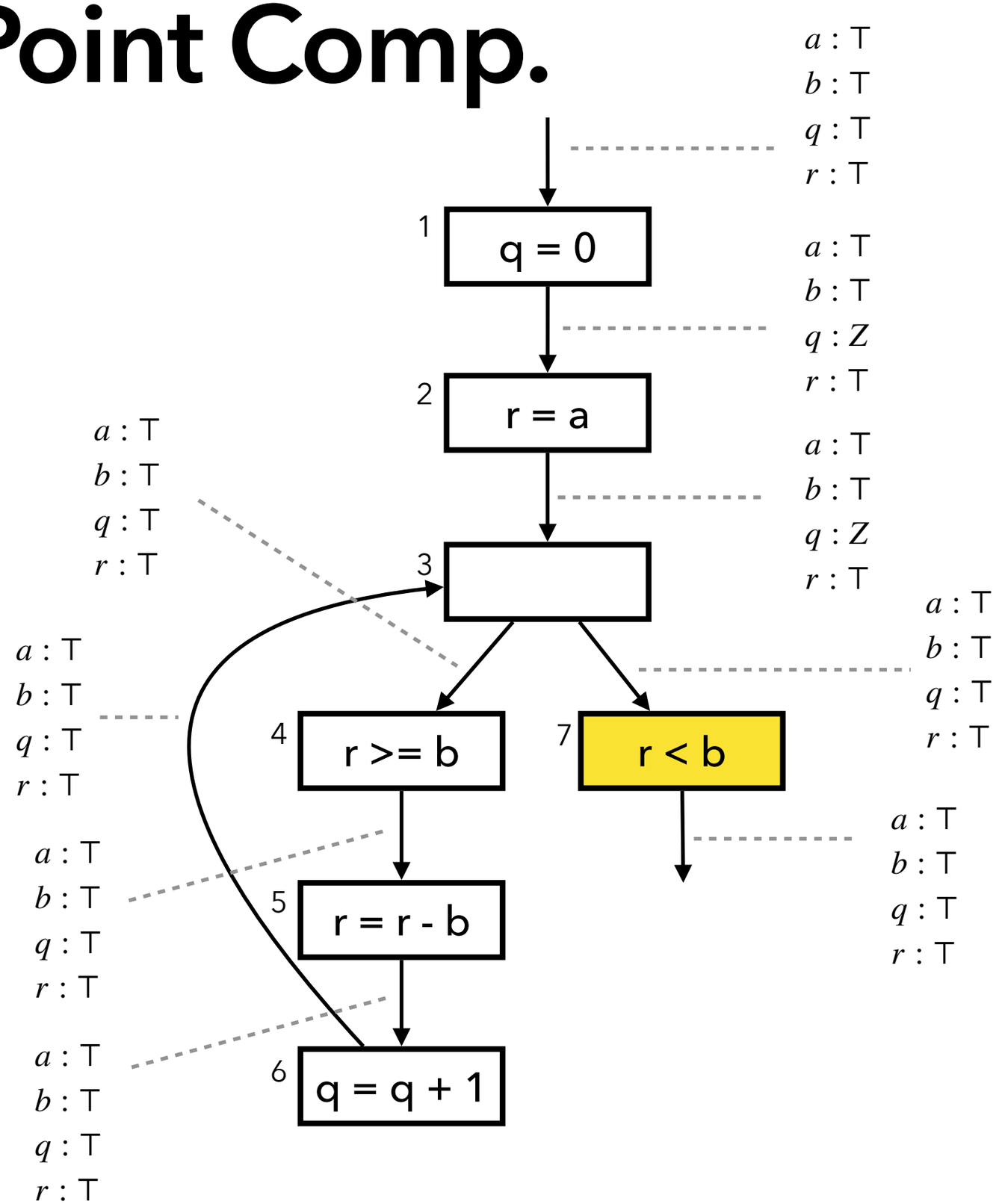

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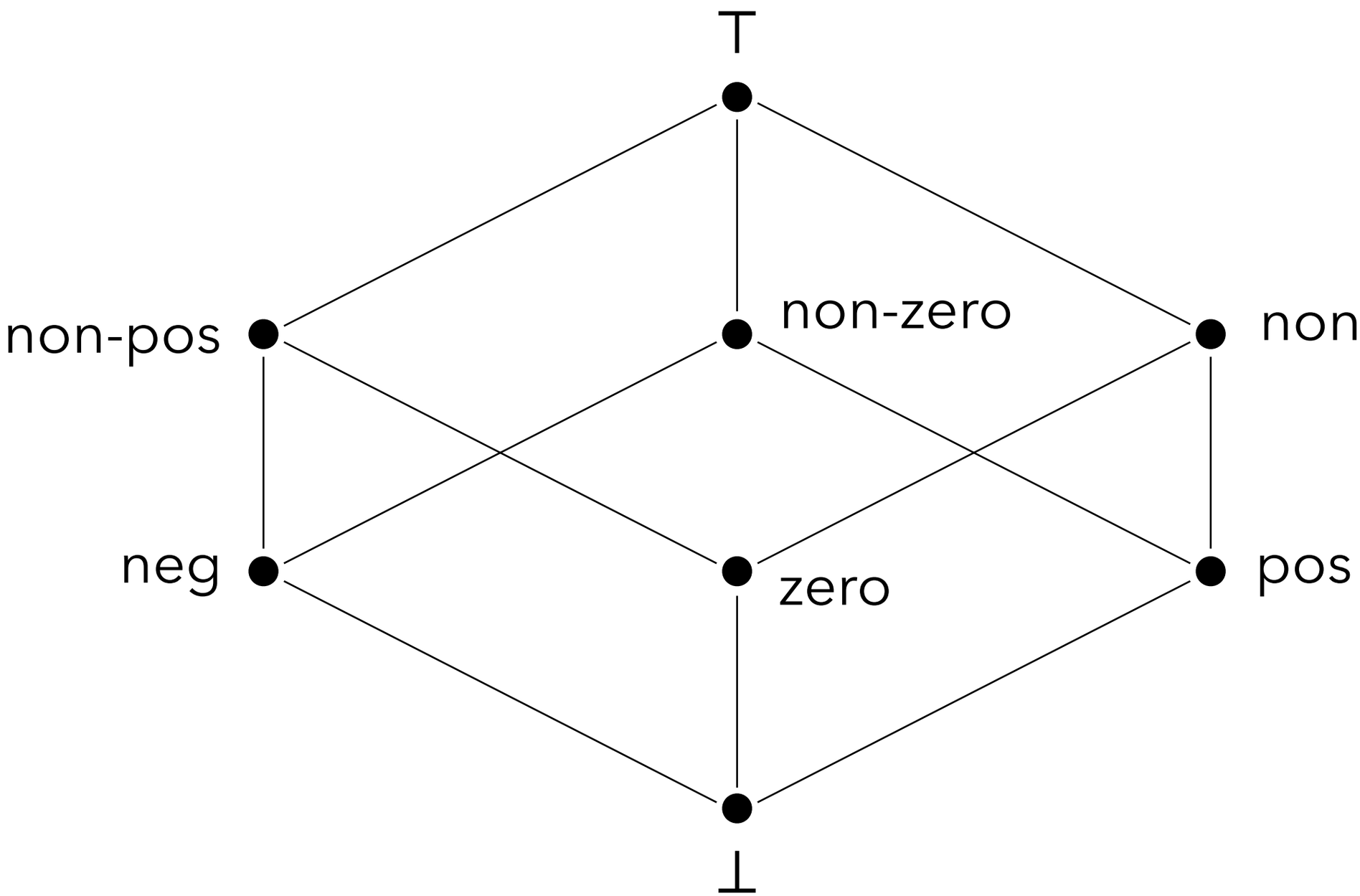
An Extended Sign Domain



+	top	neg	zero	pos	non-pos	non-zero	non-neg	bot
top								
neg								
zero								
pos								
non-pos								
non-zero								
non-neg								
bot								

−	top	neg	zero	pos	non-pos	non-zero	non-neg	bot
top								
neg								
zero								
pos								
non-pos								
non-zero								
non-neg								
bot								

Exercise (1)

Describe the result of the analysis with the extended sign domain

```
// a >= 0, b >= 0
q = 0;
r = a;
while (r >= b) {
   r = r - b;
   q = q + 1;
}
assert(q >= 0);
assert(r >= 0);
```