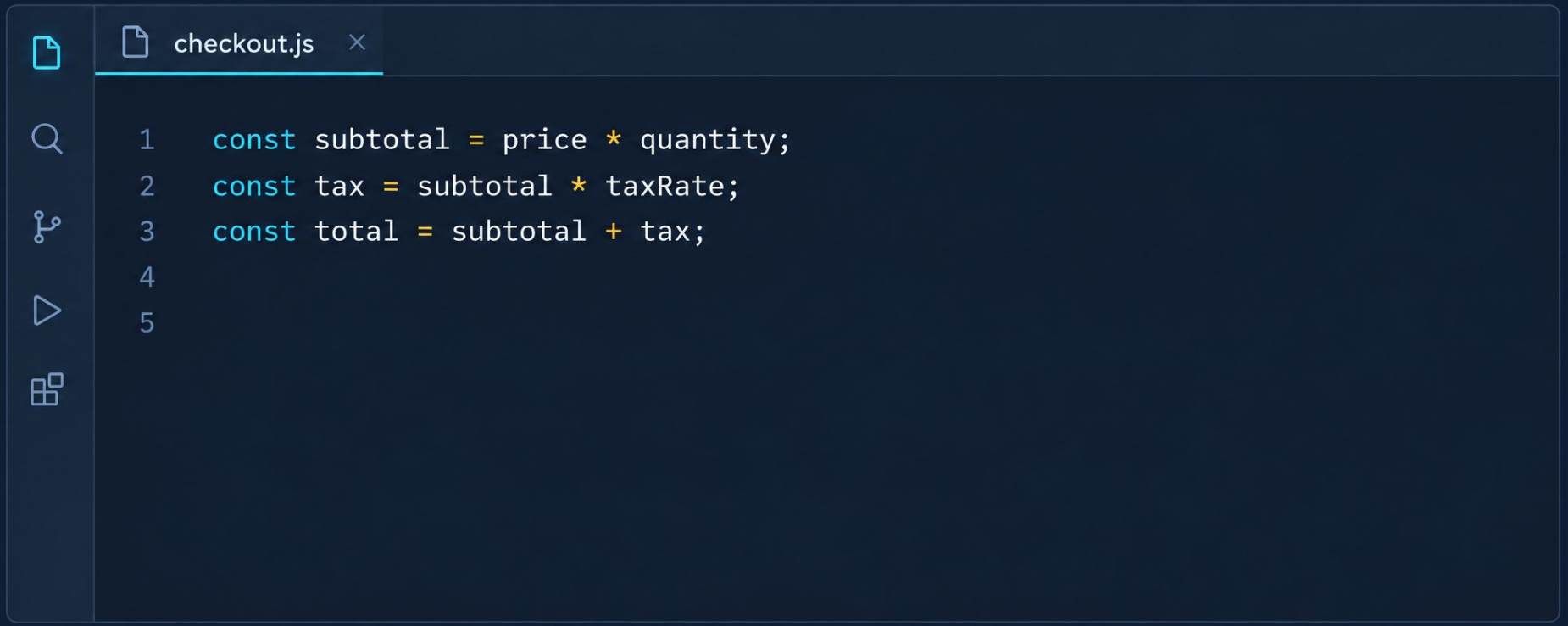
UFMG

Translating Compilers Research Into Hardware Emulation

Compilers Laboratory

Rafael Alvarenga de Azevedo
arafael@cadence.com


checkout.js
1 const subtotal = price * quantity;
2 const tax = subtotal * taxRate;
3 const total = subtotal + tax;
4
5

checkout.js

```
1  const subtotal = price * quantity;
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3  const total = subtotal + tax;
4
5
```
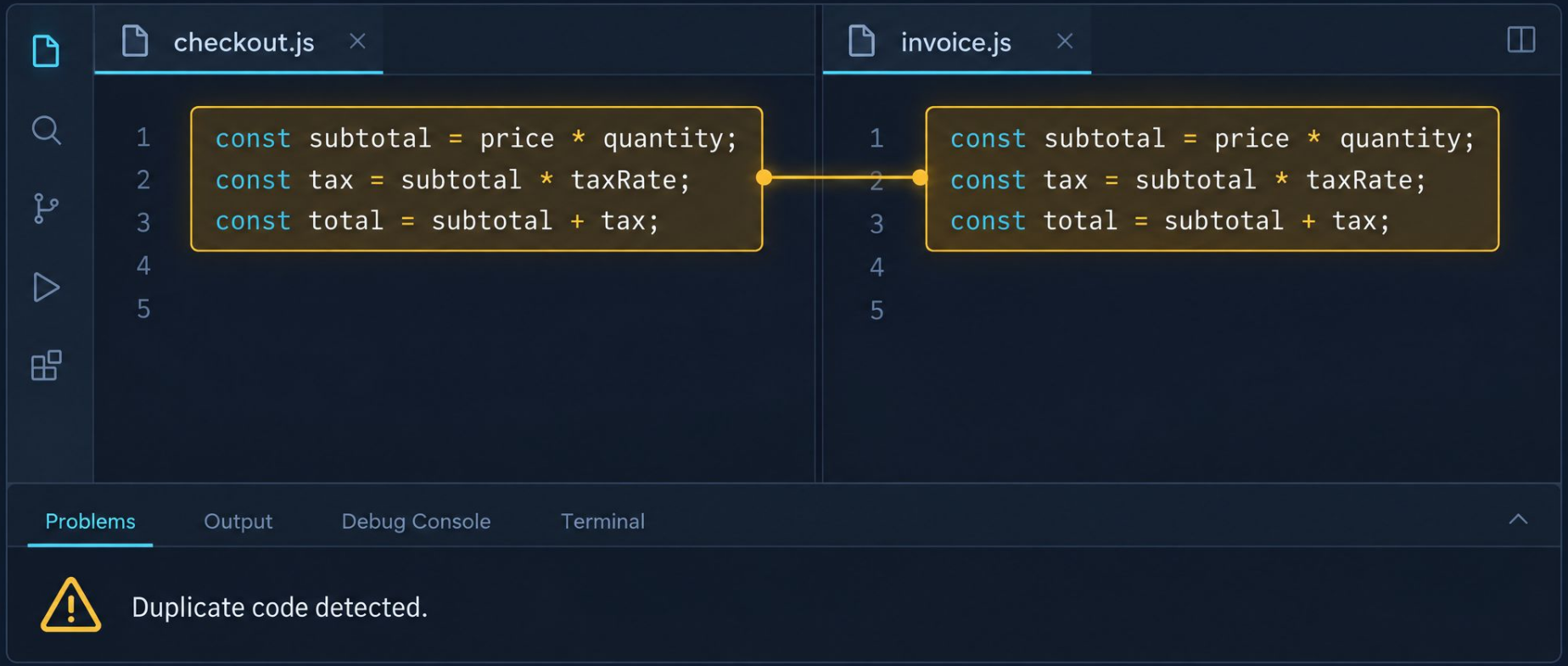
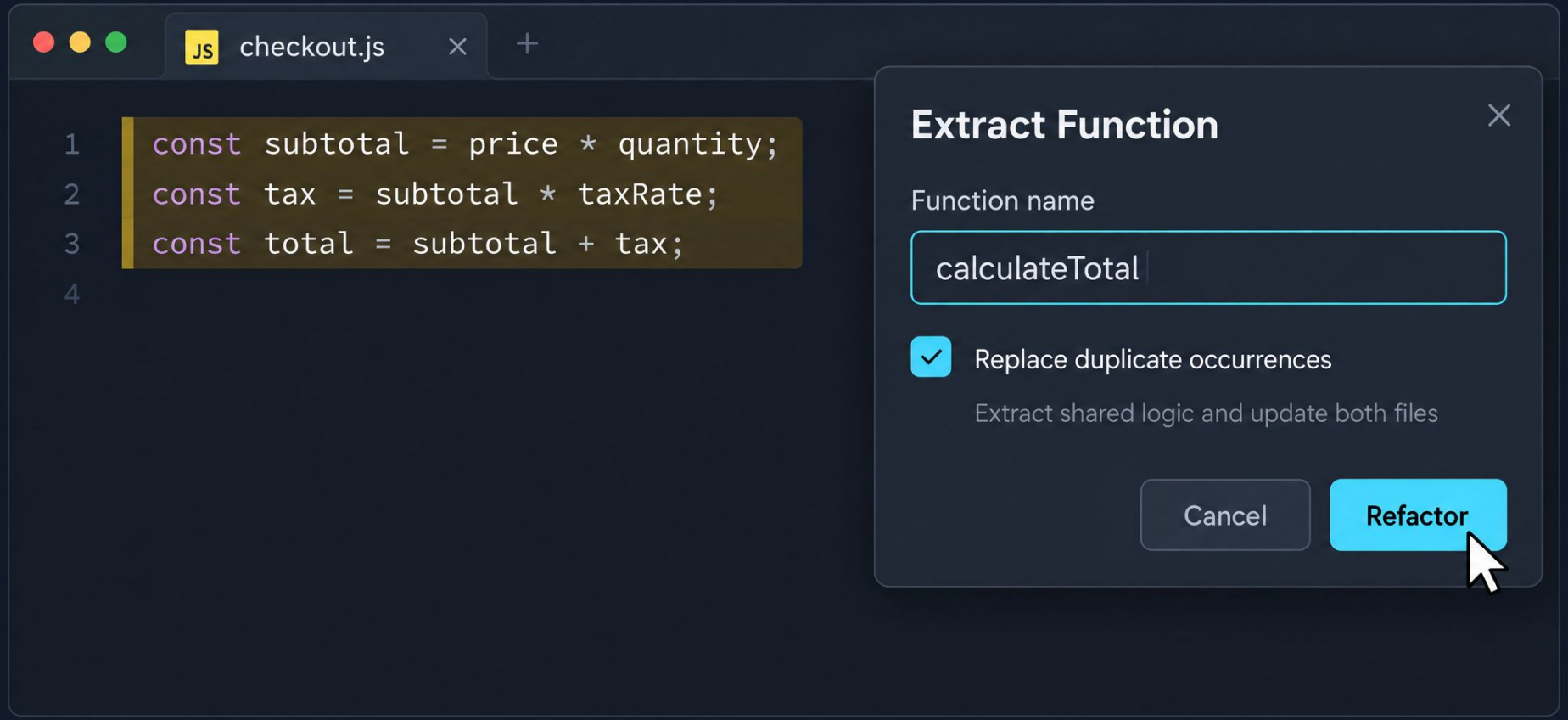

invoice.js

```
1  const subtotal = price * quantity;
2  const tax = subtotal * taxRate;
3  const total = subtotal + tax;
4
5
```

