SWEN90010 — High Integrity Systems Engineering

Lecture 12 - Ada — continued

Hira Syeda
hira.syeda@unimelb.edu.au
Level 2, Melbourne Connect

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What did we learn last time about Ada

Ada has **module system** that provides information hiding, application interface

Ada has **strong, static type system**

Ada comes with several **runtime checks**: signed overflow
we will see going forward: array index out-of-bounds,
accessing unallocated memory, range errors

Ada turns **heisenbugs** into **crashes**

because of these features, **Ada is portable**

Ada prefers **code readability**

Main Takeaway

Ada is designed for writing safe and secure code

Application Areas

Mostly real-time embedded:
that are traditionally very difficult to program,
and Ada gives highly relivable code

Avionics Railway Defence Space

Robotics Crypto(graphy)

Application Areas

Mostly real-time embedded:
that are traditionally very difficult to program,
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Avionics Railway Defence Space

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Lots of these
with formal verification
via SPARK

Muen verified Separation Kenrel

MISRA C

MISRA C: “safe” C subset used in automotive
(not all rules enforceable)

Ada is already much “safer” than C; better encapsulation

SPARK: an “even safer” subset of Ada, with
same runtime semantics (future lectures)

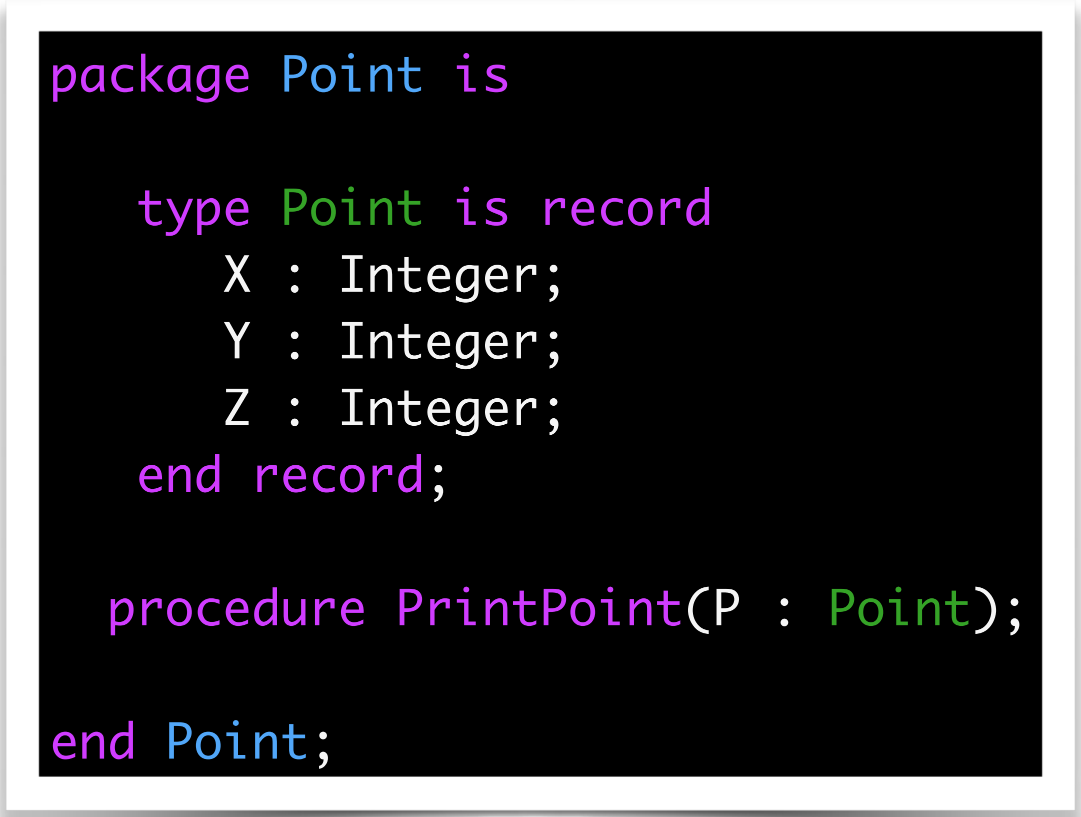
Ada: stronger type system, more static guarantees

Ada: more runtime checks
(e.g. array index out of bounds,
dynamic memory access etc.)

ADA: SOME INTERESTING HIGHLIGHTS

Packages

Packages



```
package Point is

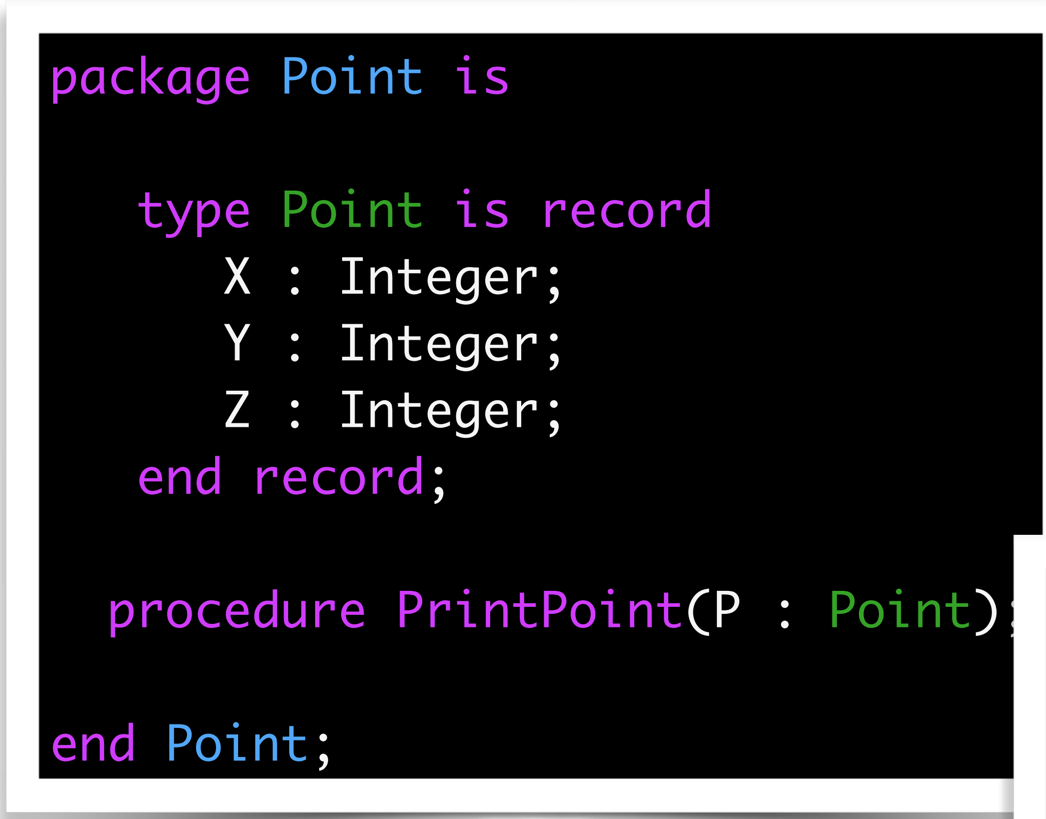
   type Point is record
      X : Integer;
      Y : Integer;
      Z : Integer;
   end record;

  procedure PrintPoint(P : Point);

end Point;
```

