

# **Progress report in Pen programming language**

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# Agenda

- Progress report
  - (Full) lambda lifting
  - Snake game
- Next plans

# Progress report

# (Full) lambda lifting

- Flatten nested functions into global functions.
- Pen supports lifting closures with free variables.
  - So far, it supported only the cases where no free variable exists.
- MIR normalization to the A-normal(-ish) form is also introduced for this change.
  - In the future, it'll be easier to write passes at the MIR level.

## References

- [Lambda lifting | Wikipedia](#)

# (Full) lambda lifting

## Algorithm

Before:

```
f = \ (x number) number {  
  g = \ (y string) number {  
    # ...  
  }  
  
  g(y)  
}
```

# (Full) lambda lifting

## Algorithm

After:

```
f = \ (x number) number {  
    lifted_g(y, x)  
}  
  
lifted_g = \ (y string, x number) number {  
    # ...  
}
```

# Benchmark

	Speed up	Heap allocation decrease
Hash map insert	6%	37.7%
Hash map update	5%	38.9%

- Probably, heap allocation is not a bottle neck in those cases...
- The bottle neck might be redundant hash calculation?

# Snake game

Demo

## Missing language features

- Pretty printing for debugging
- String concatenation operator
- General list pattern match
  - Currently, Pen can match only a head and a tail.