1. Detect duplicate code



2. Extract a reusable function



3. Reuse shared logic

totals.js

```
1  export function calculateTotal(price, quantity, taxRate) {
2    const subtotal = price * quantity;
3    const tax = subtotal * taxRate;
4    return subtotal + tax;
5  }
```

checkout.js

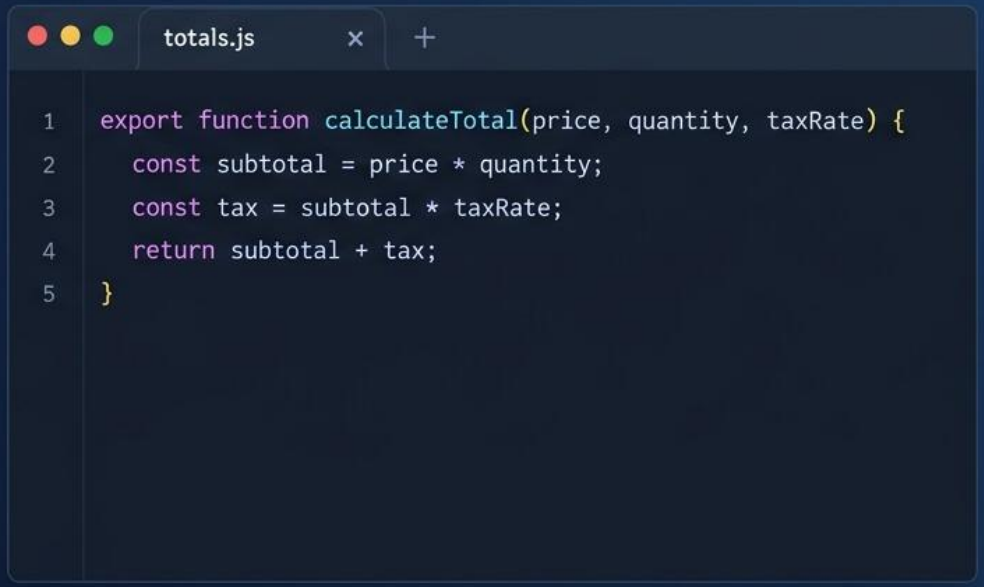
```
1  import { calculateTotal } from "./totals.js";
2  const total = calculateTotal(price, quantity, taxRate);
```

invoice.js

```
1  import { calculateTotal } from "./totals.js";
2  const total = calculateTotal(price, quantity, taxRate);
```



Duplicate code removed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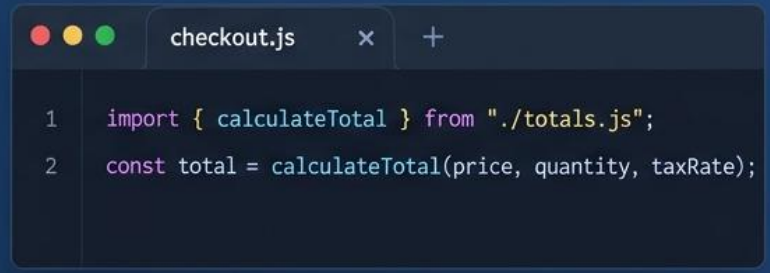
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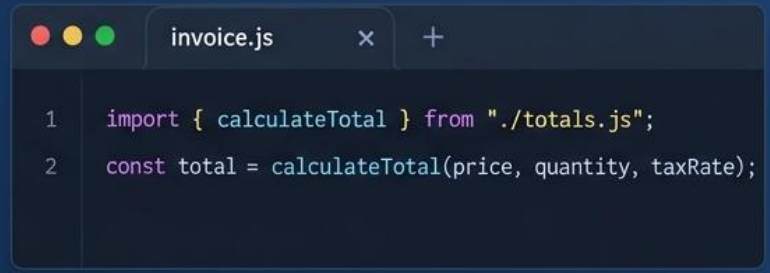
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totals.js