Spec

Packages



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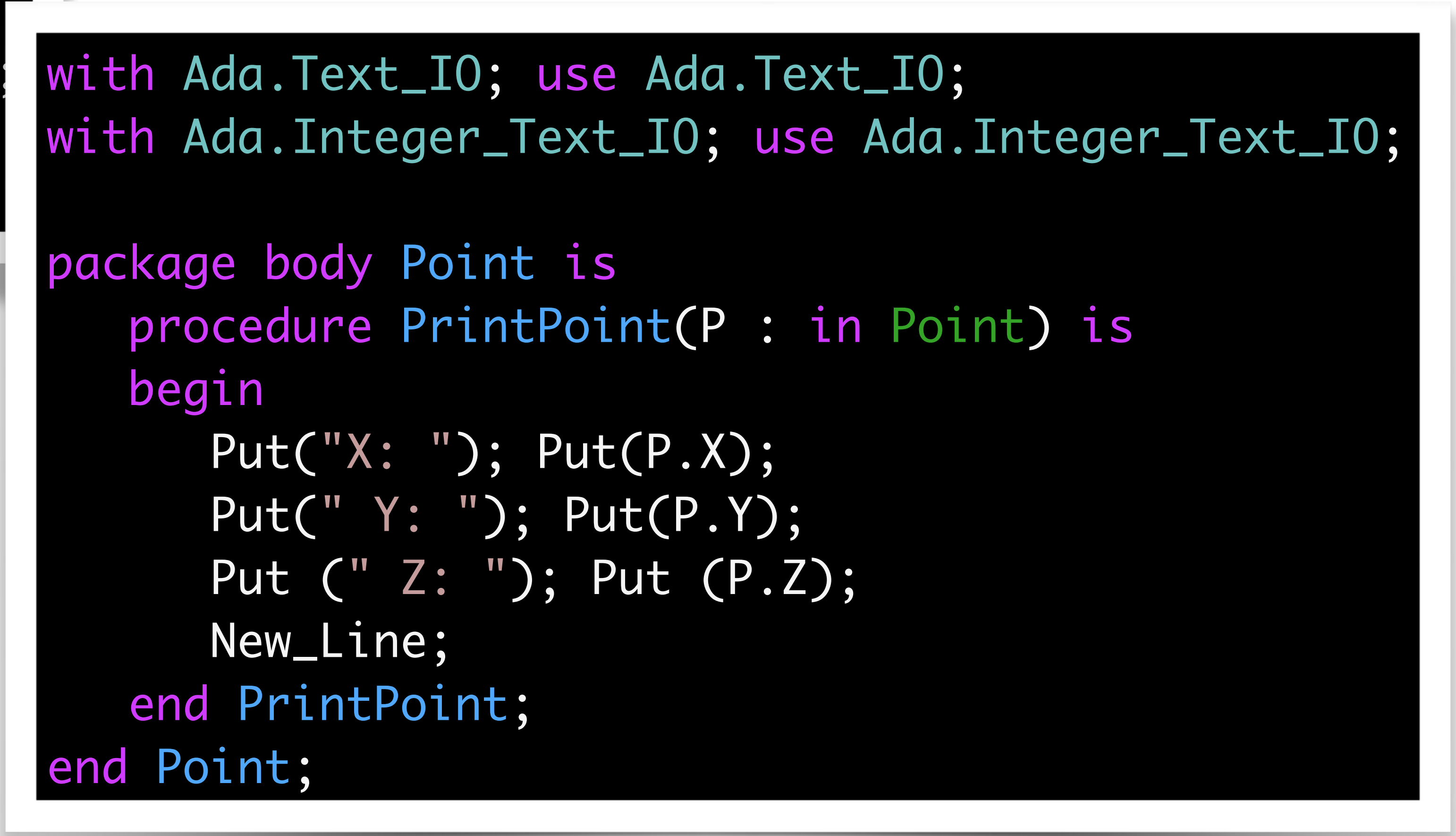
Spec

Body



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with Ada.Integer_Text_IO; use Ada.Integer_Text_IO;

package body Point is
   procedure PrintPoint(P : in Point) is
   begin
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   end PrintPoint;
end Point;
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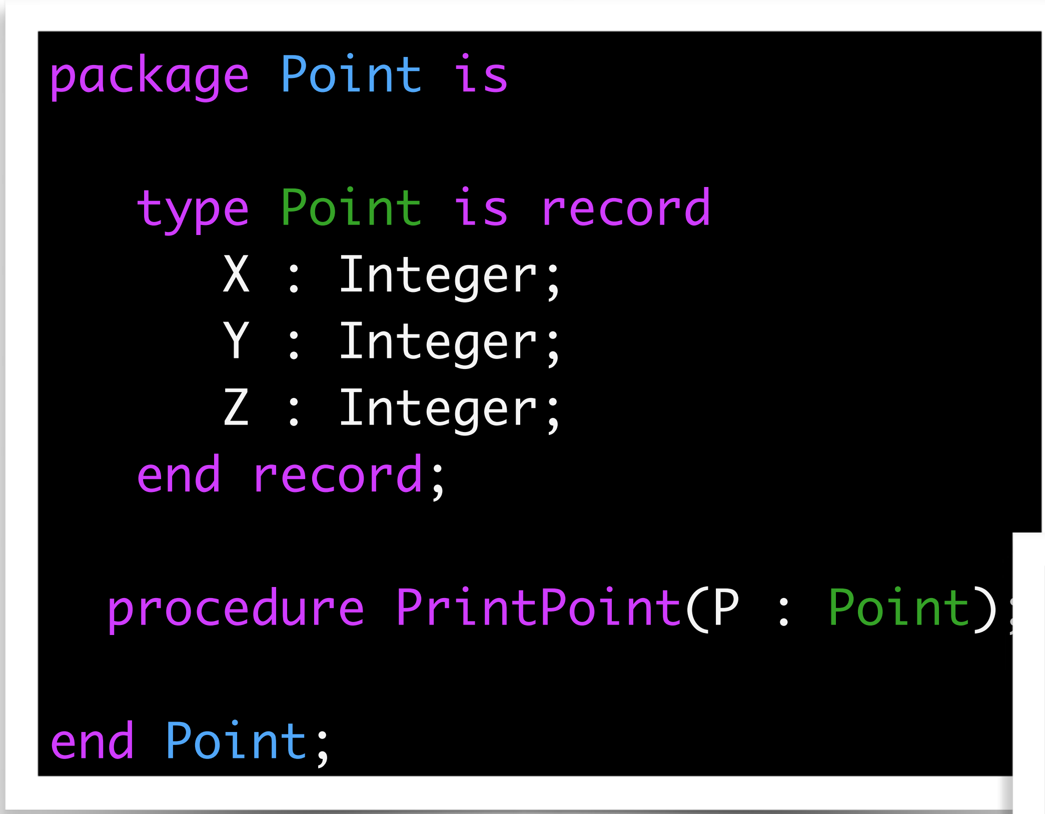
Packages



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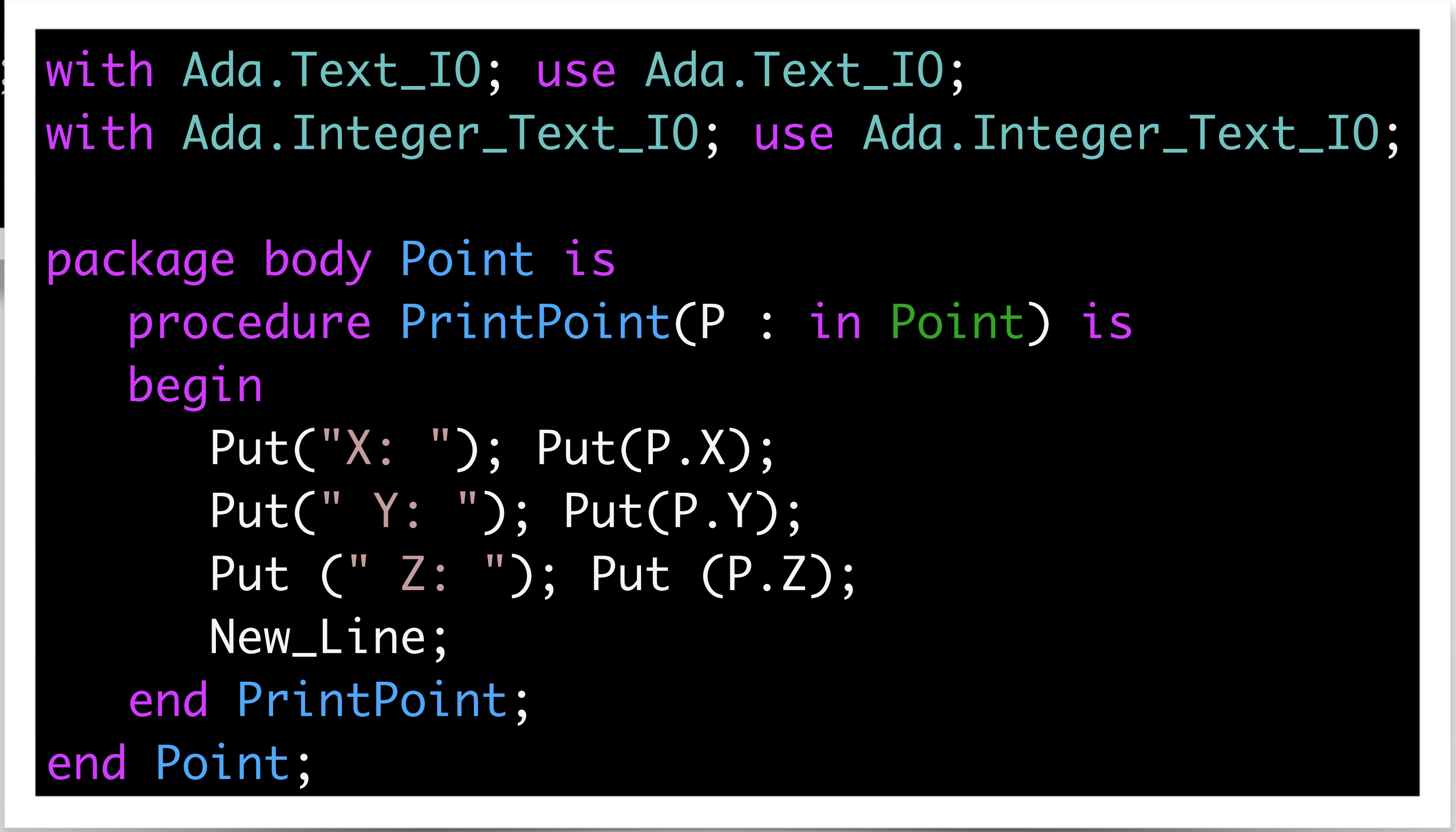
Spec

the **interface**

says “what”