# Next plans

- More applications?
  - Web services
  - Games
- Language features

# Summary

- Progress
  - (Full) lambda lifting
  - Snake game
- Next plans

# Appendix

## Benchmark results

```
> hyperfine -w 3 ./insert-*  
Benchmark 1: ./insert-new  
  Time (mean ±  $\sigma$ ):      248.7 ms ±   2.5 ms    [User: 180.5 ms, System: 17.9 ms]  
  Range (min ... max):      245.4 ms ... 252.8 ms    12 runs  
  
Benchmark 2: ./insert-old  
  Time (mean ±  $\sigma$ ):      261.1 ms ±   3.5 ms    [User: 193.0 ms, System: 17.6 ms]  
  Range (min ... max):      256.9 ms ... 269.2 ms    11 runs  
  
Summary  
  './insert-new' ran  
    1.05 ± 0.02 times faster than './insert-old'
```

```
> hyperfine -w 3 ./update-*  
Benchmark 1: ./update-new  
  Time (mean ±  $\sigma$ ):    405.6 ms ±   3.2 ms    [User: 338.5 ms, System: 16.1 ms]  
  Range (min ... max):    401.8 ms .. 410.9 ms    10 runs  
  
Benchmark 2: ./update-old  
  Time (mean ±  $\sigma$ ):    431.1 ms ±   4.6 ms    [User: 360.9 ms, System: 19.1 ms]  
  Range (min ... max):    422.6 ms .. 438.2 ms    10 runs  
  
Summary  
  './update-new' ran  
    1.06 ± 0.01 times faster than './update-old'
```

```
> valgrind ./insert-old
==595278== Memcheck, a memory error detector
==595278== Copyright (C) 2002-2022, and GNU GPL'd, by Julian Seward et al.
==595278== Using Valgrind-3.19.0 and LibVEX; rerun with -h for copyright info
==595278== Command: ./insert-old
==595278==
==595278==
==595278== HEAP SUMMARY:
==595278==     in use at exit: 10,784 bytes in 74 blocks
==595278==   total heap usage: 1,073,769 allocs, 1,073,695 frees, 50,359,170 bytes allocated
==595278==
==595278== LEAK SUMMARY:
==595278==     definitely lost: 0 bytes in 0 blocks
==595278==     indirectly lost: 0 bytes in 0 blocks
==595278==     possibly lost: 320 bytes in 3 blocks
==595278==     still reachable: 10,464 bytes in 71 blocks
==595278==                of which reachable via heuristic:
==595278==                   newarray           : 536 bytes in 2 blocks
==595278==     suppressed: 0 bytes in 0 blocks
==595278== Rerun with --leak-check=full to see details of leaked memory
==595278==
==595278== For lists of detected and suppressed errors, rerun with: -s
==595278== ERROR SUMMARY: 0 errors from 0 contexts (suppressed: 0 from 0)
```

```
> valgrind ./insert-new
==597282== Memcheck, a memory error detector
==597282== Copyright (C) 2002-2022, and GNU GPL'd, by Julian Seward et al.
==597282== Using Valgrind-3.19.0 and LibVEX; rerun with -h for copyright info
==597282== Command: ./insert-new
==597282==
==597282==
==597282== HEAP SUMMARY:
==597282==   in use at exit: 10,784 bytes in 74 blocks
==597282==   total heap usage: 669,140 allocs, 669,066 frees, 34,174,010 bytes allocated
==597282==
==597282== LEAK SUMMARY:
==597282==   definitely lost: 0 bytes in 0 blocks
==597282==   indirectly lost: 0 bytes in 0 blocks
==597282==   possibly lost: 320 bytes in 3 blocks
==597282==   still reachable: 10,464 bytes in 71 blocks
==597282==                 of which reachable via heuristic:
==597282==                     newarray      : 536 bytes in 2 blocks
==597282==   suppressed: 0 bytes in 0 blocks
==597282== Rerun with --leak-check=full to see details of leaked memory
==597282==
==597282== For lists of detected and suppressed errors, rerun with: -s
==597282== ERROR SUMMARY: 0 errors from 0 contexts (suppressed: 0 from 0)
```

```
> valgrind ./update-old
==599735== Memcheck, a memory error detector
==599735== Copyright (C) 2002-2022, and GNU GPL'd, by Julian Seward et al.
==599735== Using Valgrind-3.19.0 and LibVEX; rerun with -h for copyright info
==599735== Command: ./update-old
==599735==
==599735==
==599735== HEAP SUMMARY:
==599735==     in use at exit: 10,784 bytes in 74 blocks
==599735==   total heap usage: 2,083,027 allocs, 2,082,953 frees, 82,655,426 bytes allocated
==599735==
==599735== LEAK SUMMARY:
==599735==     definitely lost: 0 bytes in 0 blocks
==599735==     indirectly lost: 0 bytes in 0 blocks
==599735==     possibly lost: 320 bytes in 3 blocks
==599735==     still reachable: 10,464 bytes in 71 blocks
==599735==               of which reachable via heuristic:
==599735==                 newarray      : 536 bytes in 2 blocks
==599735==     suppressed: 0 bytes in 0 blocks
==599735== Rerun with --leak-check=full to see details of leaked memory
==599735==
==599735== For lists of detected and suppressed errors, rerun with: -s
==599735== ERROR SUMMARY: 0 errors from 0 contexts (suppressed: 0 from 0)
```

```
> valgrind ./update-new
==600256== Memcheck, a memory error detector
==600256== Copyright (C) 2002-2022, and GNU GPL'd, by Julian Seward et al.
==600256== Using Valgrind-3.19.0 and LibVEX; rerun with -h for copyright info
==600256== Command: ./update-new
==600256==
==600256==
==600256== HEAP SUMMARY:
==600256==     in use at exit: 10,784 bytes in 74 blocks
==600256==   total heap usage: 1,273,769 allocs, 1,273,695 frees, 50,285,106 bytes allocated
==600256==
==600256== LEAK SUMMARY:
==600256==    definitely lost: 0 bytes in 0 blocks
==600256==    indirectly lost: 0 bytes in 0 blocks
==600256==    possibly lost: 320 bytes in 3 blocks
==600256==    still reachable: 10,464 bytes in 71 blocks
==600256==                  of which reachable via heuristic:
==600256==                      newarray          : 536 bytes in 2 blocks
==600256==    suppressed: 0 bytes in 0 blocks
==600256== Rerun with --leak-check=full to see details of leaked memory
==600256==
==600256== For lists of detected and suppressed errors, rerun with: -s
==600256== ERROR SUMMARY: 0 errors from 0 contexts (suppressed: 0 from 0)
```