Guide to Profile-Guided Optimization:

inlining, devirtualizing, and profiling

Satoru Kawahara

@Go Conference 2024

Who talks

Hello, I’m bisho-jo!

- 🏢 **Kanmu,Inc.**
- 📎 Nymphium
- 🔰 2nd-year Golang student

Today's Topic

By the way, do you ...

Today's Topic

By the way, do you ...

 Use the Go Compiler?

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- 🙋‍♀️ Use the Go Compiler?
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Do you use

Profile-Guided Optimization?

Today’s Topic

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Learn about

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and

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Profile-Guided Optimization (**PGO**, abbrev.)
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- Uses *profiling information* from **program execution**
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Learn about

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👉 **its associated optimizations**

- 🤔 *Function Inlining*
- 🤔 *Devirtualization*

Function Inlining

Function inlining, or simply *inlining*, is the process of replacing a func call with its body.

```
func f (x int) int {
  return x * x
}

func main() {
  fmt.printf("%d", f(3))
}
```

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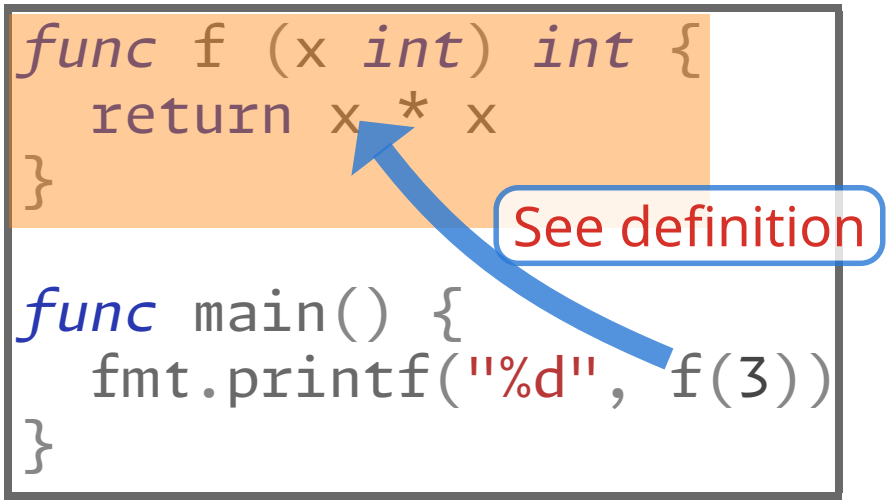

