#### Section 12:

# **Peephole Optimization**

CS 164 @ UC Berkeley, Fall 2023

#### $AST \rightarrow AST$

```
(let
    ((time-limit
         (* 5 (* seconds-per-minute milliseconds-per-second))))
    ...)
```

#### $AST \rightarrow AST$

```
(let
  ((time-limit
     (* 5 (* seconds-per-minute milliseconds-per-second))))
...)
```

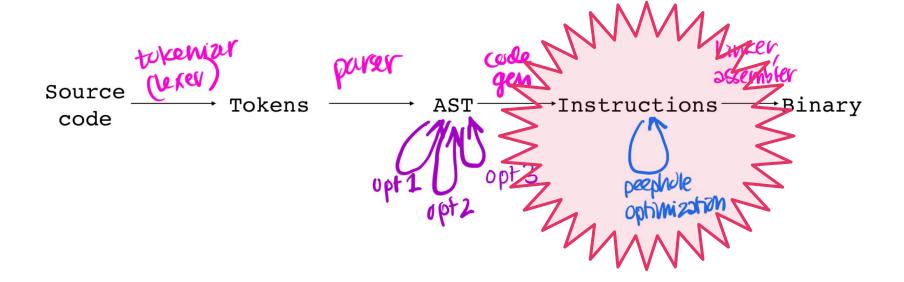
```
(let
((time-limit
300000))
...)
```

#### **AST** → **AST** Instruction → Instruction?

```
(let
   ((time-limit
        (* 5 (* seconds-per-minute milliseconds-per-second))))
...)
```

```
(let
((time-limit
300000))
...)
```

## **Peephole Optimization (Instruction** → **Instruction)**



```
default rel
                                    _then__0:
                                                                        _else__4:
global _lisp_entry
                                        mov rax, 12
                                                                            mov rax, 28
extern _lisp_error
                                        mov QWORD [-8 + rsp], rax
                                                                        continue 5:
                                                                            jmp _continue__2
extern _read_num
                                        mov rax, 16
extern _print_value
                                        cmp QWORD [-8 + rsp], rax
                                                                        _else__1:
extern _print_newline
                                        mov rax, 0
                                                                            mov rax, 28
    section .text
                                        setl al
                                                                        _continue__2:
_function_f_18913907:
                                        shl rax, 7
                                                                            mov QWORD [-8 + rsp], rax
   mov rax, 12
                                                                            mov rax, 0
                                        or rax, 31
                                                                            add rax, QWORD [-8 + rsp]
   mov QWORD [-8 + rsp], rax
                                        cmp rax, 31
                                        ie else 4
                                                                            mov QWORD [-8 + rsp], rdi
   mov rax, 16
                                                                            mov rdi, rax
    cmp QWORD [-8 + rsp], rax
                                    _then__3:
                                                                            add rsp, -8
   mov rax, 0
                                        mov rax, 28
                                                                            call _print_value
    setl al
                                        imp _continue__5
    shl rax, 7
                                                                             sub rsp, -8
                                        mov rax, r8
                                                                            mov rdi, OWORD [-8 + rsp]
    or rax, 31
                                        mul rax, 1
    cmp rax, 31
                                        mov r8, rax
                                                                            mov rax, 159
    je _else__1
                                        ret
                                                                            ret
                                                                        _lisp_entry:
                                                                            add rsp, -8
                                                                            call _function_f_18913907
                                                                             sub rsp, -8
                                                                             ret
```

```
default rel
                                    _then__0:
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global _lisp_entry
                                        mov rax, 12
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                                                                        _else__1:
extern _print_newline
                                        mov rax. 0
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                                        setl al
                                                                        _continue__2:
_function_f_18913907:
                                        shl rax, 7
                                                                            mov QWORD [-8 + rsp], rax
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                                        cmp rax, 31
                                        ie else 4
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   mov rax, 16
                                                                            mov rdi, rax
    cmp QWORD [-8 + rsp], rax
                                    _then__3:
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                                                                            sub rsp, -8
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                                                                            mov rax, 159
    je _else__1
                                        ret
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                                                                        _lisp_entry:
                                                                            add rsp, -8
                                                                            call _function_f_18913907
                                                                            sub rsp, -8
                                                                            ret
```