Body



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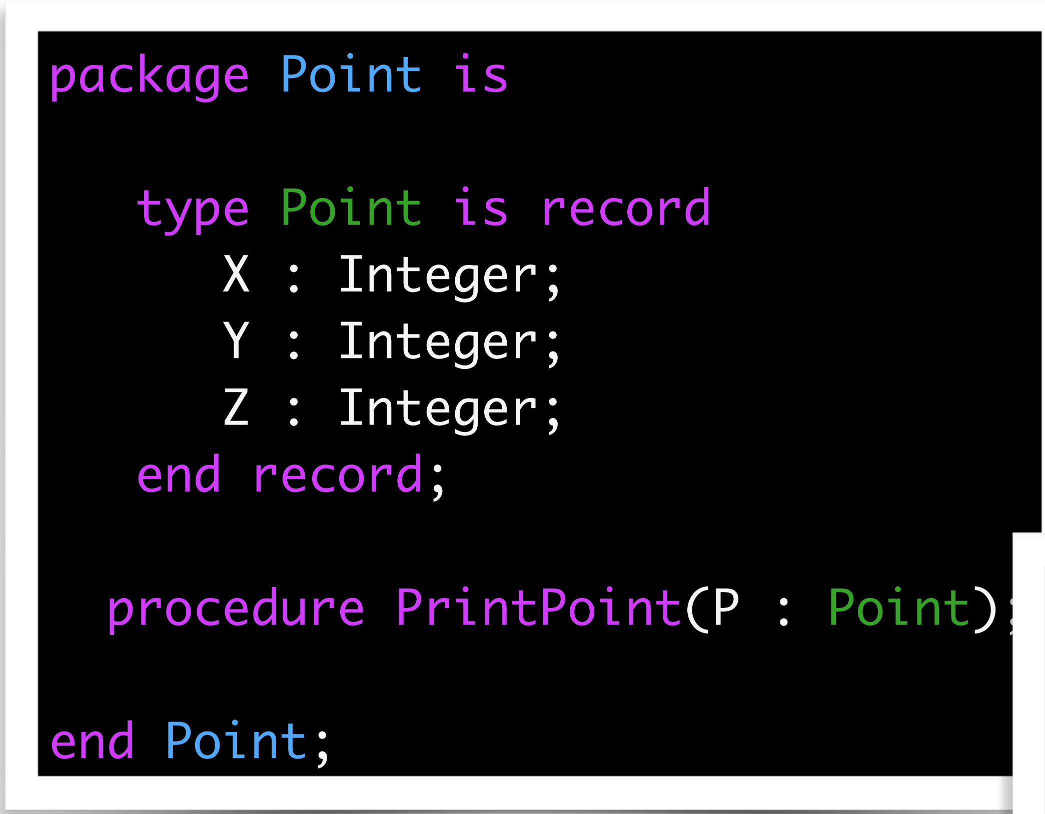

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Spec

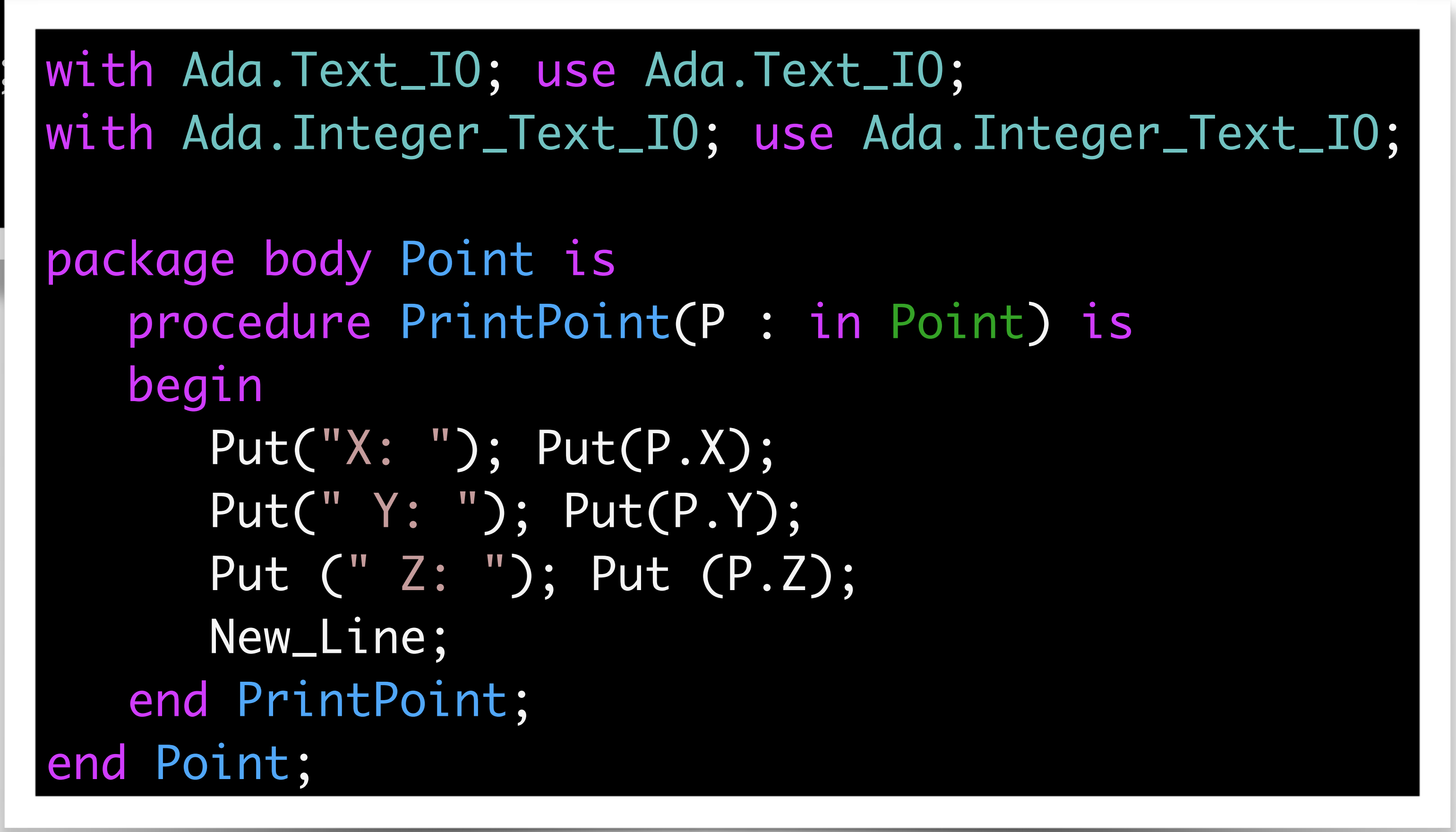
the **interface**

says “what”

says “how”