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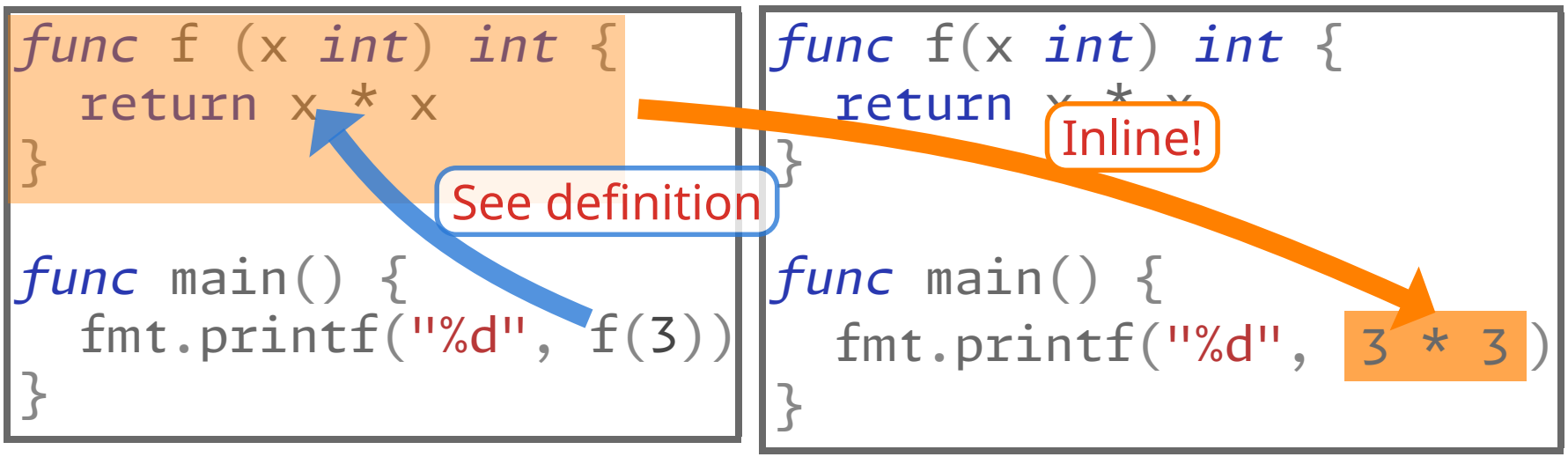
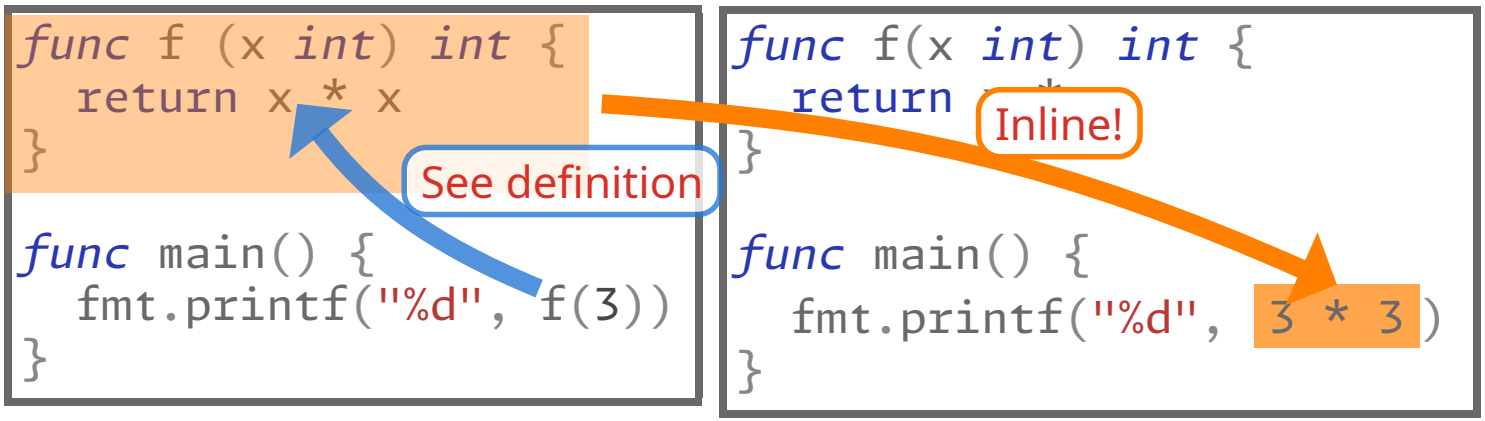


Function Inlining

Function inlining, or simply *inlining*, is the process of replacing a func call with its body.

- Reduces ***function call overhead:***
  No stack frame setup, no return address,
  no arguments copying
- Enables ***further optimizations***:
  E.g., *constant propagation*, *dead code elimination*



Conditions for Inlining

Several conditionals to be applied[*2]:

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●Conditions for Inlining

Several conditionals to be applied[*2]:

- **Non-leaf** function:
  The func shouldn't call other funcs.

```
func f (x int) int {
  return x * x
}

func g (x int) int {
  return f(x) + 1
}
```

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calls f → g is **non-leaf function**

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Several conditionals to be applied[*2]:

- **Non-leaf** function:
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- **Small function**, *"Budget"* ≤ 80:
  Constructs are rated by their cost:
  - 57 for non-leaf func call
  - 1 for `panic`
  - etc.

  The *budget* is the total cost of func body.

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  The budget is the total cost of func body.
- And so on $\cdots$
  - Not external function (e.g., C functions)
  - No specific tags set, *`//go:noinline`*, *`//go:systemstack`*, etc.
  - Not a complex body, including `defer`, `select`, etc.