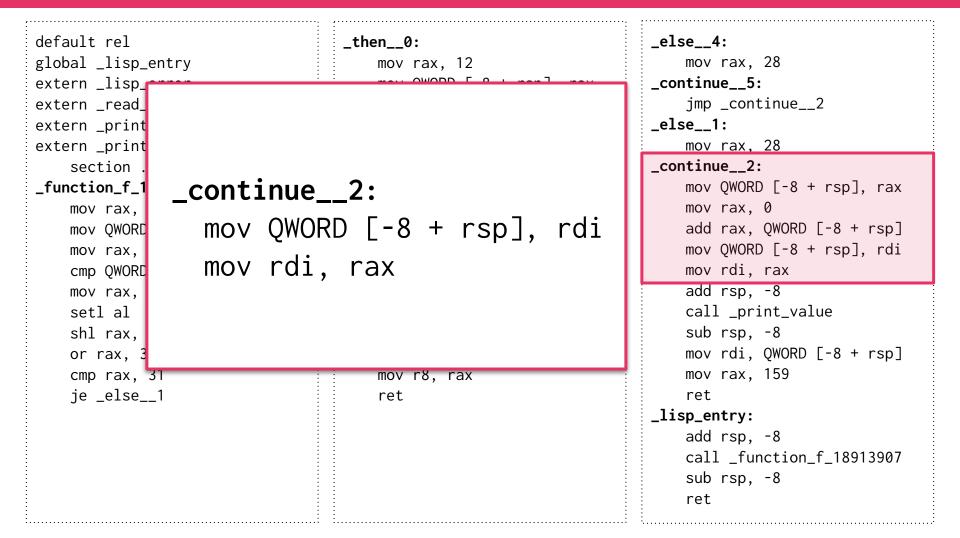
```
default rel
                                    _then__0:
                                                                        _else__4:
global _lisp_entry
                                        mov rax, 12
                                                                            mov rax, 28
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extern _print_value
                                        cmp QWORD [-8 + rsp], rax
                                                                        _else__1:
                                                                            mov rax, 28
extern _print_newline
                                        mov rax. 0
                                                                        _continue__2:
    section .text
                                        setl al
_function_f_18913907:
                                        shl rax, 7
                                                                            mov QWORD [-8 + rsp], rax
   mov rax, 12
                                                                            mov rax, 0
                                        or rax, 31
                                                                            add rax, QWORD [-8 + rsp]
   mov QWORD [-8 + rsp], rax
                                        cmp rax, 31
                                        ie else 4
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   mov rax, 16
                                                                            mov rdi, rax
    cmp QWORD [-8 + rsp], rax
                                    _then__3:
                                                                            add rsp, -8
   mov rax, 0
                                        mov rax, 28
                                                                            call _print_value
    setl al
                                        imp _continue__5
    shl rax, 7
                                                                            sub rsp, -8
                                        mov rax, r8
                                                                            mov rdi, QWORD [-8 + rsp]
    or rax, 31
                                        mul rax, 1
    cmp rax, 31
                                        mov r8, rax
                                                                            mov rax, 159
    je _else__1
                                        ret
                                                                            ret
                                                                        _lisp_entry:
                                                                            add rsp, -8
                                                                            call _function_f_18913907
                                                                            sub rsp, -8
                                                                            ret
```