the **implementation**

Body



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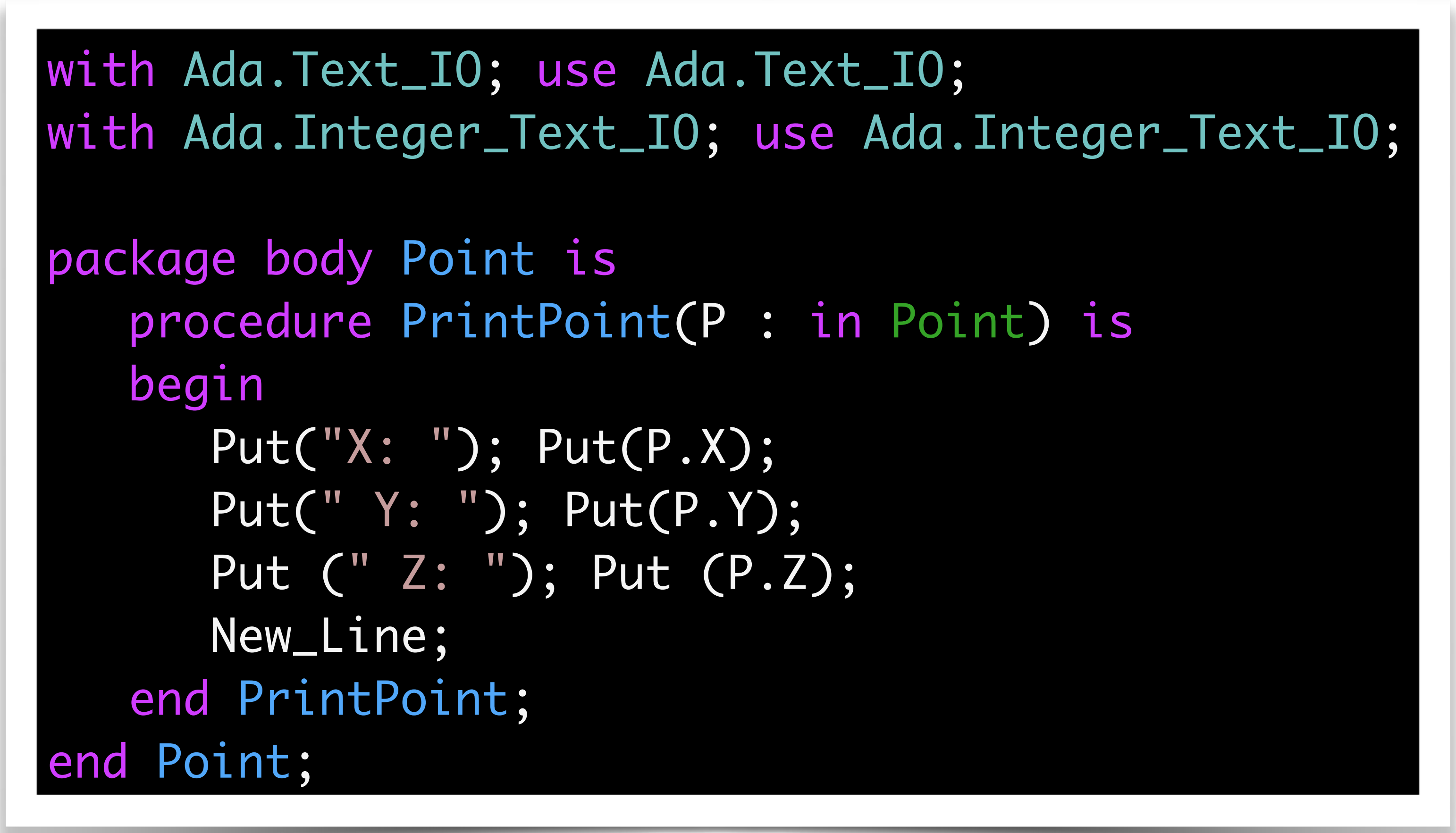
Packages: **with** and **use**



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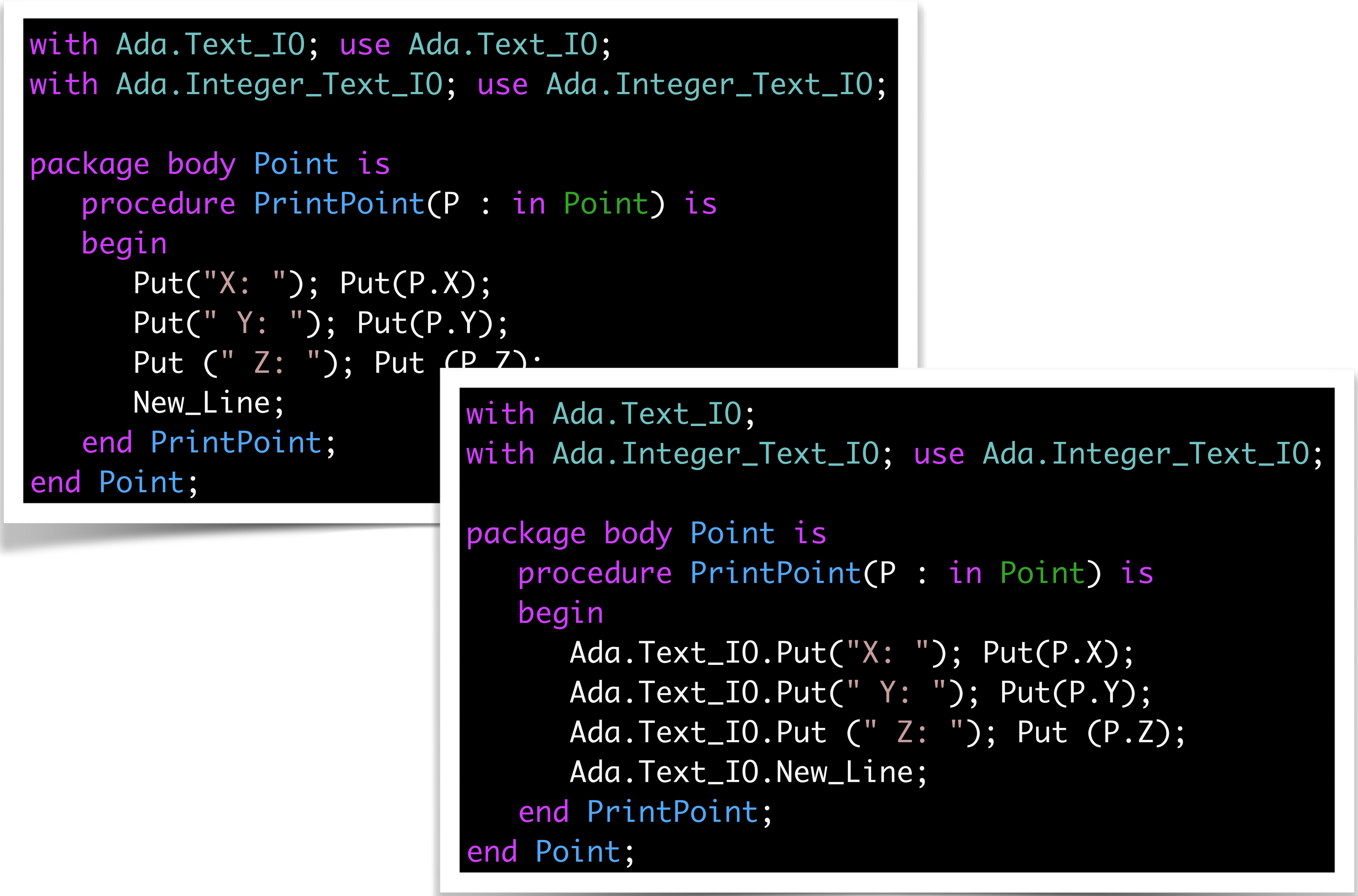