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Devirtualization

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WAIT!

Can you explain

how

interface method call

works?

•Interface Method Call

Interface method calls in Go is perforemed based on *dynamic dispatch*[*3].

```
var r io.Reader
r = strings.NewReader("Hello")
buf := make([]byte, 5)
n, _ := r.Read(buf)
```

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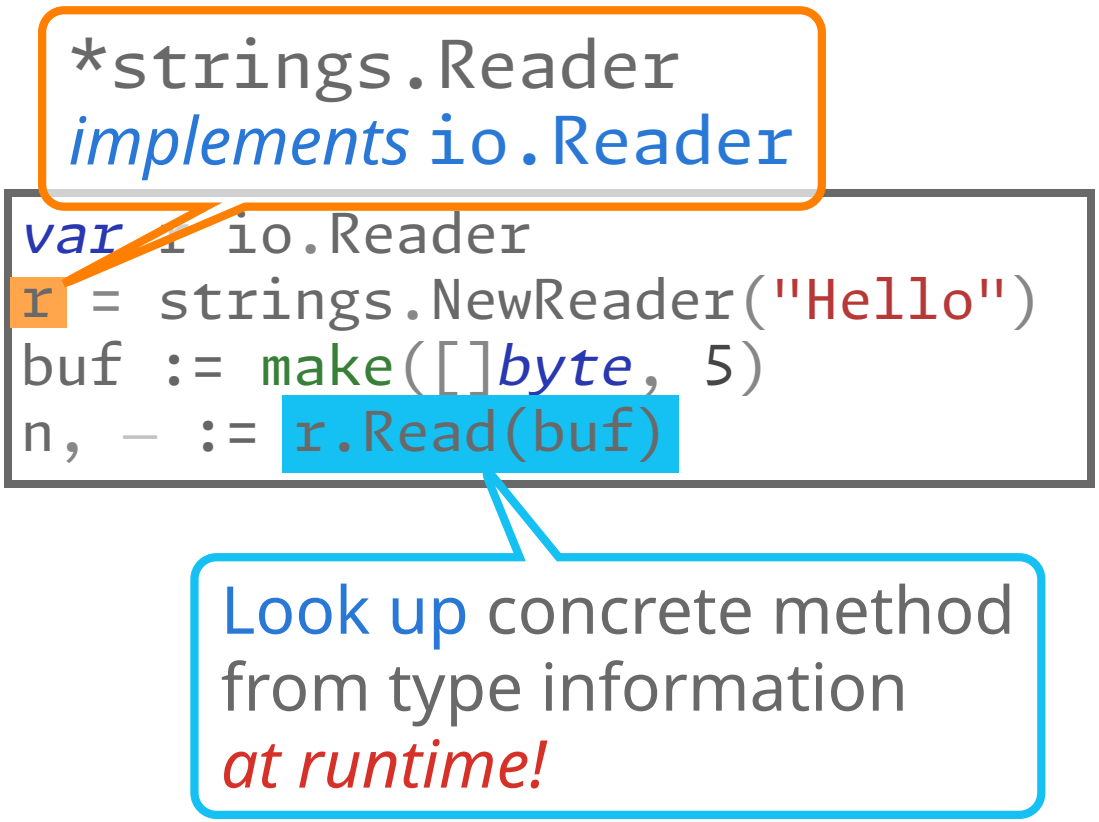