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invoice.js

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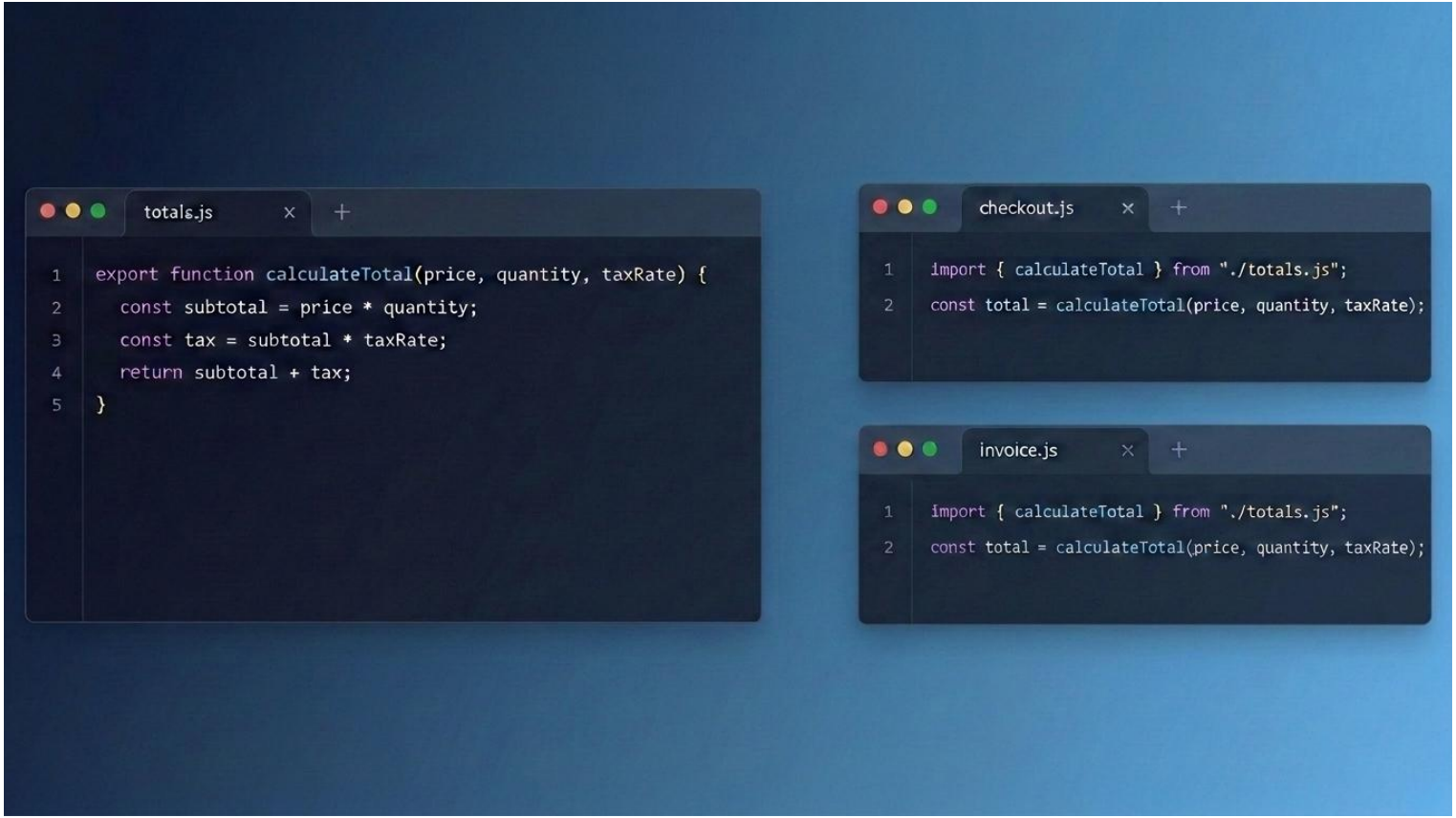
```

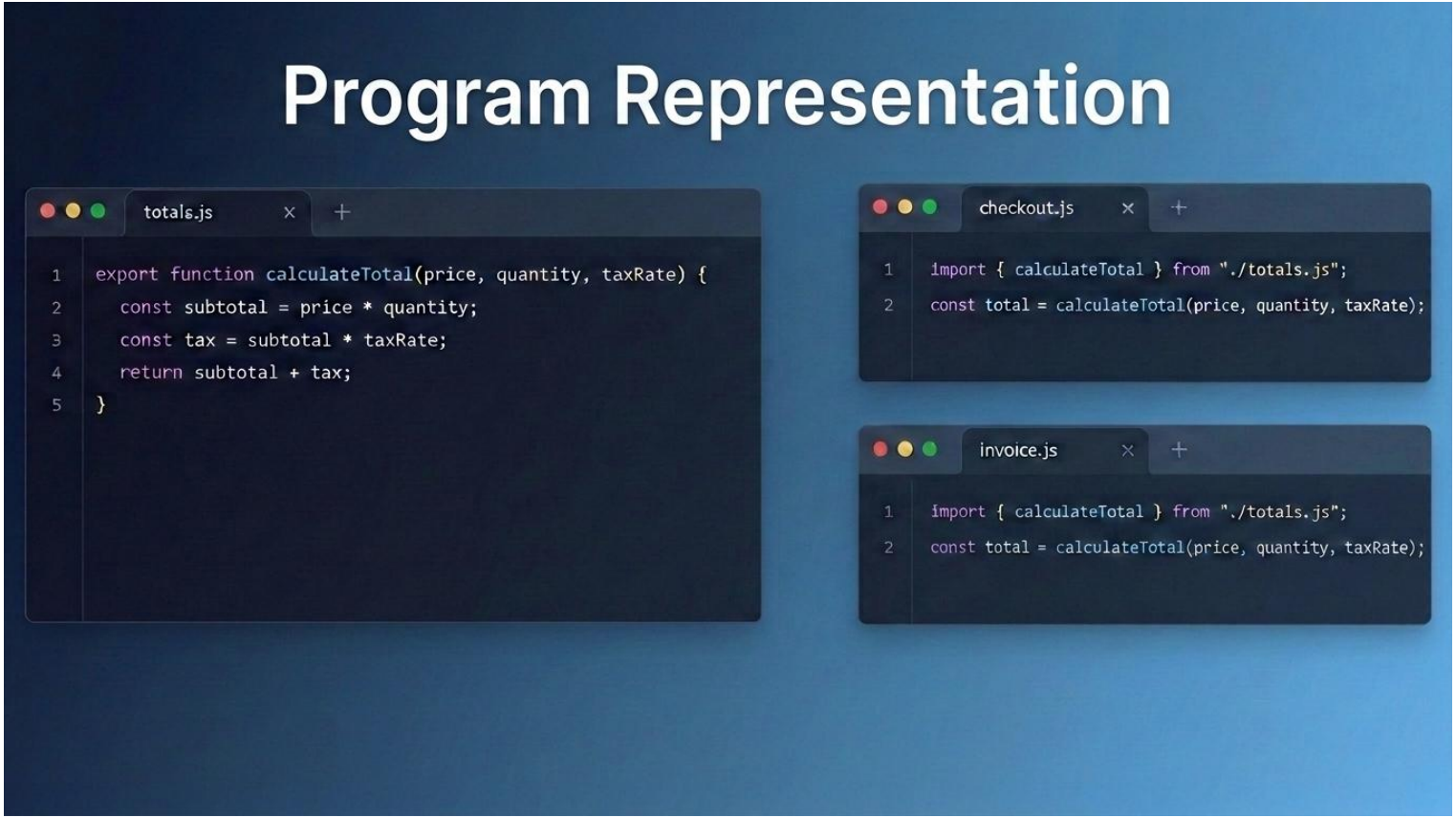
Problem: how to write a program that does this automatically?

Compiler Theory



Problem: how to write a program that does this automatically?

Program Representation