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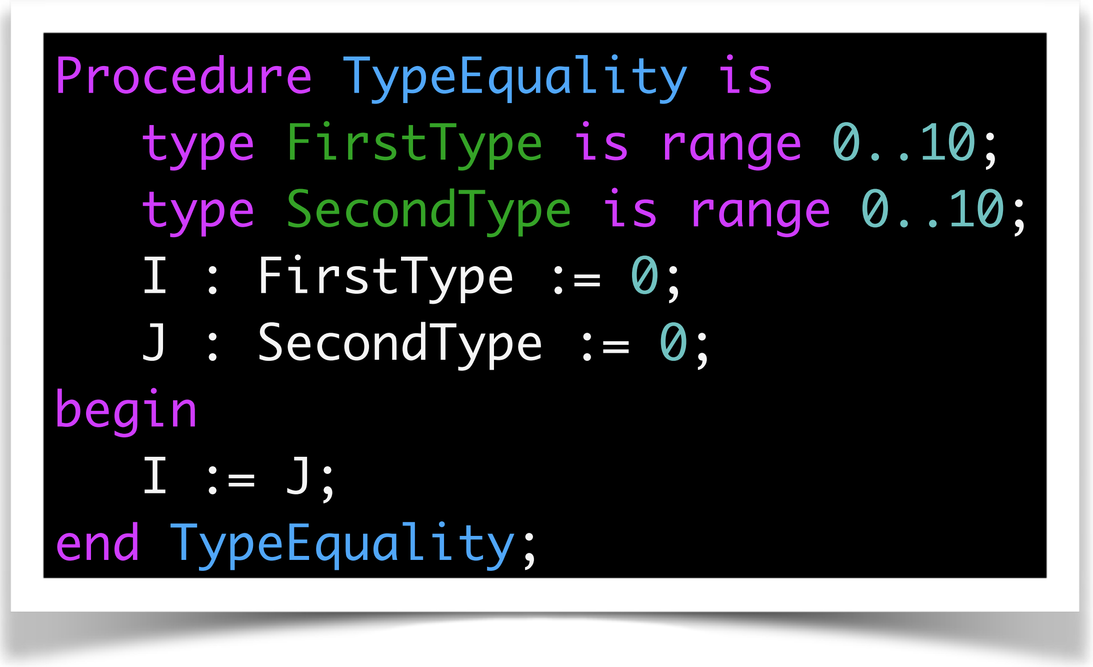
      Ada.Text_IO.Put (" Z: "); Put (P.Z);
      Ada.Text_IO.New_Line;
   end PrintPoint;
end Point;
```

Types

Type equality is by name



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Procedure TypeEquality is
   type FirstType is range 0..10;
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   I : FirstType := 0;
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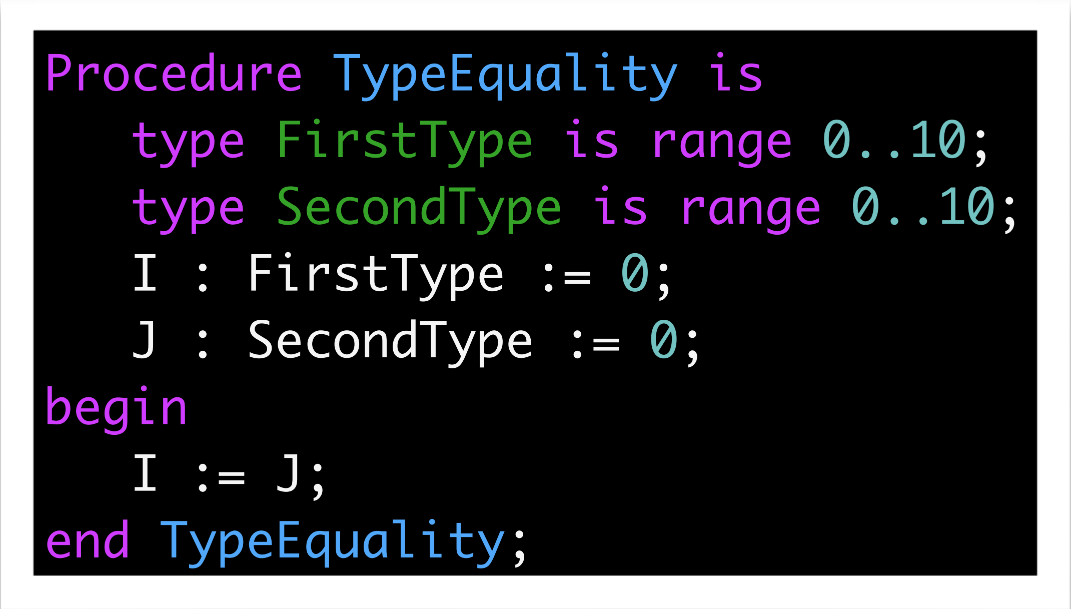

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Will this code compile correctly?

Types

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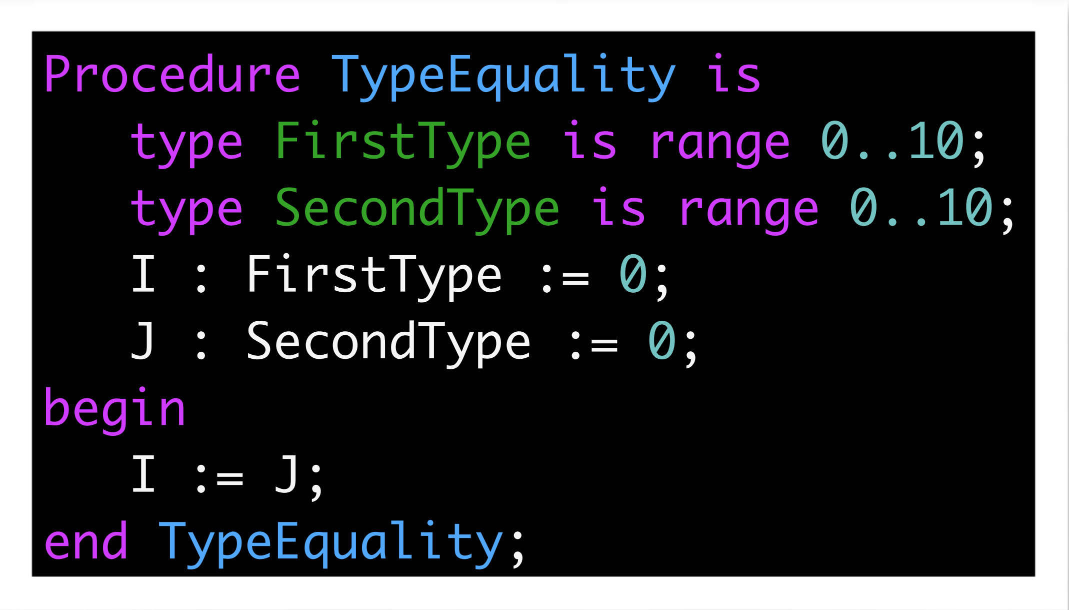

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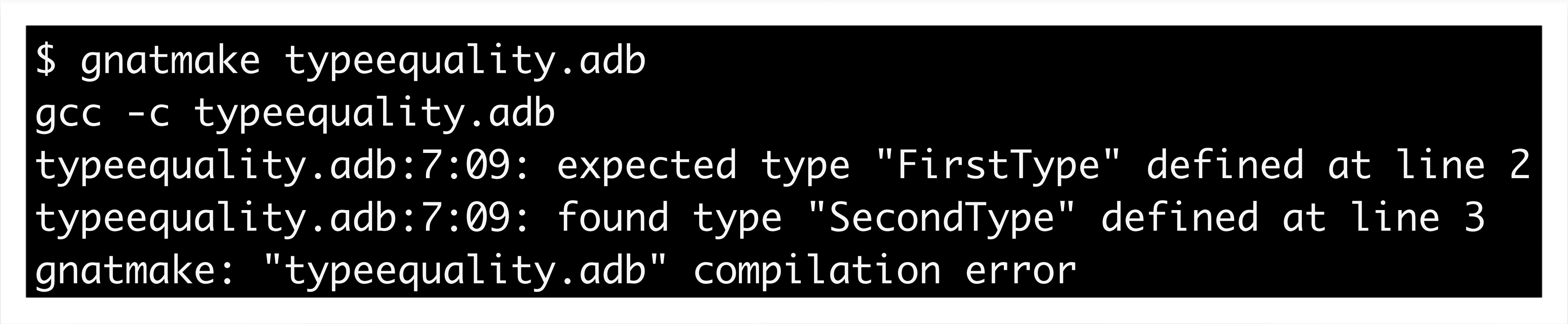

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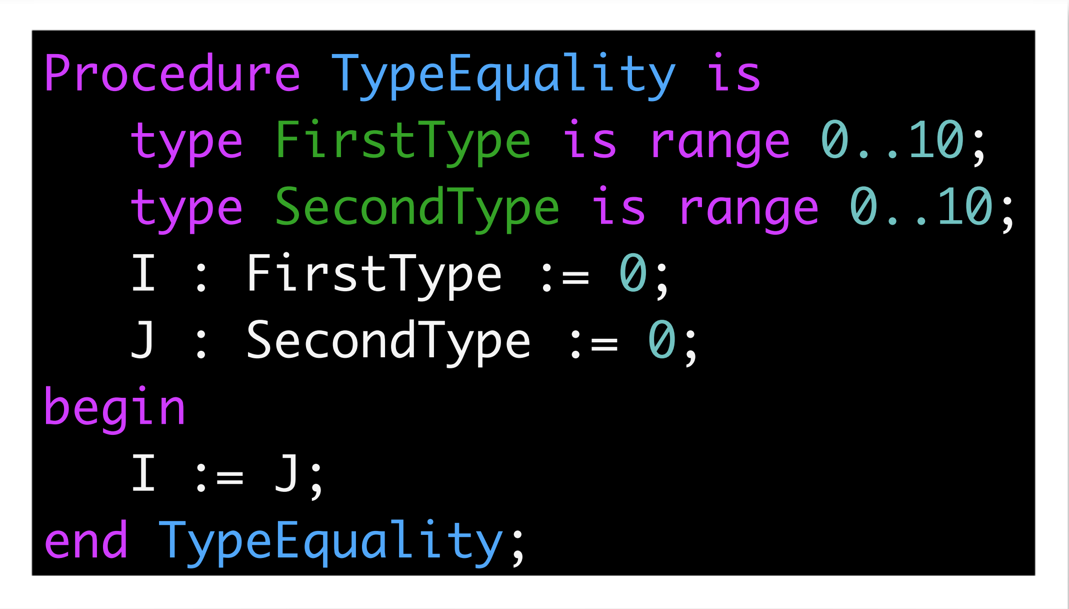
$ gnatmake typeequality.adb
gcc -c typeequality.adb
typeequality.adb:7:09: expected type "FirstType" defined at line 2
typeequality.adb:7:09: found type "SecondType" defined at line 3
gnatmake: "typeequality.adb" compilation error
```

Types

Type equality is by name

What errors does this catch statically?