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default rel
                                    _then__0:
                                                                        _else__4:
global _lisp_entry
                                        mov rax, 12
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                                        cmp QWORD [-8 + rsp], rax
                                                                        _else__1:
                                                                            mov rax, 28
extern _print_newline
                                        mov rax. 0
                                                                        _continue__2:
    section .text
                                        setl al
_function_f_18913907:
                                        shl rax, 7
                                                                            mov QWORD [-8 + rsp], rax
                                                                            mov rax, 0
   mov rax, 12
                                        or rax, 31
                                                                            add rax, QWORD [-8 + rsp]
   mov QWORD [-8 + rsp], rax
                                        cmp rax, 31
   mov rax, 16
                                        ie else 4
                                                                            mov QWORD [-8 + rsp], rdi
                                                                            mov rdi, rax
    cmp QWORD [-8 + rsp], rax
                                    _then__3:
                                        mov rax, 28
                                                                            add rsp, -8
   mov rax, 0
                                                                            call _print_value
    setl al
                                        jmp _continue__5
    shl rax, 7
                                                                            sub rsp, -8
                                        mov rax, r8
    or rax, 31
                                        mul rax, 1
                                                                            mov rai, QWURD [-8 + rsp]
    cmp rax, 31
                                        mov r8, rax
                                                                            mov rax, 159
    je _else__1
                                        ret
                                                                            ret
                                                                        _lisp_entry:
                                                                            add rsp, -8
                                                                            call _function_f_18913907
                                                                            sub rsp, -8
                                                                            ret
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default rel
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global _lisp_entry
                                        mov rax, 12
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                                        cmp QWORD [-8 + rsp], rax
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                                        cmp rax, 31
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   mov rax, 16
                                                                            mov rdi, rax
    cmp QWORD [-8 + rsp], rax
                                    _then__3:
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   mov rax, 0
                                        mov rax, 28
                                                                            call _print_value
    setl al
                                        imp _continue__5
    shl rax, 7
                                                                            sub rsp, -8
                                        mov rax, r8
                                                                            mov rdi, QWORD [-8 + rsp]
    or rax, 31
                                        mul rax, 1
                                                                            mov rax, 159
    cmp rax, 31
                                        mov r8, rax
    je _else__1
                                                                            ret
                                        ret
                                                                        _lisp_entry:
                                                                            add rsp, -8
                                                                            call _function_f_18913907
                                                                            sub rsp, -8
                                                                            ret
```

```
default rel
                                    _then__0:
                                                                        _else__4:
global _lisp_entry
                                        mov rax, 12
                                                                            mov rax, 28
extern _lisp_error
                                        mov QWORD [-8 + rsp], rax
                                                                        continue 5:
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extern _read_num
                                        mov rax, 16
extern _print_value
                                        cmp QWORD [-8 + rsp], rax
                                                                        _else__1:
                                                                            mov rax, 28
extern _print_newline
                                        mov rax. 0
                                                                        _continue__2:
    section .text
                                        setl al
_function_f_18913907:
                                        shl rax, 7
                                                                            mov QWORD [-8 + rsp], rax
                                                                            mov rax, 0
   mov rax, 12
                                        or rax, 31
                                                                            add rax, QWORD [-8 + rsp]
   mov QWORD [-8 + rsp], rax
                                        cmp rax, 31
                                        ie else 4
                                                                            mov QWORD [-8 + rsp], rdi
   mov rax, 16
                                                                            mov rdi, rax
    cmp QWORD [-8 + rsp], rax
                                    _then__3:
   mov rax, 0
                                                                            add rsp, -8
                                        mov rax, 28
                                                                            call _print_value
    setl al
                                        imp _continue__5
    shl rax, 7
                                                                            sub rsp, -8
                                        mov rax, r8
                                                                            mov rdi, QWORD [-8 + rsp]
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                                        mul rax, 1
    cmp rax, 31
                                        mov r8, rax
                                                                            mov rax, 159
    je _else__1
                                                                            ret
                                        ret
                                                                        _lisp_entry:
                                                                            add rsp, -8
                                                                            call _function_f_18913907
                                                                            sub rsp, -8
                                                                            ret
```

```
default rel
                                    _then__0:
                                                                        _else__4:
global _lisp_entry
                                        mov rax, 12
                                                                            mov rax, 28
extern _lisp_error
                                        mov QWORD [-8 + rsp], rax
                                                                        continue 5:
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extern _read_num
                                        mov rax, 16
extern _print_value
                                        cmp QWORD [-8 + rsp], rax
                                                                        _else__1:
extern _print_newline
                                        mov rax. 0
                                                                            mov rax, 28
                                                                        _continue__2:
    section .text
                                        setl al
_function_f_18913907:
                                        shl rax, 7
                                                                            mov QWORD [-8 + rsp], rax
   mov rax, 12
                                                                            mov rax, 0
                                        or rax, 31
                                                                            add rax, QWORD [-8 + rsp]
   mov QWORD [-8 + rsp], rax
                                        cmp rax, 31
                                        ie else 4
                                                                            mov QWORD [-8 + rsp], rdi
   mov rax, 16
                                                                            mov rdi. rax
    cmp QWORD [-8 + rsp], rax
                                    _then__3:
                                                                            add rsp, -8
   mov rax, 0
                                        mov rax, 28
                                                                            call _print_value
    setl al
                                        imp _continue__5
    shl rax, 7
                                                                            sub rsp, -8
                                        mov rax, r8
                                                                            mov rdi, OWORD [-8 + rsp]
    or rax, 31
                                        mul rax, 1
    cmp rax, 31
                                        mov r8, rax
                                                                            mov rax, 159
    je _else__1
                                        ret
                                                                            ret
                                                                        _lisp_entry:
                                                                            add rsp, -8
                                                                            call _function_f_18913907
                                                                            sub rsp, -8
                                                                            ret
```



default rel \_then\_\_0: global \_lisp\_entry mov rax, 12 extern \_lisp\_error mov QWORD [-8 + rsp], rax extern \_read\_num mov rax, 16 extern \_print\_value cmp QWORD [-8 + rsp], rax extern \_print\_newline mov rax, 0 section .text setl al \_function\_f\_18913907: shl rax, 7 mov rax, 12 or rax, 31 mov QWORD [-8 + rsp], rax cmp rax, 31 je \_else\_\_4 mov rax, 16 cmp QWORD [-8 + rsp], rax \_then\_\_3: mov rax, 28 mov rax, 0 setl al imp \_continue\_\_5 shl rax, 7 mov rax, r8 or rax, 31 mul rax, 1 cmp rax, 31 mov r8, rax je \_else\_\_1 ret

Activity: Come Up With Peephole Optimizations!