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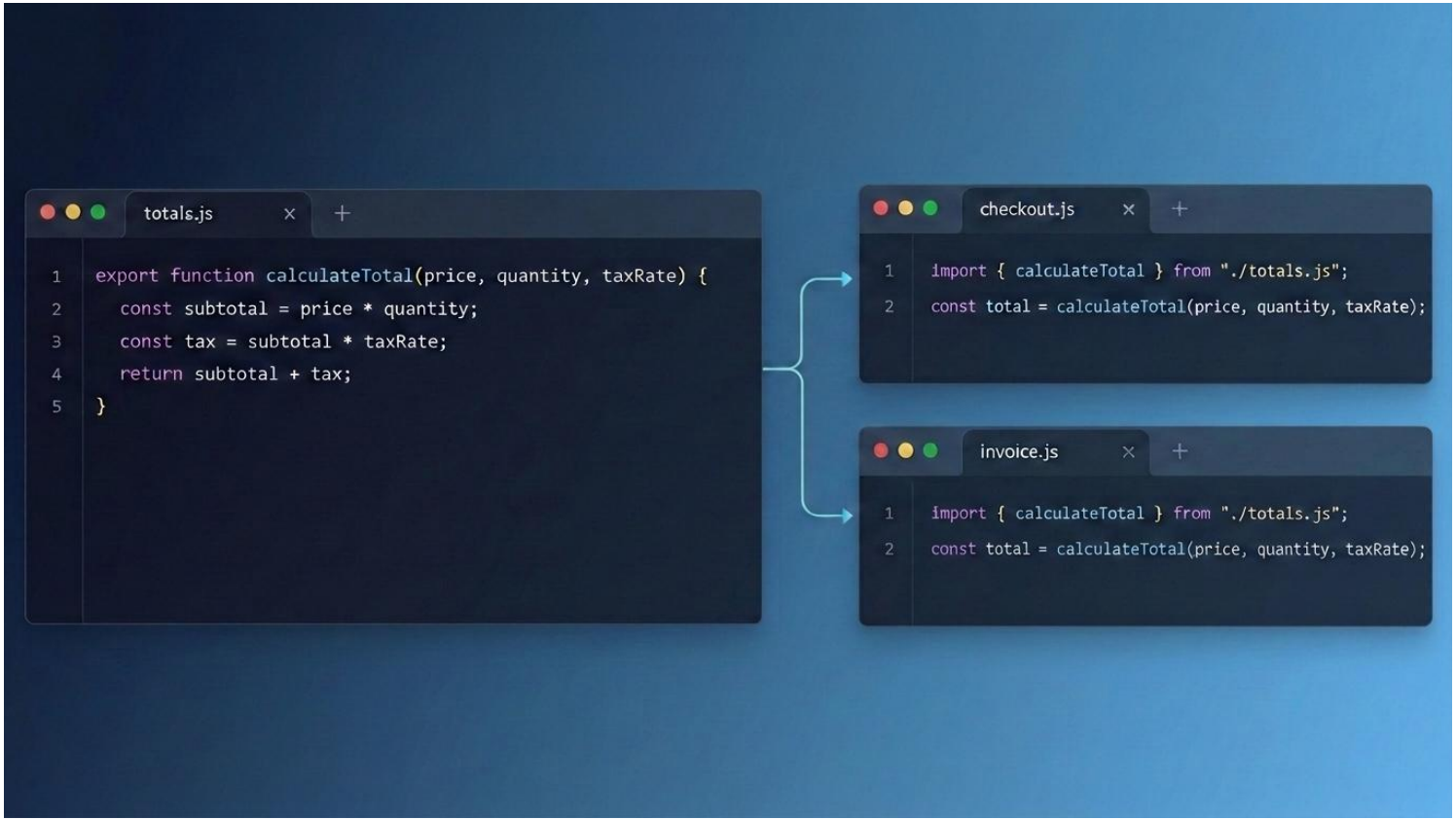

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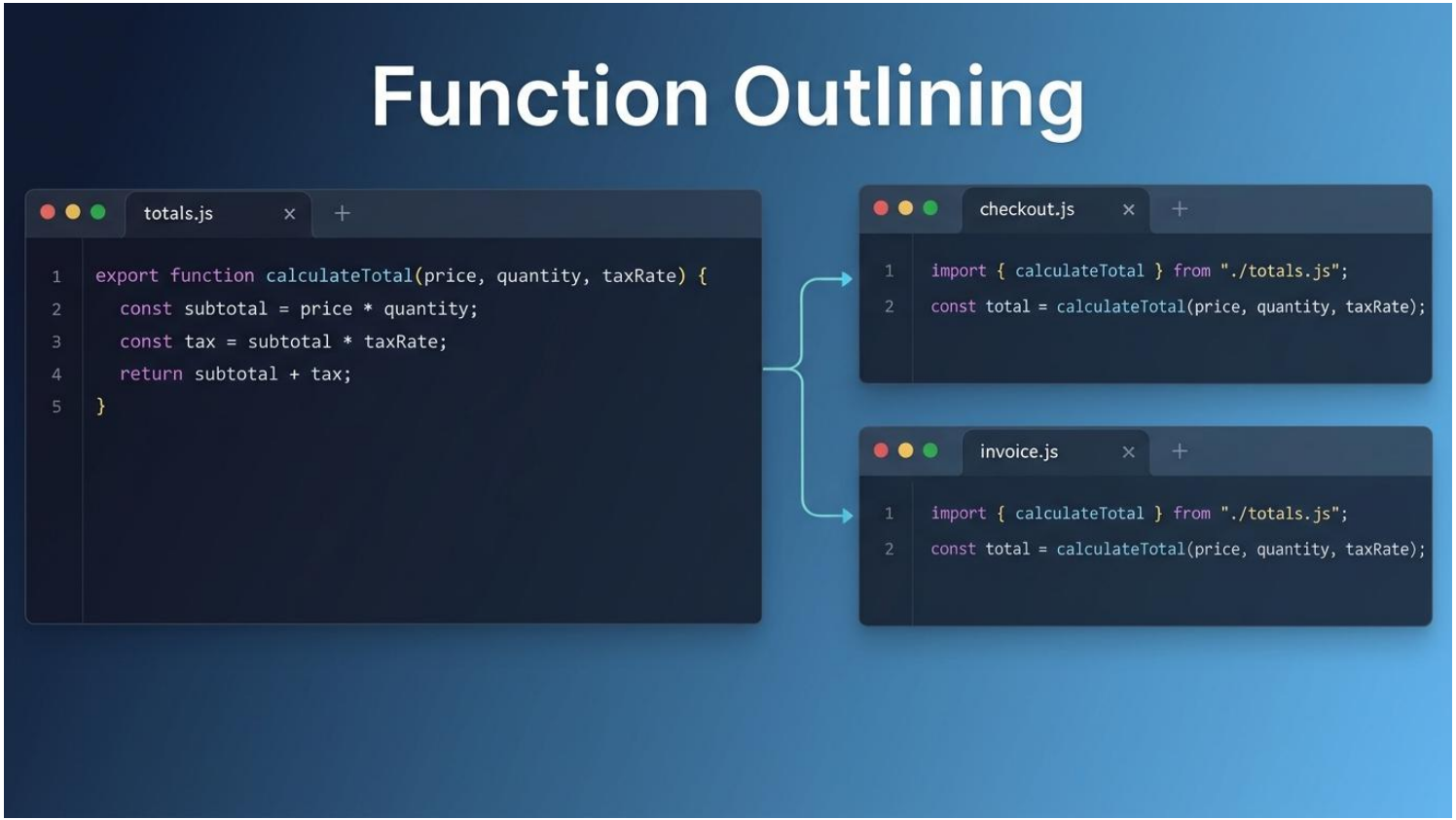
Function Outlining



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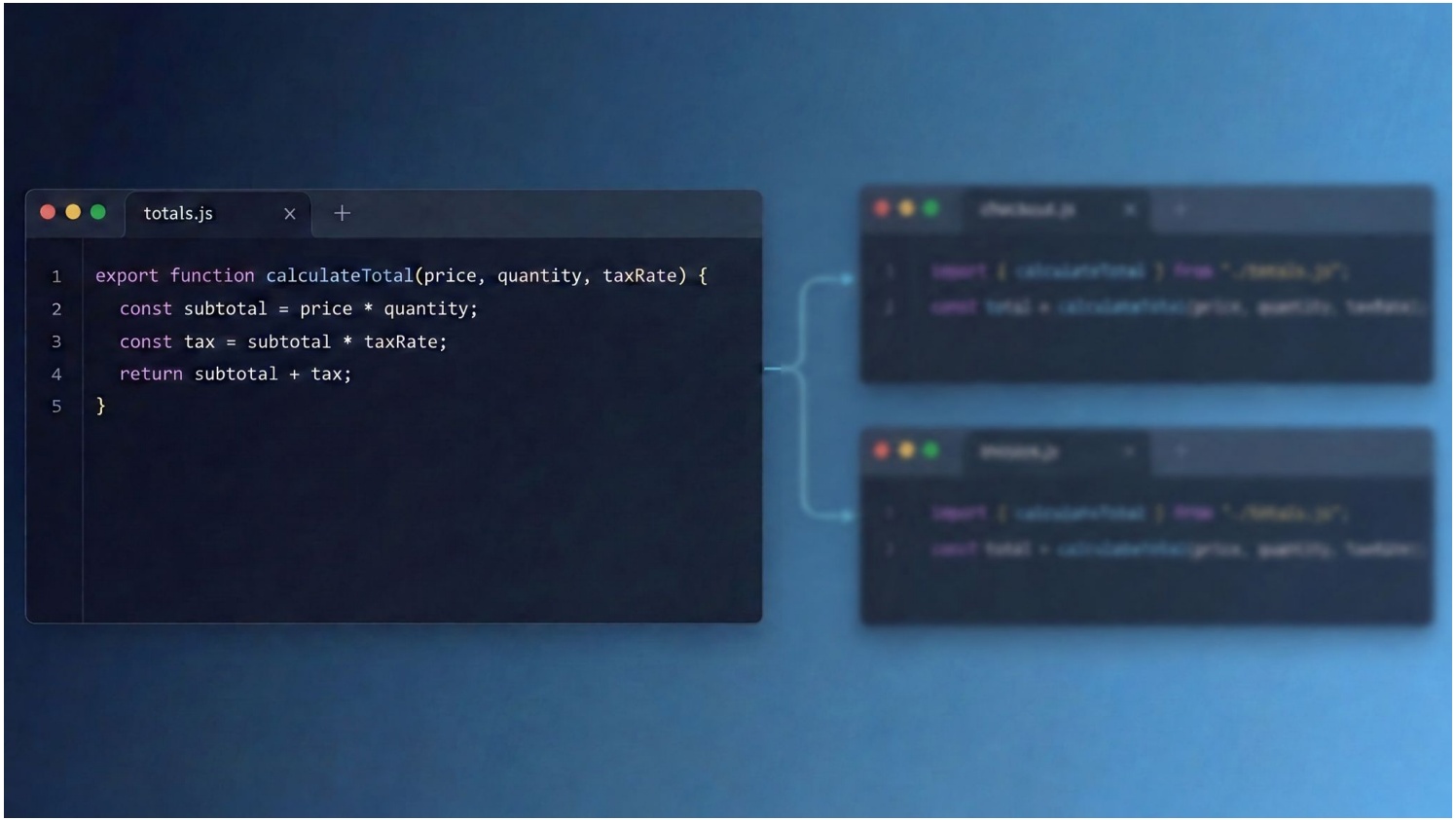

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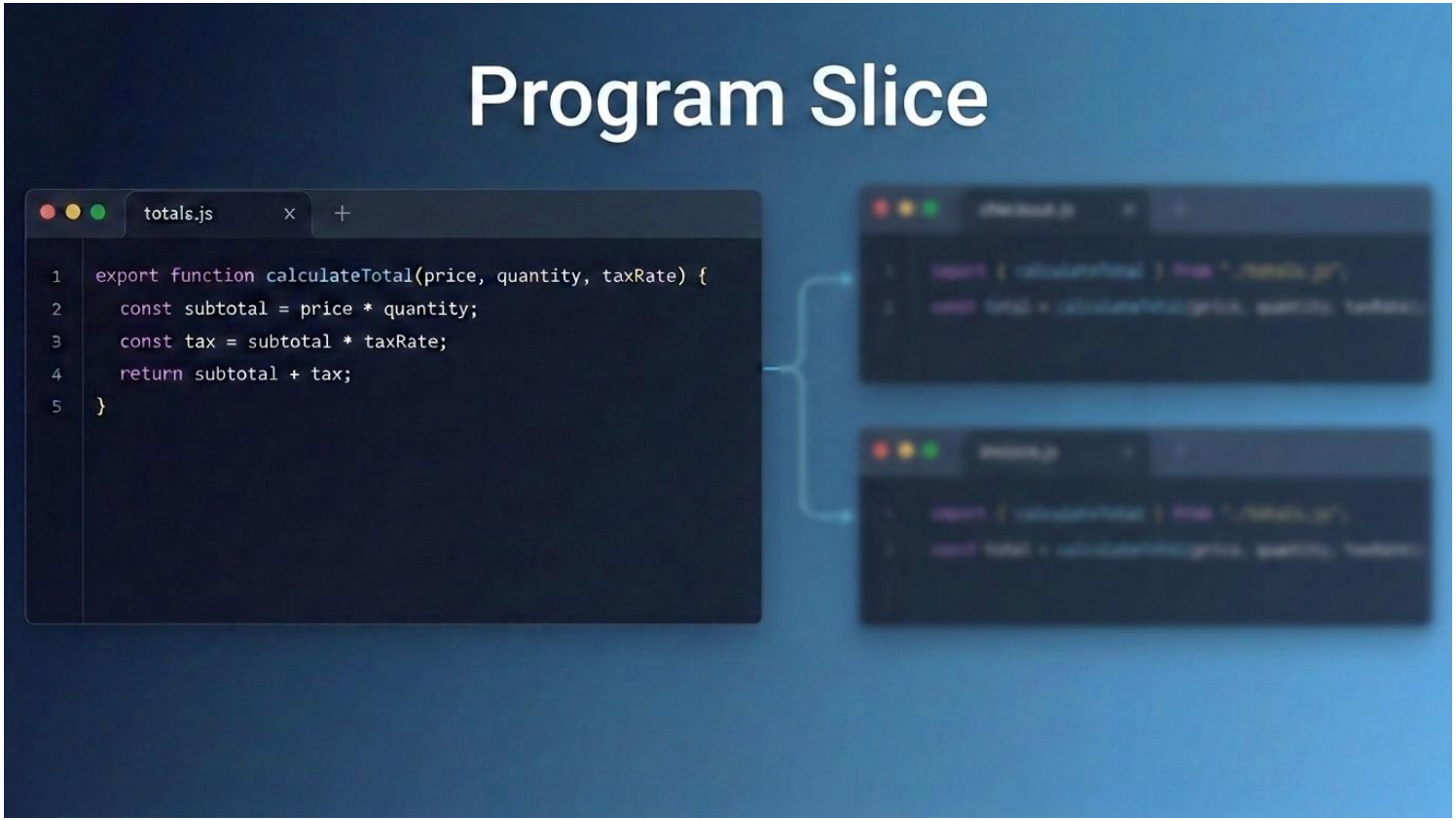
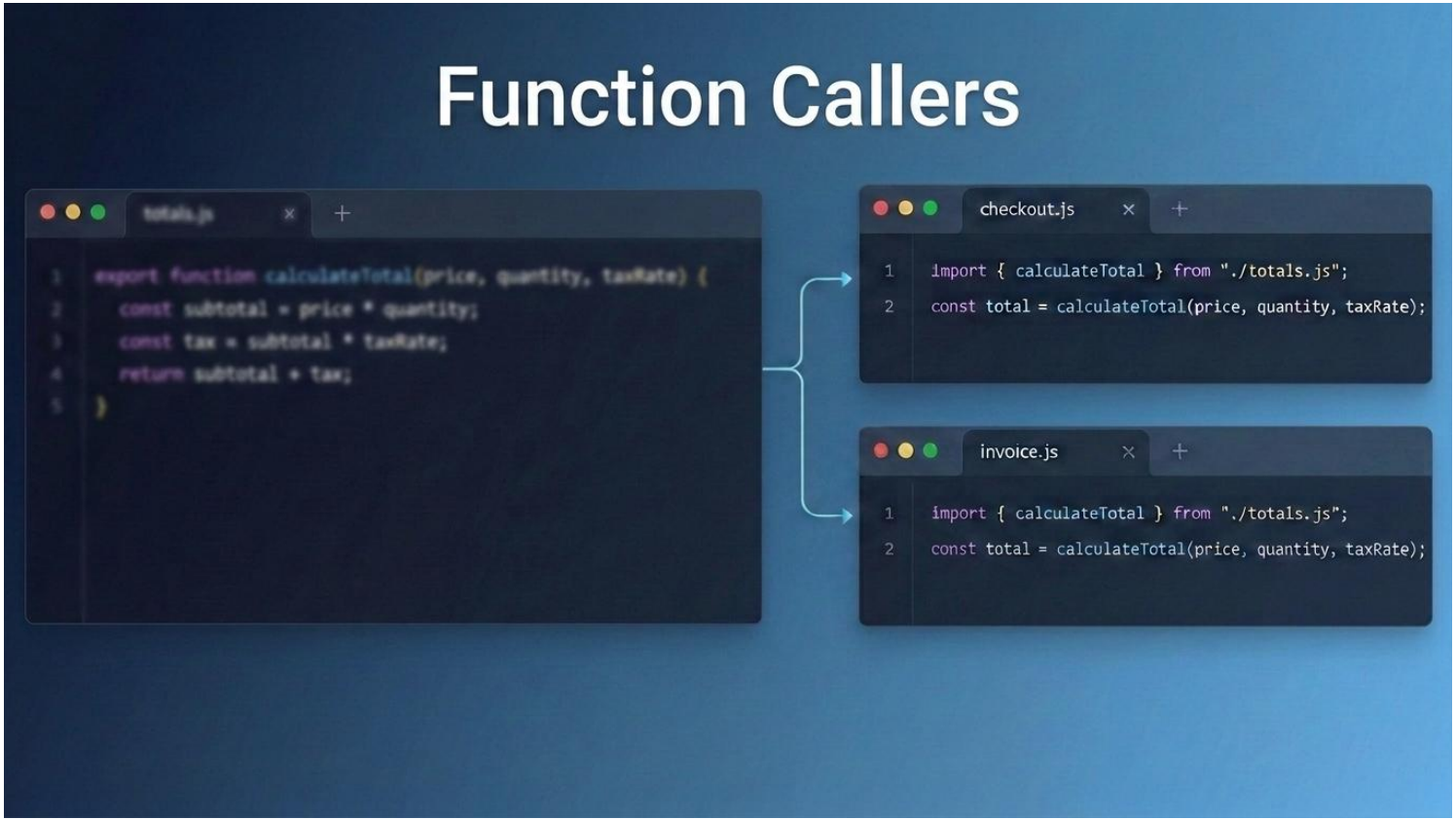