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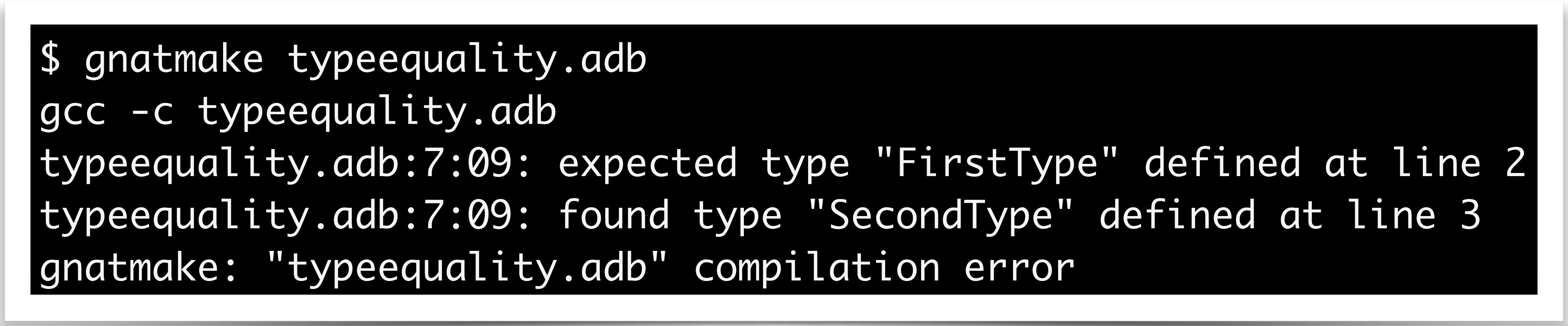

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Type Casts

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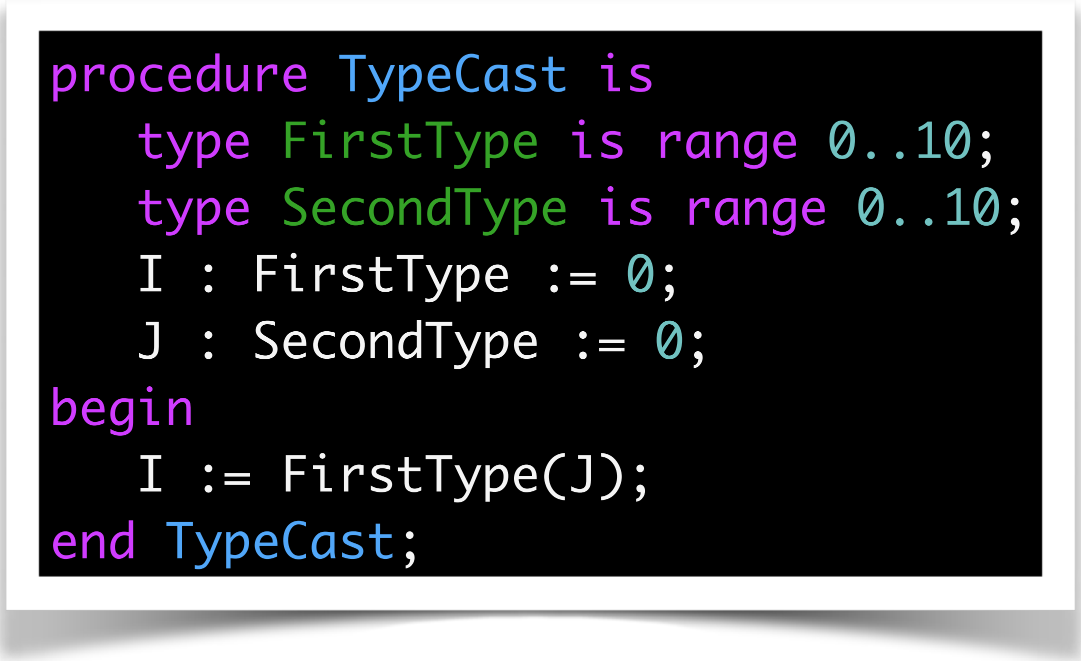