```
else 4:
   mov rax, 28
continue 5:
    jmp _continue__2
_else__1:
    mov rax, 28
_continue__2:
    mov QWORD [-8 + rsp], rax
    mov rax, 0
    add rax, QWORD [-8 + rsp]
    mov QWORD [-8 + rsp], rdi
    mov rdi, rax
    add rsp, -8
    call _print_value
    sub rsp, -8
    mov rdi, OWORD [-8 + rsp]
    mov rax, 159
    ret
_lisp_entry:
    add rsp, -8
    call _function_f_18913907
    sub rsp, -8
    ret
```

• Algebraic simplifications

$$\circ$$
 x = x + 0 x = x \* 1

```
default rel
                                    _then__0:
                                                                        _else__4:
global _lisp_entry
                                        mov rax, 12
                                                                            mov rax, 28
extern _lisp_error
                                        mov QWORD [-8 + rsp], rax
                                                                        continue 5:
                                                                            jmp _continue__2
extern _read_num
                                        mov rax, 16
extern _print_value
                                        cmp QWORD [-8 + rsp], rax
                                                                        _else__1:
extern _print_newline
                                        mov rax, 0
                                                                            mov rax, 28
    section .text
                                        setl al
                                                                        _continue__2:
_function_f_18913907:
                                        shl rax, 7
                                                                            mov QWORD [-8 + rsp], rax
   mov rax, 12
                                                                            mov rax, 0
                                        or rax, 31
                                                                            add rax, QWORD [-8 + rsp]
   mov QWORD [-8 + rsp], rax
                                        cmp rax, 31
                                        ie else 4
                                                                            mov QWORD [-8 + rsp], rdi
   mov rax, 16
                                                                            mov rdi, rax
    cmp QWORD [-8 + rsp], rax
                                    _then__3:
                                                                            add rsp, -8
   mov rax, 0
                                        mov rax, 28
                                                                            call _print_value
    setl al
                                        imp _continue__5
    shl rax, 7
                                                                             sub rsp, -8
                                        mov rax, r8
                                                                            mov rdi, OWORD [-8 + rsp]
    or rax, 31
                                        mul rax, 1
    cmp rax, 31
                                        mov r8, rax
                                                                            mov rax, 159
    je _else__1
                                        ret
                                                                            ret
                                                                        _lisp_entry:
                                                                            add rsp, -8
                                                                            call _function_f_18913907
                                                                             sub rsp, -8
                                                                             ret
```