Problem: how to write a program that does this automatically?

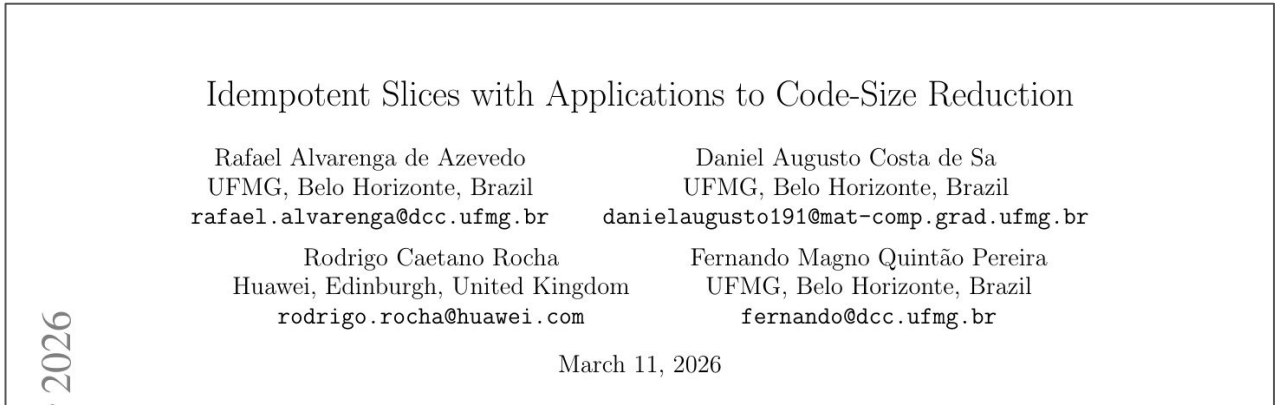
Function Callers



Problem: how to write a program that does this automatically?

Idempotent Backward Slice

Idempotent Backward Slice



Idempotent Slices with Applications to Code-Size Reduction

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March 11, 2026

2026

Example

Example

DCC