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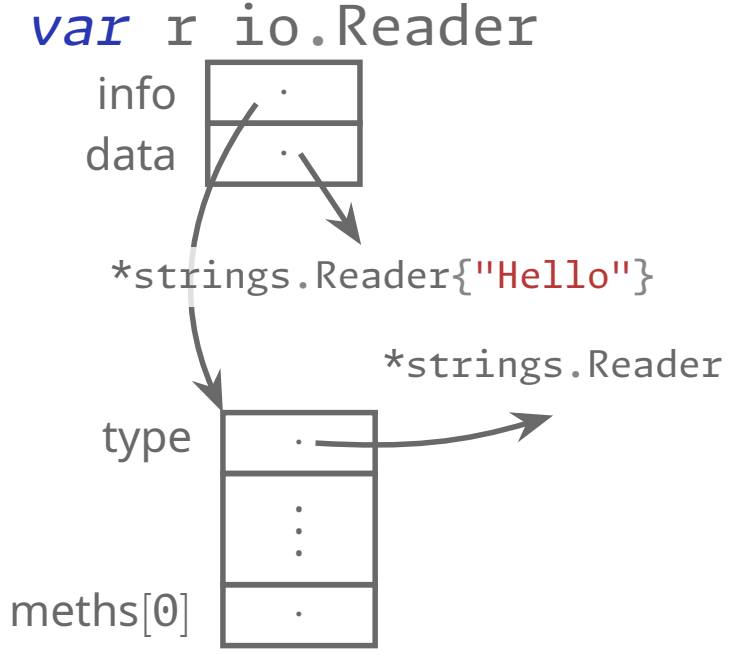
Look up concrete method from type information *at runtime!*



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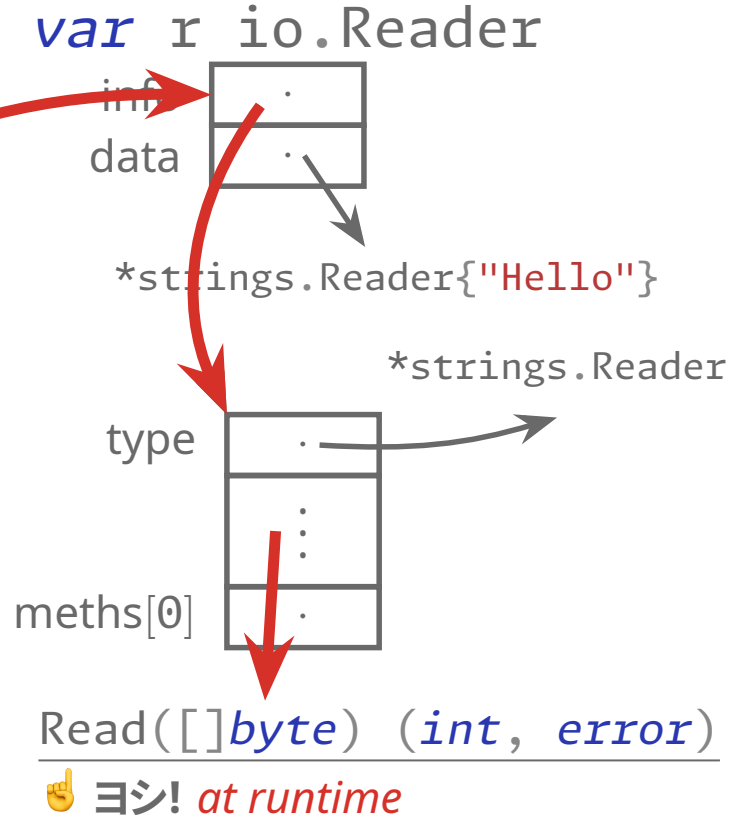

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Devirtualization is a kind of optimizations that an converts **interface method call** 👍 with concrete func call.

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→ Can analyze it calls `(*strings.Reader).Read` at ***compile time!***

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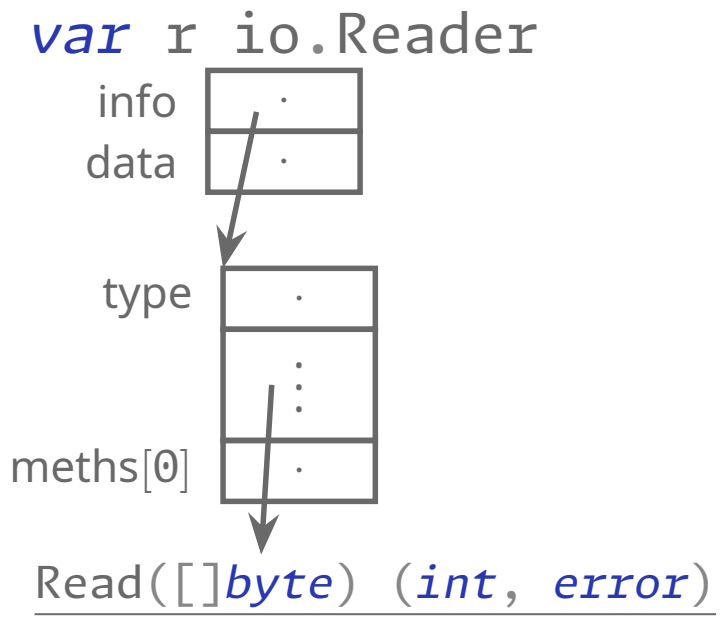