```
default rel
                                    _then__0:
                                                                        _else__4:
global _lisp_entry
                                        mov rax, 12
                                                                            mov rax, 28
extern _lisp_error
                                        mov QWORD [-8 + rsp], rax
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                                                                            jmp _continue__2
extern _read_num
                                        mov rax, 16
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                                        cmp QWORD [-8 + rsp], rax
                                                                        _else__1:
extern _print_newline
                                        mov rax. 0
                                                                            mov rax, 28
                                                                        _continue__2:
    section .text
                                        setl al
_function_f_18913907:
                                        shl rax, 7
                                                                            mov QWORD [-8 + rsp], rax
   mov rax, 12
                                                                            mov rax, 0
                                        or rax, 31
                                                                            add rax, QWORD [-8 + rsp]
   mov QWORD [-8 + rsp], rax
                                        cmp rax, 31
                                        ie else 4
                                                                            mov QWORD [-8 + rsp], rdi
   mov rax, 16
                                                                            mov rdi, rax
    cmp QWORD [-8 + rsp], rax
                                    _then__3:
                                                                            add rsp, -8
   mov rax, 0
                                        mov rax, 28
                                                                            call _print_value
    setl al
                                        jmp _continue__5
    shl rax, 7
                                                                             sub rsp, -8
                                        mov rax, r8
                                                                            mov rdi, OWORD [-8 + rsp]
    or rax, 31
                                        mul rax, 1
    cmp rax, 31
                                        mov r8, rax
                                                                            mov rax, 159
    je _else__1
                                        ret
                                                                            ret
                                                                         _lisp_entry:
                                                                            add rsp, -8
                                                                            call _function_f_18913907
                                                                             sub rsp, -8
                                                                             ret
```

• Algebraic simplifications

$$\circ$$
 x = x + 0 x = x \* 1

• Algebraic simplifications

```
0 x = x + 0 x = x * 1
```

Eliminating redundant loads and stores

```
o LD R0, a ST a, R0
```

```
default rel
                                    _then__0:
                                                                        _else__4:
global _lisp_entry
                                        mov rax, 12
                                                                            mov rax, 28
extern _lisp_error
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                                        mov rax, 0
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    section .text
                                        setl al
                                                                        _continue__2:
_function_f_18913907:
                                        shl rax, 7
                                                                            mov QWORD [-8 + rsp], rax
   mov rax, 12
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                                        cmp rax, 31
                                        ie else 4
                                                                            mov QWORD [-8 + rsp], rdi
   mov rax, 16
                                                                            mov rdi, rax
    cmp QWORD [-8 + rsp], rax
                                    _then__3:
                                                                            add rsp, -8
   mov rax, 0
                                        mov rax, 28
                                                                            call _print_value
    setl al
                                        imp _continue__5
    shl rax, 7
                                                                             sub rsp, -8
                                        mov rax, r8
                                                                            mov rdi, OWORD [-8 + rsp]
    or rax, 31
                                        mul rax, 1
    cmp rax, 31
                                        mov r8, rax
                                                                            mov rax, 159
    je _else__1
                                        ret
                                                                            ret
                                                                        _lisp_entry:
                                                                            add rsp, -8
                                                                            call _function_f_18913907
                                                                             sub rsp, -8
                                                                             ret
```

```
default rel
                                    _then__0:
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                                        mov rax, 12
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                                                                        _else__1:
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extern _print_newline
                                        mov rax. 0
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                                        setl al
_function_f_18913907:
                                        shl rax, 7
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                                        or rax, 31
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                                        cmp rax, 31
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                                                                            mov QWORD [-8 + rsp], rdi
   mov rax, 16
                                                                            mov rdi, rax
    cmp QWORD [-8 + rsp], rax
                                    _then__3:
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                                        mov rax, 28
                                                                            call _print_value
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    shl rax, 7
                                        mov rax, r8
                                                                            sub rsp, -8
                                                                            mov rdi, OWORD [-8 + rsp]
    or rax, 31
                                        mul rax, 1
                                                                            mov rax, 159
    cmp rax, 31
                                        mov r8, rax
    je _else__1
                                                                            ret
                                        ret
                                                                        _lisp_entry:
                                                                            add rsp, -8
                                                                            call _function_f_18913907
                                                                            sub rsp, -8
                                                                            ret
```

• Algebraic simplifications

```
0 x = x + 0 x = x * 1
```

Eliminating redundant loads and stores

```
o LD R0, a ST a, R0
```

Algebraic simplifications

```
\circ x = x + 0 x = x * 1
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Eliminating redundant loads and stores

```
o LD R0, a ST a, R0
```

Eliminating unreachable code

```
o jmp L1
mov rax, 0
L1:
```

Algebraic simplifications

```
\circ x = x + 0 x = x * 1
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Eliminating redundant loads and stores