```
01  int foo(int N) {
02    int x = 0;
03    int s = 1;
04    int t = 0;
05    while (x < N) {
06      x += 1;
07      s *= 2;
08      t += 3;
09    }
10    s = s + 1;
11    u = s = t;
12    return u;
13  }
```

Example

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slice criterion

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07      s *= 2;
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Example - **Program Slice**

DCC

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Example

DCC

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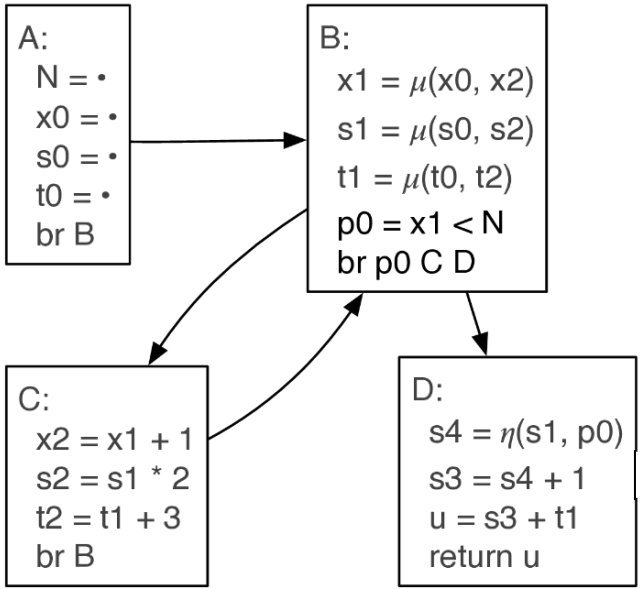
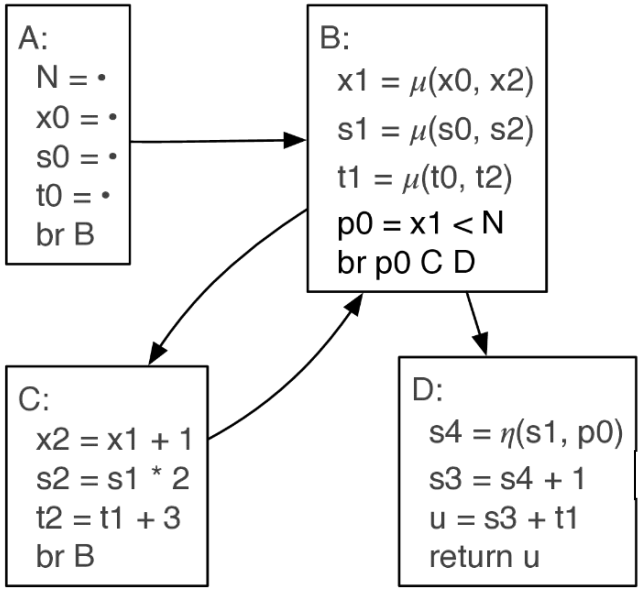
Example

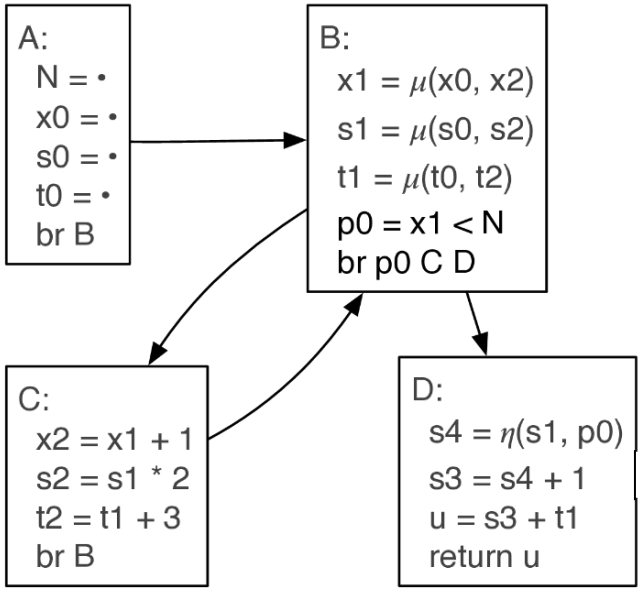

A:
N = •
x0 = •
s0 = •
t0 = •
br B
B:
x1 = μ(x0, x2)
s1 = μ(s0, s2)
t1 = μ(t0, t2)
p0 = x1 < N
br p0 C D
C:
x2 = x1 + 1
s2 = s1 * 2
t2 = t1 + 3
br B
D:
s4 = η(s1, p0)
s3 = s4 + 1
u = s3 + t1
return u

Example



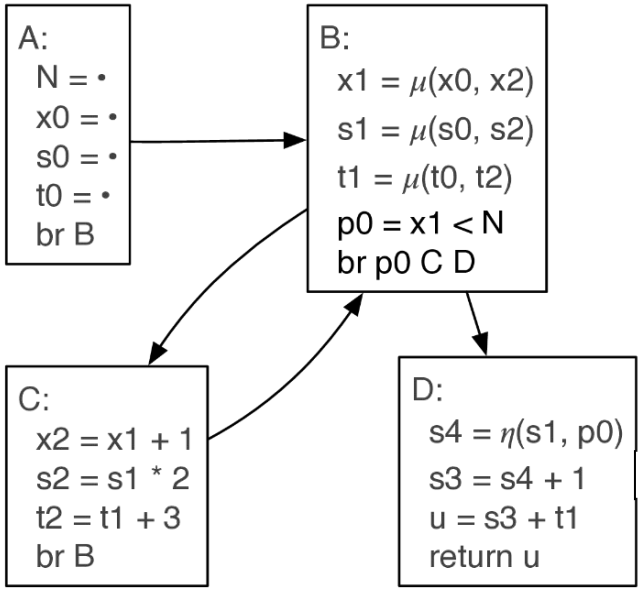
Control flow graph

Example

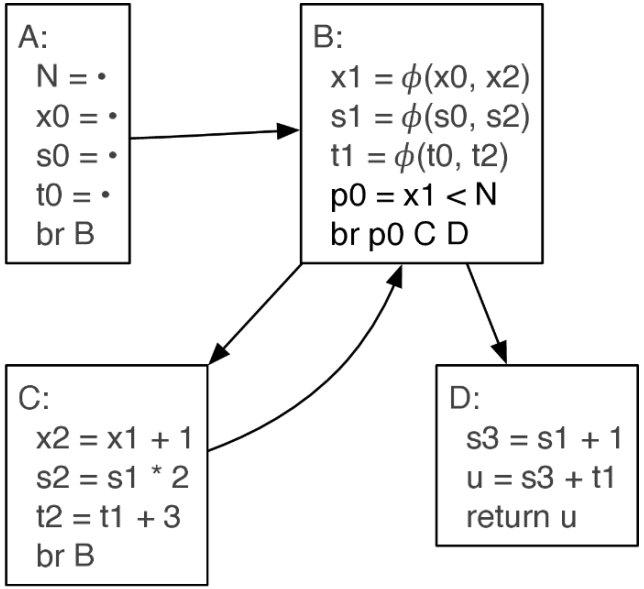


GSA form

Example



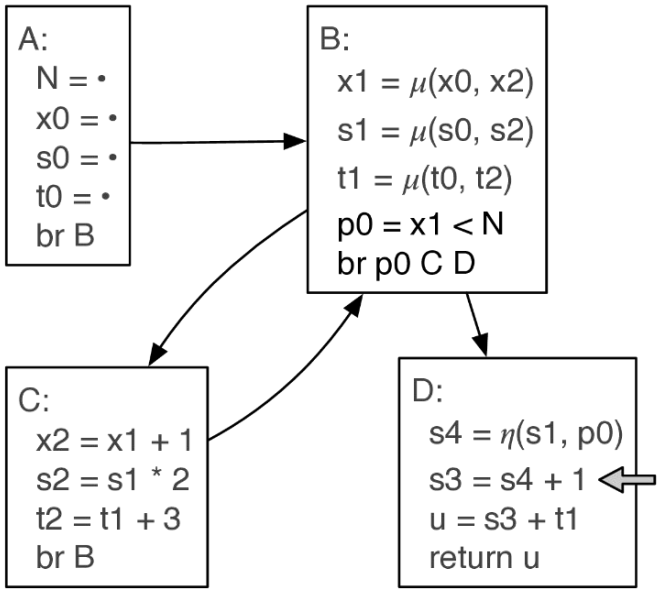
GSA form



SSA form

Example - **Program Representation**

DCC



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```

LLVM Pass

LLVM Pass

DCC

LLVM Pass

DCC



Project Daedalus

A code compression technique based on the identification and extraction of recurrent program slices in the LLVM IR

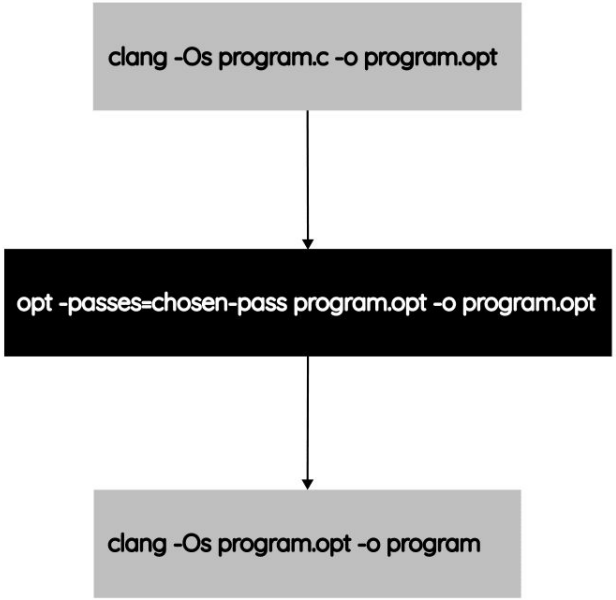
Evaluation

DCC

Evaluation

DCC

Compilation pipeline

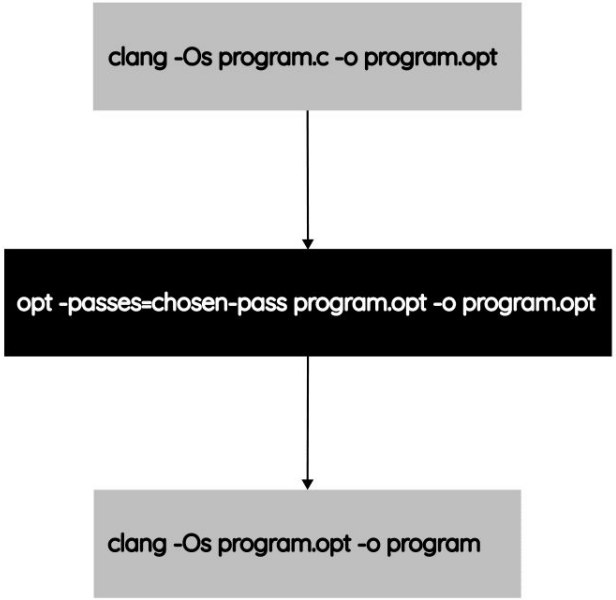


Evaluation

DCC

Compilation pipeline

LLVM Test Suite

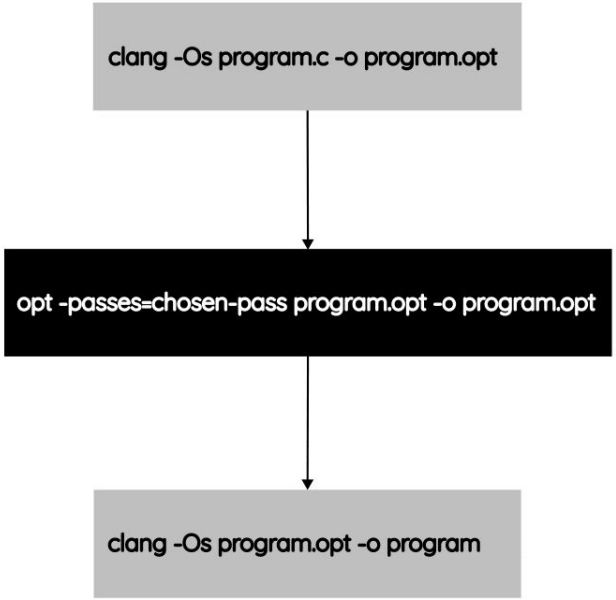


Evaluation

DCC

Compilation pipeline

- LLVM Test Suite
- 2007 programs



Evaluation

DCC

2007 programs total

Evaluation

DCC

2007 programs total

Metric
Instcount
.text size
Exec. Time
Comp. Time

Evaluation

DCC

2007 programs total

Metric
Instcount
.text size
Exec. Time
Comp. Time

Number of LLVM instructions

Evaluation

DCC

2007 programs total

Metric
Instcount
.text size
Exec. Time
Comp. Time



Evaluation

DCC

2007 programs total

Metric
Instcount
.text size
Exec. Time
Comp. Time

Test execution time

Evaluation

DCC

2007 programs total

Metric
Instcount
.text size
Exec. Time
Comp. Time

Test compilation time

Evaluation

DCC

2007 programs total

	Daedalus	
Metric	**Affected**	**Geom.**
Instcount	142	-0.24%
.text size	133	0.11%
Exec. Time	161	0.06%
Comp. Time	303	4.22%

Evaluation

DCC

2007 programs total

	Daedalus	
Metric	**Affected**	**Geom.**
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2007 programs total