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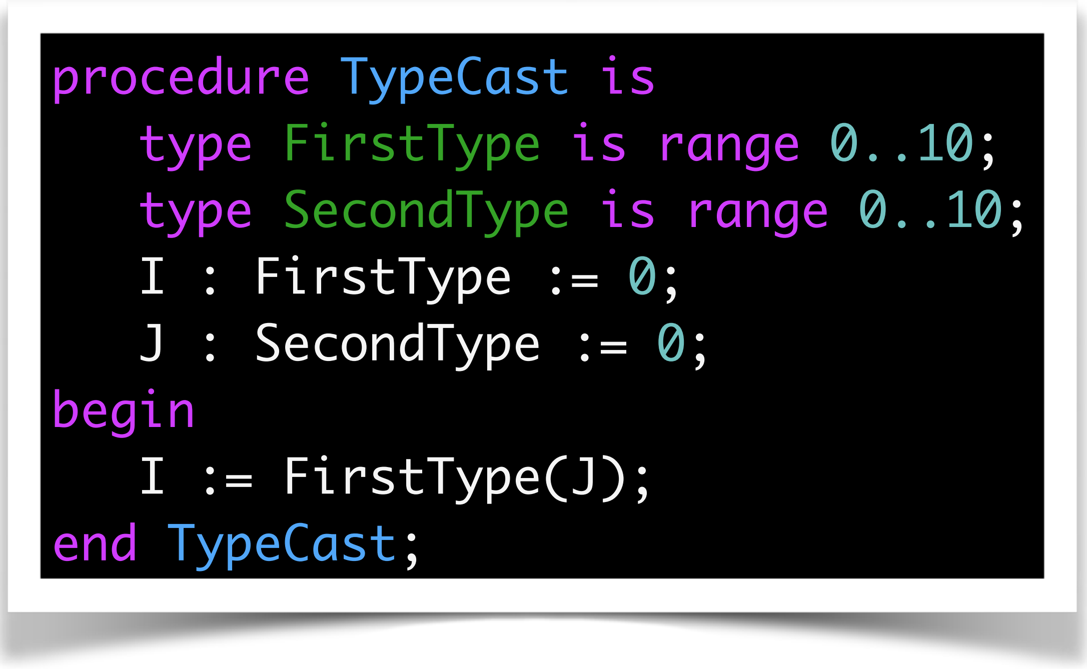
procedure TypeCast is
   type FirstType is range 0..10;
   type SecondType is range 0..10;
   I : FirstType := 0;
   J : SecondType := 0;
begin
   I := FirstType(J);
end TypeCast;
```

Type Casts



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This compiles and runs without error.

Type Casts and Errors

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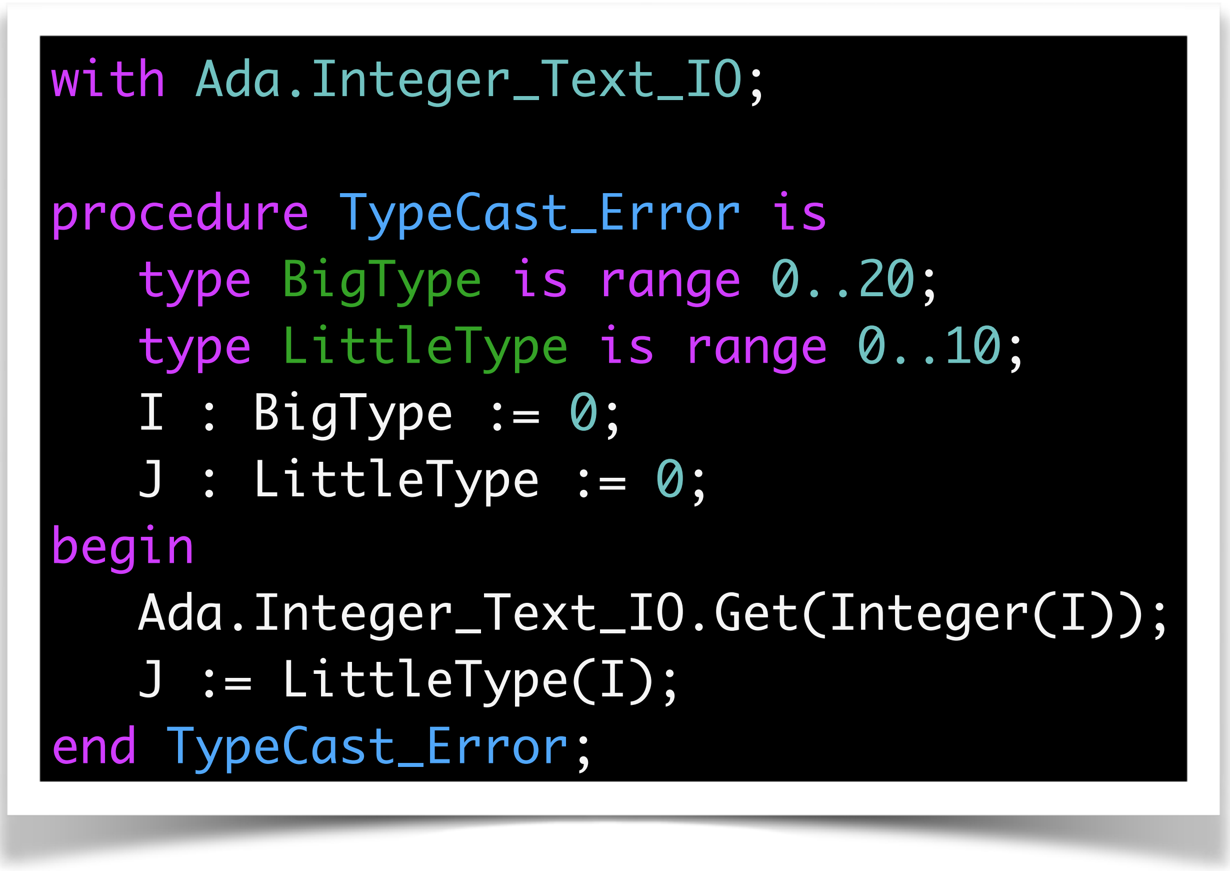
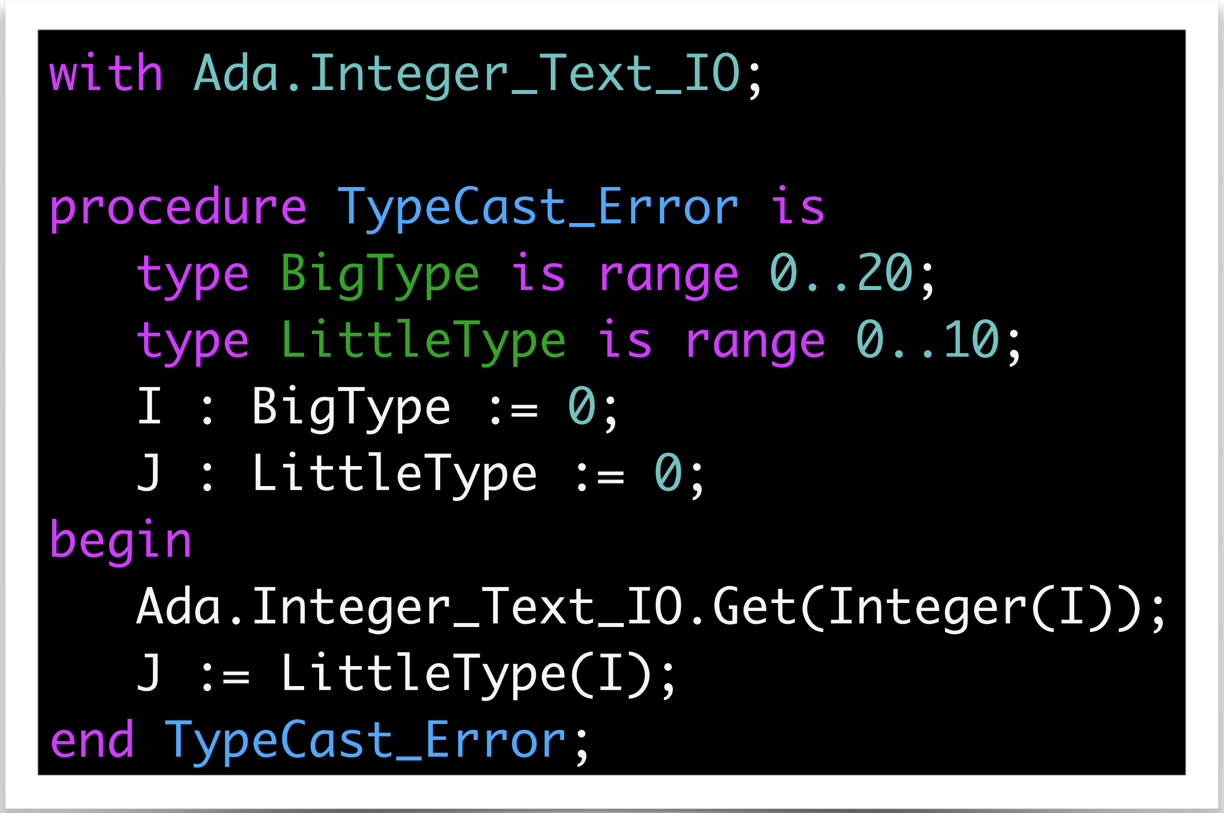


```
with Ada.Integer_Text_IO;

