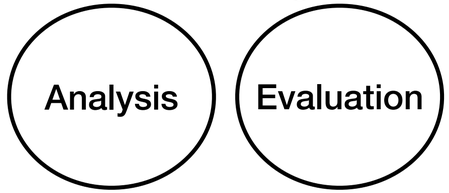
Core Design Concepts Discussed:

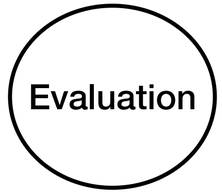


Performance and Optimization of Recursive Functions

Harley Eades III

The Performance Hit

Core Design Concepts:



Consider evaluating the following recursive function:

```
1. let rec mult m n =
2.  if m == 0
3.  then 0
4.  else if n == 0
5.       then 0
6.       else let rc = mult m (n - 1) in
7.            let ret = m + rc in
8.            ret
9.
10. let main =
11.   let m = 1 in
12.    let n = 2 in
13.      let answ = mult m n in
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Frame	Symbol	Value
init line: 16	ackermann main	<fun> <fun>

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Frame	Symbol	Value
init line: 16	ackermann main	<fun> <fun>
main line: 13	m n	1 2
mult: line 7	m n rc	1 2 ?

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init line: 16	`ackermann` `main`	`<fun>` `<fun>`
main line: 13	`m` `n`	`1` `2`

mult:
line 7
	`m`
	`n`
	`rc`
		`1`
		`2`
		`?`

mult:
line 7
	`m`
	`n`
	`rc`
		`1`
		`1`
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Frame	Symbol	Value
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mult line: 8	m n rc	1 2 ?
mult line: 8	m n rc	1 1 ?
mult line: 5	m n	1 0

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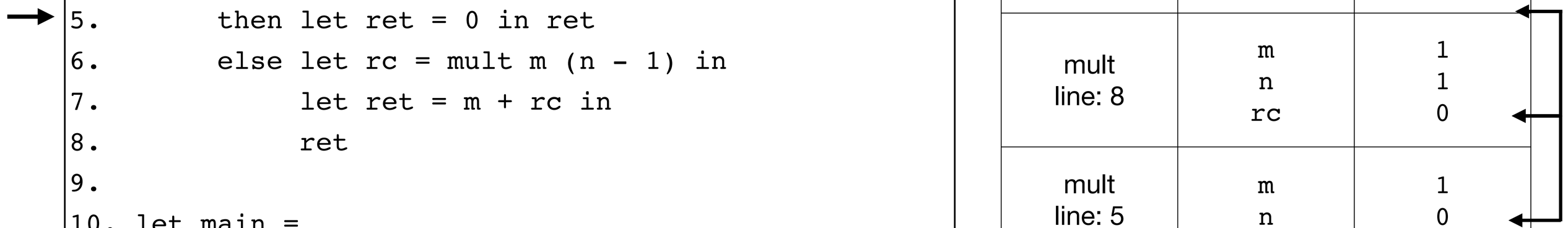

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- Bad for performance: making a recursive call in an argument position (line 7).
- This results in the bindings of an activation record depending on the return value of a new activation record.
- Thus, the compiler will create lots of activation records that cannot be popped off of the stack until the end of evaluation.
- This results in a bad use of memory.

Tail Recursion using the accumulator pattern

Non-tail recursive:

```
1. let rec mult m n =
2.  if m == 0
3.  then 0
4.  else if n == 0
5.       then 0
6.       else m + (mult m (n - 1))
```

Tail recursive:

```
1. let rec mult_helper acc m n =
2.   if m == 0
3.   then 0
4.   else if n == 0
5.        then acc
6.        else mult_helper (m + acc) m (n - 1)
7.
8. let mult m n = mult_helper 0 m n
```

Evaluation of Tail Recursion

Frame	Symbol	Value
init	mult	<fun>
line: 16	main	<fun>

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2.   let rec mult_helper acc n' =
3.     if m == 0
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Optimization: Tail Recursion

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Tail Call Optimization

- Tail calls do not require any modifications to the activation frame. Thus, we do not need to keep them around.
- Compiler can detect tail recursion, and then optimize its stack usage by discarding each activation frame during evaluation.
  - Constant space usage!
  - The same performance as loops!
- Not all PLs offer this tail call optimization!

Tail Call Optimization

PL	Tail Call Optimized	Compiler
C/C++	Yes	GCC
Swift	Yes	All
Python	No	All
C#	No	All
Java	Partially	JVM
OCaml	Yes	All
Haskell	Yes	GHC
javascript	Yes	ES6