```
LD R0, aST a, R0
```

Eliminating unreachable code

```
o jmp L1
mov rax, 0
L1:
```

```
default rel
                                    _then__0:
                                                                        _else__4:
global _lisp_entry
                                        mov rax, 12
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extern _lisp_error
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                                        setl al
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                                        shl rax, 7
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   mov rax, 12
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   mov rax, 16
                                                                            mov rdi, rax
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                                    _then__3:
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                                        mov rax, 28
                                                                            call _print_value
    setl al
                                        imp _continue__5
    shl rax, 7
                                                                             sub rsp, -8
                                        mov rax, r8
                                                                            mov rdi, OWORD [-8 + rsp]
    or rax, 31
                                        mul rax, 1
    cmp rax, 31
                                        mov r8, rax
                                                                            mov rax, 159
    je _else__1
                                        ret
                                                                            ret
                                                                        _lisp_entry:
                                                                            add rsp, -8
                                                                            call _function_f_18913907
                                                                             sub rsp, -8
                                                                             ret
```

```
default rel
                                    _then__0:
                                                                        _else__4:
global _lisp_entry
                                        mov rax, 12
                                                                            mov rax, 28
extern _lisp_error
                                        mov QWORD [-8 + rsp], rax
                                                                        continue 5:
                                                                            jmp _continue__2
extern _read_num
                                        mov rax, 16
extern _print_value
                                        cmp QWORD [-8 + rsp], rax
                                                                        _else__1:
extern _print_newline
                                        mov rax. 0
                                                                            mov rax, 28
                                                                        _continue__2:
    section .text
                                        setl al
_function_f_18913907:
                                        shl rax, 7
                                                                            mov QWORD [-8 + rsp], rax
                                                                            mov rax, 0
   mov rax, 12
                                        or rax, 31
                                                                            add rax, QWORD [-8 + rsp]
   mov QWORD [-8 + rsp], rax
                                        cmp rax, 31
                                        ie else 4
                                                                            mov QWORD [-8 + rsp], rdi
   mov rax, 16
                                                                            mov rdi, rax
    cmp QWORD [-8 + rsp], rax
                                    _then__3:
                                                                            add rsp, -8
                                        mov rax, 28
   mov rax, 0
                                                                            call _print_value
    setl al
                                        jmp _continue__5
    shl rax, 7
                                        mov rax, r8
                                                                             sub rsp, -8
                                                                            mov rdi, OWORD [-8 + rsp]
    or rax, 31
                                        mul rax, 1
                                                                            mov rax, 159
    cmp rax, 31
                                        mov r8, rax
    je _else__1
                                                                            ret
                                        ret
                                                                        _lisp_entry:
                                                                            add rsp, -8
                                                                            call _function_f_18913907
                                                                             sub rsp, -8
                                                                             ret
```

Algebraic simplifications

```
\circ x = x + 0 x = x * 1
```

Eliminating redundant loads and stores

```
o LD R0, a ST a, R0
```

Eliminating unreachable code

```
o jmp L1
mov rax, 0
L1:
```

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Flow-of-control optimizations

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○ jmp L1
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o jmp L1 mov rax, 0 L1:
```

Flow-of-control optimizations

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```

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```
default rel
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                                        mov rax, 12
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                                        setl al
                                                                        _continue__2:
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                                        shl rax, 7
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                                        cmp rax, 31
                                        ie else 4
                                                                            mov QWORD [-8 + rsp], rdi
   mov rax, 16
                                                                            mov rdi, rax
    cmp QWORD [-8 + rsp], rax
                                    _then__3:
                                                                            add rsp, -8
   mov rax, 0
                                        mov rax, 28
                                                                            call _print_value
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                                                                             sub rsp, -8
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                                                                             ret
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```
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                                        mov rax, 12
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extern _lisp_error
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                                                                         _continue__5:
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                                                                         _else__1:
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                                        cmp QWORD [-8 + rsp], rax
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                                        setl al
_function_f_18913907:
                                        shl rax, 7
                                                                             mov QWORD [-8 + rsp], rax
   mov rax, 12
                                                                            mov rax, 0
                                        or rax, 31
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                                                                             mov QWORD [-8 + rsp], rdi
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                                    _then__3:
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                                                                             sub rsp, -8
                                                                             ret
```

What is one advantage of **Instruction** → **Instruction** (peephole) optimization?

What is one advantage of  $AST \rightarrow AST$  optimization?