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Reduction

Growth

Evaluation

DCC

2007 programs total

	Daedalus		Func. Merging	
Metric	**Affected**	**Geom.**	**Affected**	**Geom.**
Instcount	142	-0.24%	183	-0.35%
.text size	133	0.11%	190	0.39%
Exec. Time	161	0.06%	177	0.25%
Comp. Time	303	4.22%	241	2.06%

Evaluation

DCC

2007 programs total

	Daedalus		Func. Merging		IROutliner	
Metric	**Affected**	**Geom.**	**Affected**	**Geom.**	**Affected**	**Geom.**
Instcount	142	-0.24%	183	-0.35%	207	-0.65%
.text size	133	0.11%	190	0.39%	160	-0.19%
Exec. Time	161	0.06%	177	0.25%	160	-0.09%
Comp. Time	303	4.22%	241	2.06%	258	2.48%

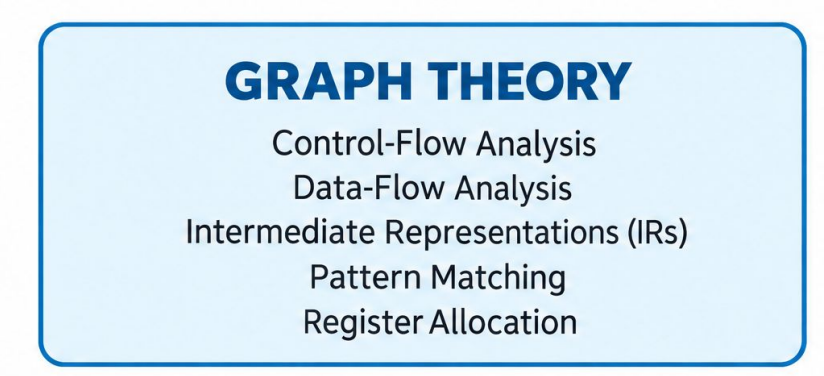
What Compilers Teach You

What Compilers Teach You

DCC

What Compilers Teach You

DCC



What Compilers Teach You

DCC

GRAPH THEORY

Control-Flow Analysis
Data-Flow Analysis
Intermediate Representations (IRs)
Pattern Matching
Register Allocation

CORRECTNESS

Formal Methods
Formal Verification
Bug Prevention
Specification Testing
Proving Compiler Logic

What Compilers Teach You

DCC

GRAPH THEORY

Control-Flow Analysis
Data-Flow Analysis
Intermediate Representations (IRs)
Pattern Matching
Register Allocation

SYSTEMS PROGRAMMING

Optimizing for Hardware
Kernel/OS Integration
Runtime Systems
Direct Hardware Access
Multi-core Processing

CORRECTNESS

Formal Methods
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What Compilers Teach You

DCC

GRAPH THEORY

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CORRECTNESS

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Formal Verification
Bug Prevention
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Proving Compiler Logic

TRADE-OFFS

Balancing Performance
Code Size
Compile Time
Memory Usage
Security

From Compilers to Hardware Emulation

Hardware Emulation

DCC

Hardware Emulation - Synthesis

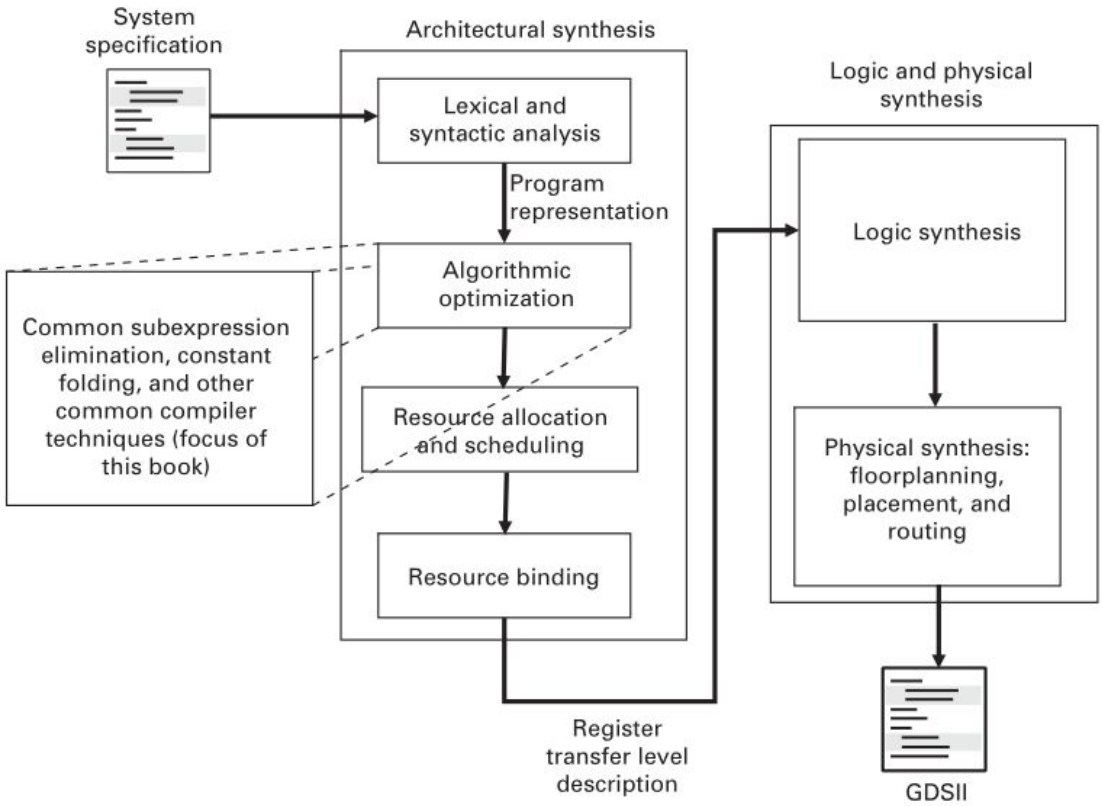


Image from [2]

Hardware Emulation

DCC

Hardware Emulation

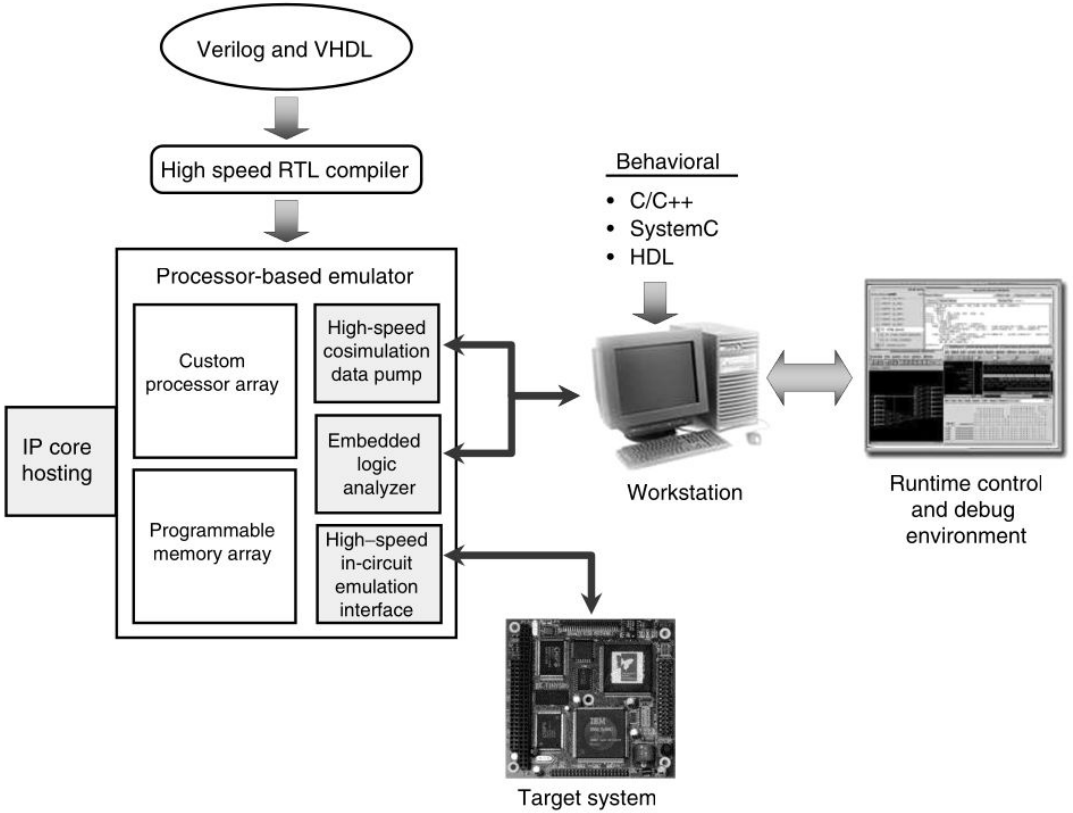
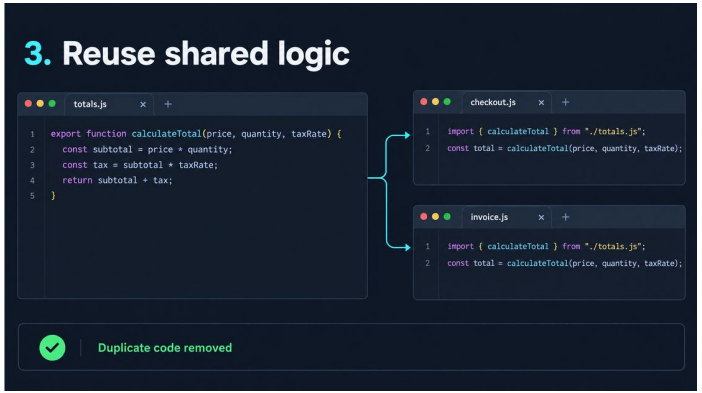


Image from [3]

Conclusion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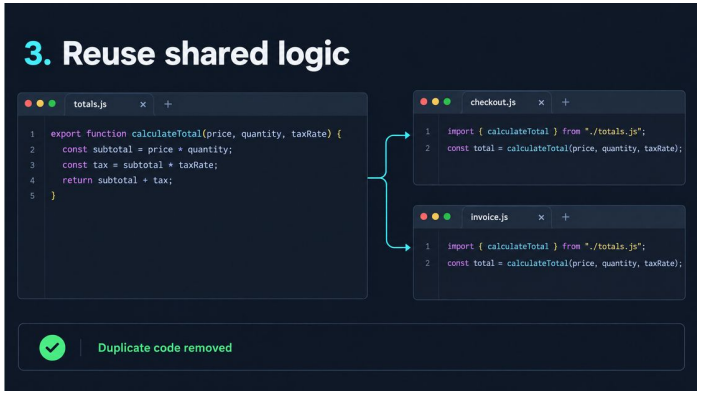
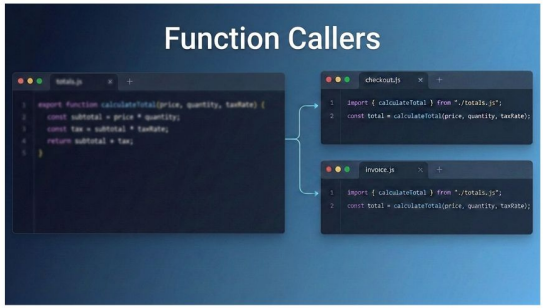
invoice.js
import { calculateTotal } from "./totals.js";
const total = calculateTotal(price, quantity, taxRate);
Duplicate code removed

Conclusion



Conclusion



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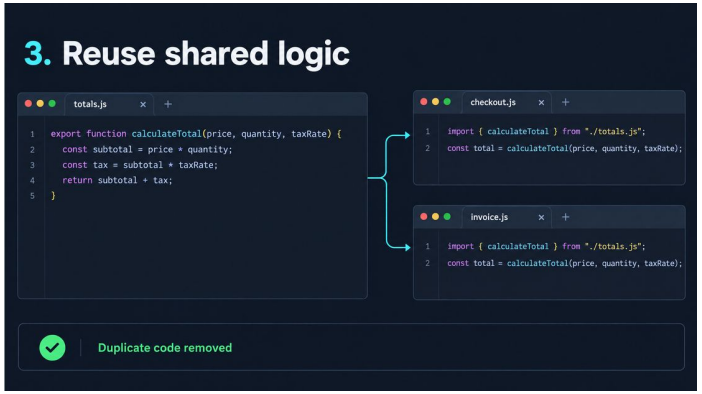
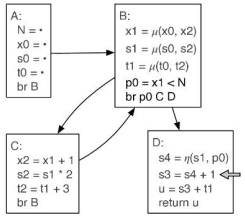


Example - **Program Representation**

DCC



GSA form