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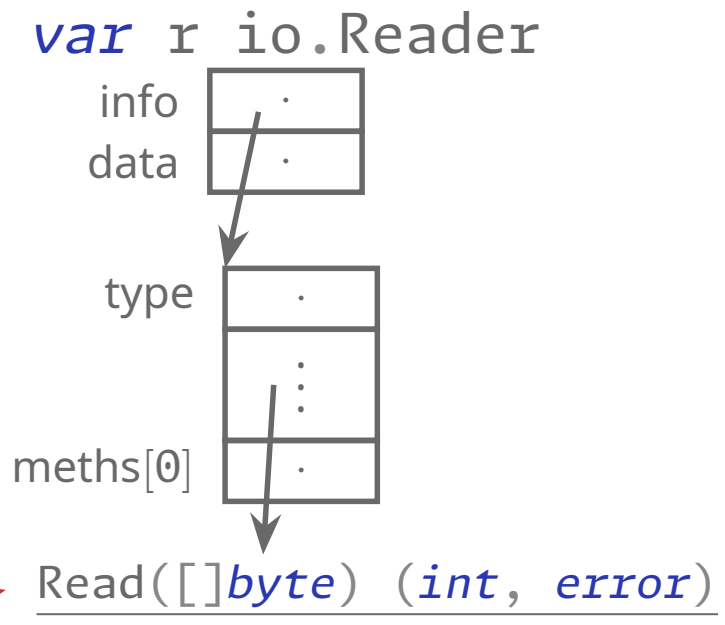

☝ ヨシ! ***at compile runtime***

■Devirtualization

Devirtualization is a kind of optimizations that an converts **interface method call** 👍 with concrete func call.

- Reduces ***interface method call overhead:***
  No look up and typechecking at runtime
- Enables ***further optimizations:***
  Same to inlining

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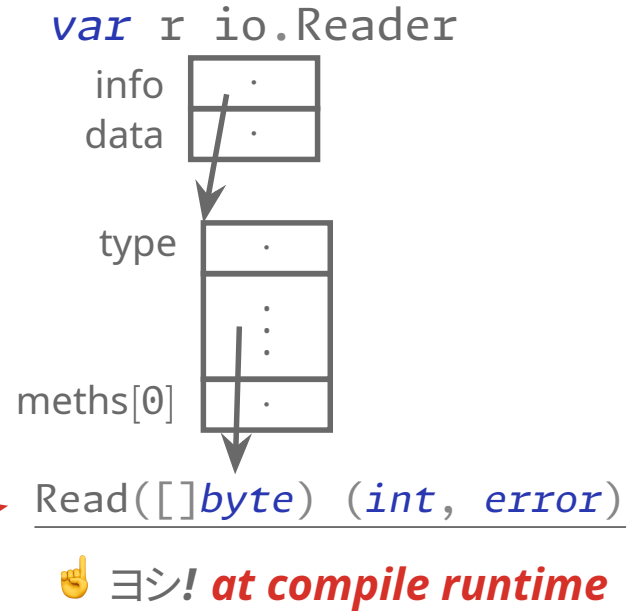

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Limitation for Devirtualization