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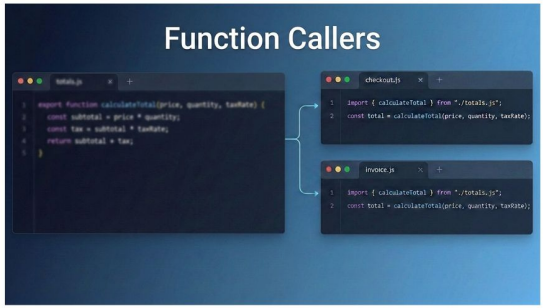
Conclusion



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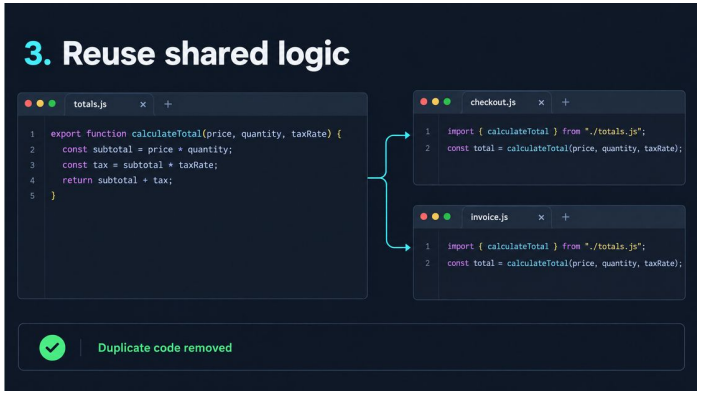
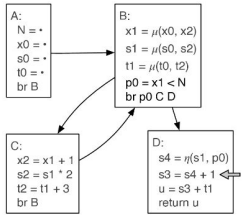


Example - **Program Representation**

DCC



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09   }
10   s = s + 1;⇦
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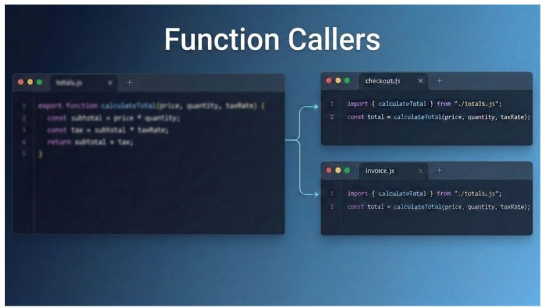
Conclusion



Problem: how to write a program that does this automatically?

LLVM Pass



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3. Reuse shared logic

totals.js

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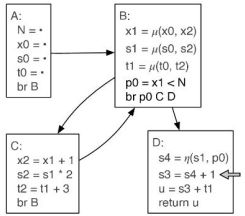
Duplicate code removed

Example - **Program Representation**

DCC



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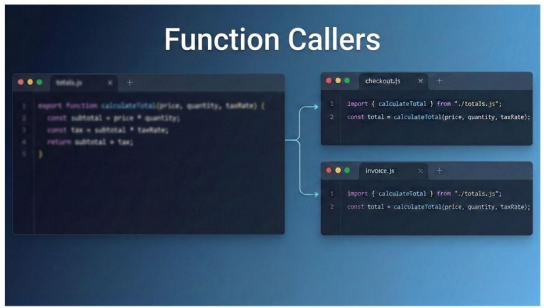
Conclusion

Function Callers



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Evaluation

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	Daedalus		Func. Merging		IROutliner	
Metric	Affected	Geom.	Affected	Geom.	Affected	Geom.
Instcount	142	-0.24%	183	-0.35%	207	-0.65%
.text size	133	0.11%	190	0.39%	160	-0.19%
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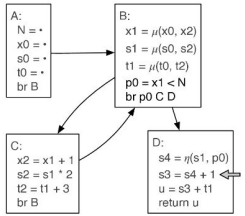

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What Compilers Teach You

DCC

GRAPH THEORY
Control-Flow Analysis
Data-Flow Analysis
Intermediate Representations (IRs)
Pattern Matching
Register Allocation

SYSTEMS PROGRAMMING
Optimizing for Hardware
Kernel/OS Integration
Runtime Systems
Direct Hardware Access
Multi-core Processing

CORRECTNESS
Formal Methods
Formal Verification
Bug Prevention
Specification Testing
Proving Compiler Logic

TRADE-OFFS
Balancing Performance
Code Size
Compile Time
Memory Usage
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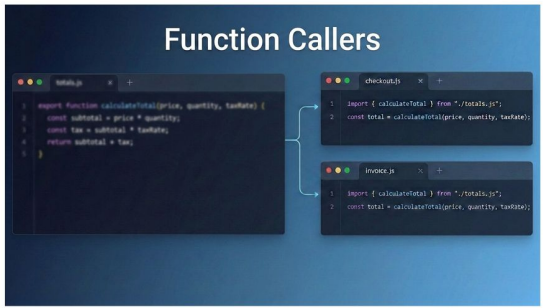

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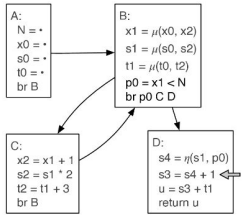

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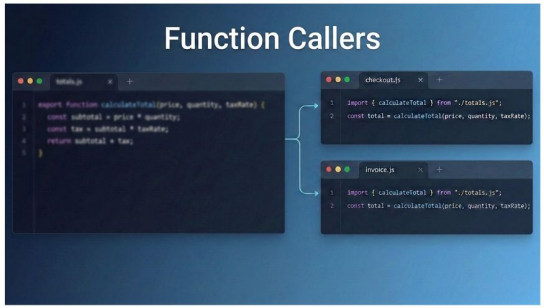

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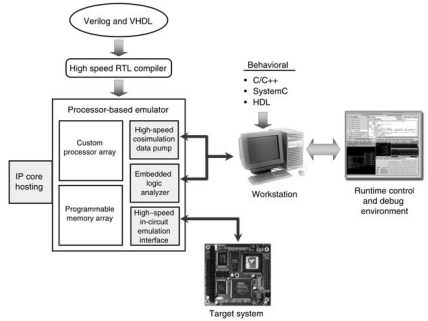

Image from [3]

References & Contact

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arafael@cadence.com

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[1] Azevedo, Rafael Alvarenga de, et al. **Idempotent Slices with Applications to Code-Size Reduction**. arXiv:2603.09726, arXiv, 10 Mar. 2026. arXiv.org, https://doi.org/10.48550/arXiv.2603.09726.

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