⚠**Limitation**: can only be applied if concrete method is **determined statically**.

```
var r io.Reader
if os.Getenv("MODE") == "string" {
  r = strings.NewReader("Hello")
} else {
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dynamic conditional

Can't resolve ***statically***, which should call `(*strings.Reader).Read` or `(*bytes.Reader).Read`?

Profile-Guided Optimization

Go compiler performs several optimizations,

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Go compiler performs several optimizations, *and* there are **still room for more!**

- *Conditionals* for inlining
- *Limitation* for devirtualization

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This is where

Profile-Guided Optimization

comes in 😎

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Profile-Guided Optimization

PGO is an optimization method that:

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So,
***how to* collect profiles?**

- Enables *more aggressive optimizations*, such as inlining and devirtualization

👍 👍

Creating and Collecting Profiles

Profile data is represented as *pprof* format.
There are several choices to create:

- `runtime/pprof`
  Writes out profile files
- `net/http/pprof`
  Runs HTTP server for get profiling data
- gopkg.in/DataDog/dd-trace-go.v1/profiler
  Sends profiles to the Datadog API

■#PR

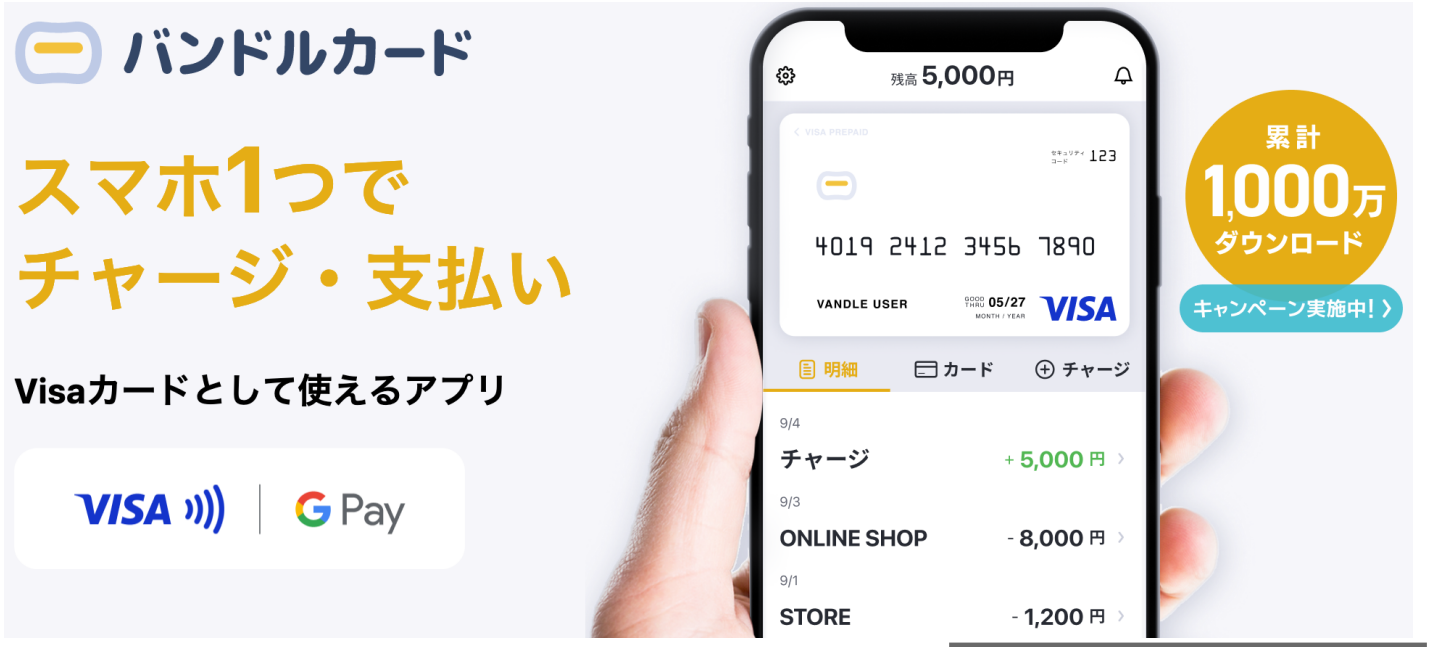
突然ですが

ここで宣伝です

■#PR


バンドルカード
スマホ1つで
チャージ・支払い
Visaカードとして使えるアプリ
VISA
Pay
残高 5,000円
VISA PREPAID
123
4019 2412 3456 7890
VANDLE USER
05/27
VISA
明細
カード
チャージ
9/4
チャージ
+ 5,000 円
9/3
ONLINE SHOP
- 8,000 円
9/1
STORE
- 1,200 円
累計
1,000万
ダウンロード
キャンペーン実施中!

■#PR



Vandle API server → 🐶**Datadog**

profiles,logs
via `dd-trace-go/profiler`

●Creating and Collecting Profiles

To fetch profiles from 🐶Datadog……

- **datadog-pgo**
  Can fetch many profiles(up to 30?) at once!

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  At build phase:

```
ENV DD_API_KEY=${DD_API_KEY}
ENV DD_APP_KEY=${DD_APP_KEY}

RUN datadog-pgo -profiles 30 \
  'service:vandle-api env:prd' ./default.pgo
```

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To fetch profiles from 🐶Datadog……

- **datadog-pgo**
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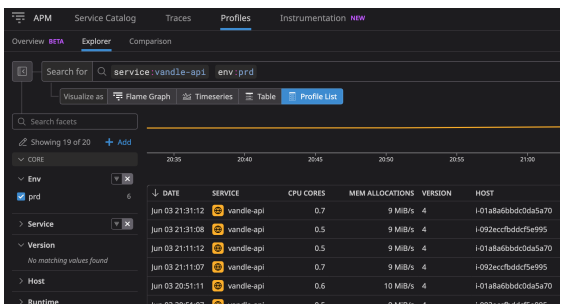
- ✋ Pick from APM profile list BY HAND



Difficult to get many profiles😭

Compiling with PGO

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```
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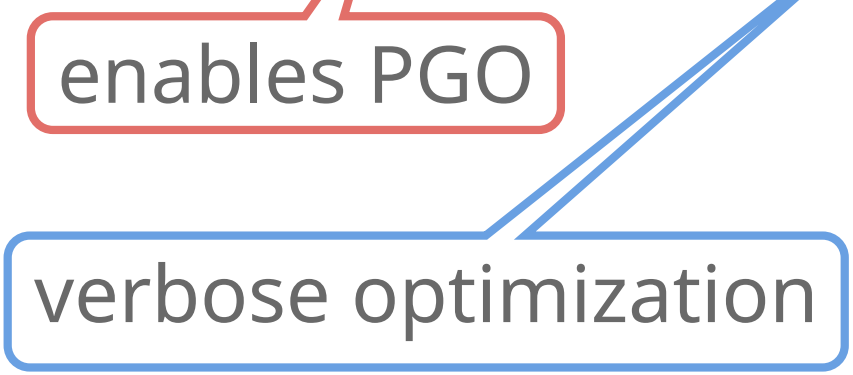

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controls inlining, `-l=4` enables inlining **non-leaf functions** (!)

verbose optimization

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```

Devirtualize statically ambiguous interface call!

Not inlined, but budget is lifted to 2000!

Evaluation

≈ 240000 lines

Compiling **Vandle** API server,
with or without PGO and `-l`, then count output

```
$ go build ..... \
  | grep -E '(can inline|PGO devirtualizing)' \
  | wc -l
```

Evaluation

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flags	result (lines)	inlining	PGO devirt
`-pgo=off` (default)	110313	110313	-
`-pgo=off -l=4`	+67561	177874	-
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- `-l=4` accelerates devirtualization
- WHAT?!

  Optimizations is so complicated ... 😌

Conclusion

- Introduces **profile-guided optimization**, **inlining** and **devirtualization**
- Evaluates PGO with `-l` flag, using production code
- Vandle card is running with PGO build!
- **Optimizations are so deep and intereseting!**

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- Introduces **profile-guided optimization**, **inlining** and **devirtualization**
- Evaluates PGO with `-l` flag, using production code
- Vandle card is running with PGO build!
- **Optimizations are so deep and intereseting!**
- Couldn't talk today 😭:
  - Pprof for visualizing call site
  - PGO calculates hotness by **CFD**
  - **AutoFDO**, Continuous compiling with profiles
  - Comparison with other languages' compilers
    - Haskell, resolves *all* typeclass constraints
    - JVM, *JIT*
    - PGO in .NET
  - Interface with Generics