procedure TypeCast_Error is
   type BigType is range 0..20;
   type LittleType is range 0..10;
   I : BigType := 0;
   J : LittleType := 0;
begin
   Ada.Integer_Text_IO.Get(Integer(I));
   J := LittleType(I);
end TypeCast_Error;
```

Type Casts and Errors



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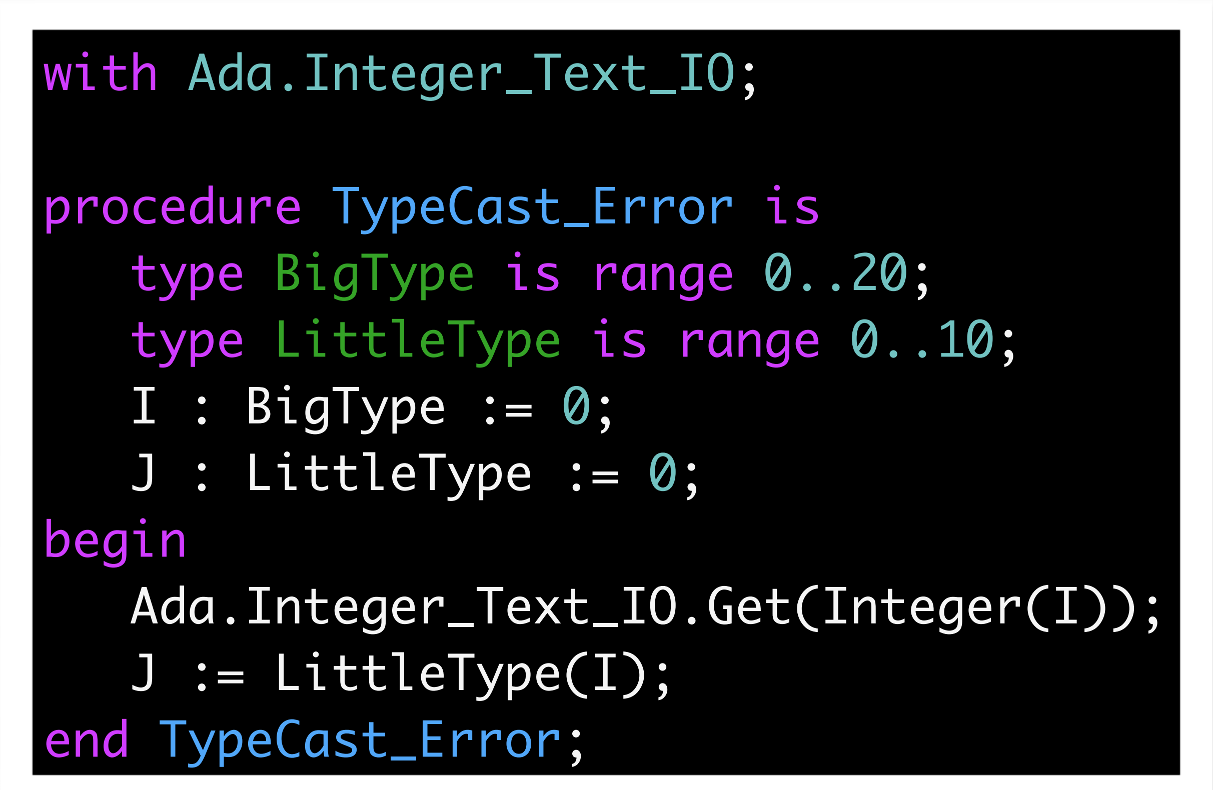

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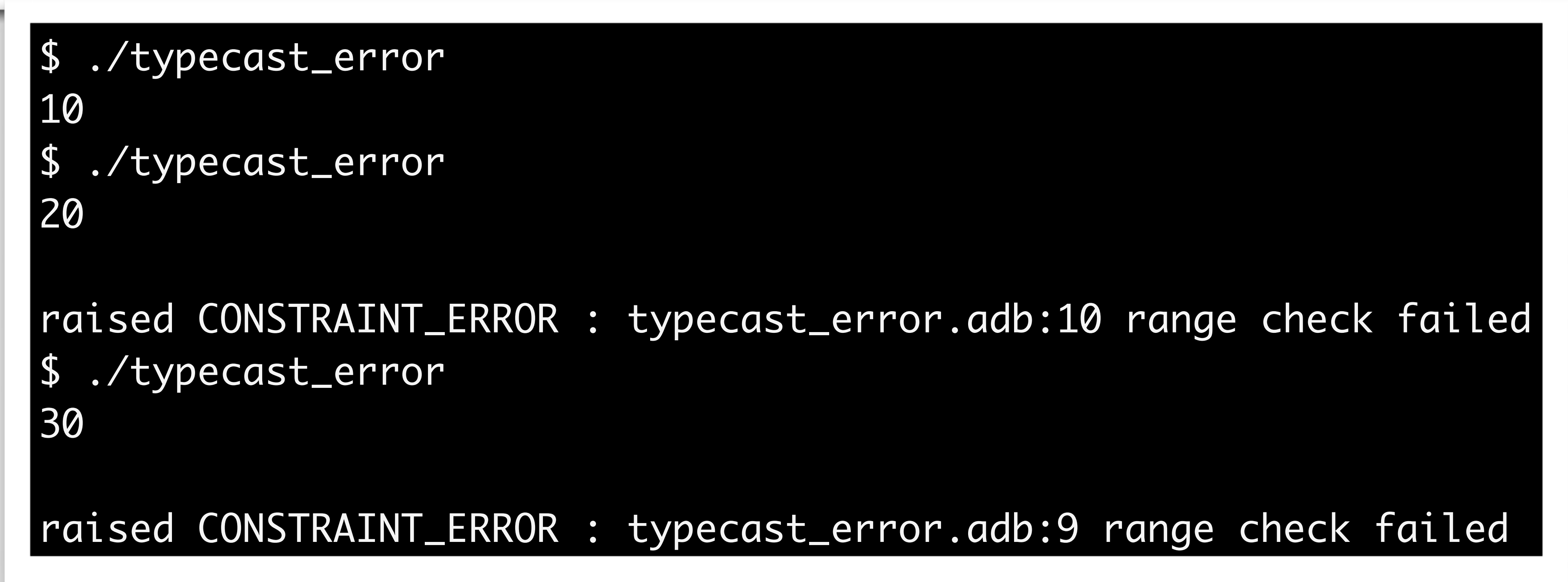
Compiles without error.



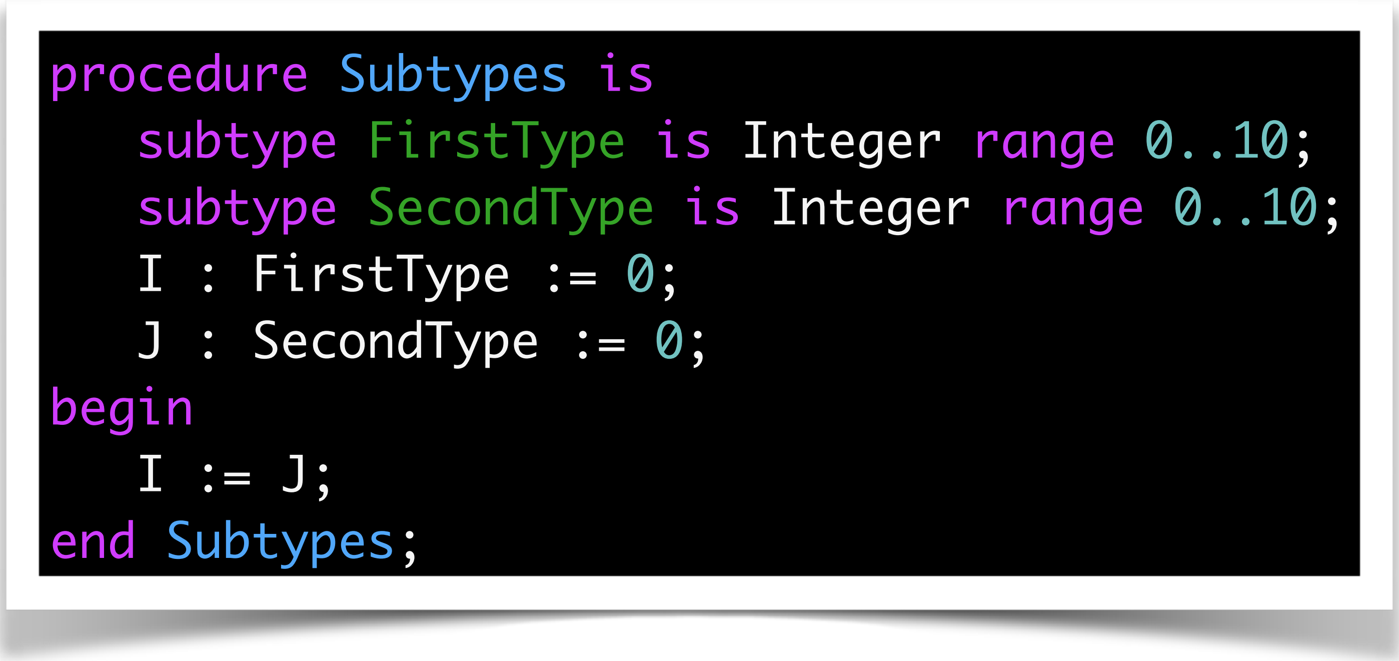
```
$ ./typecast_error
10
$ ./typecast_error
20

raised CONSTRAINT_ERROR : typecast_error.adb:10 range check failed
$ ./typecast_error
30

raised CONSTRAINT_ERROR : typecast_error.adb:9 range check failed
```

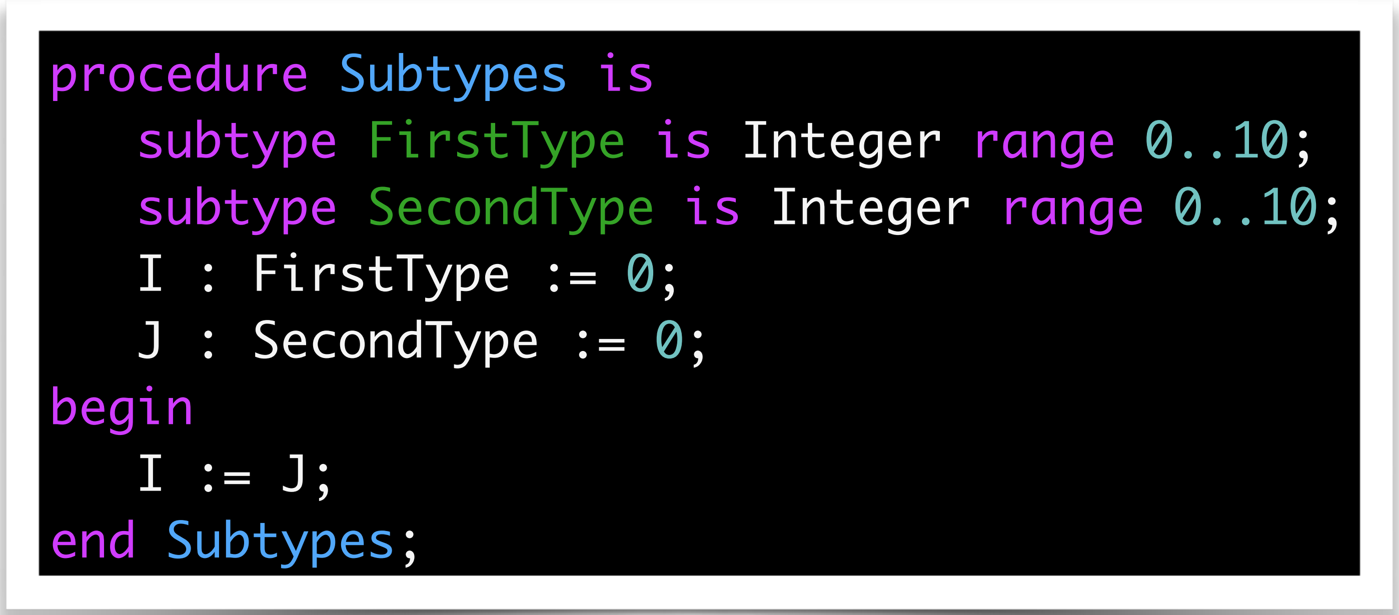
Subtypes

Subtypes



```
procedure Subtypes is
   subtype FirstType is Integer range 0..10;
   subtype SecondType is Integer range 0..10;
   I : FirstType := 0;
   J : SecondType := 0;
begin
   I := J;
end Subtypes;
```

Subtypes



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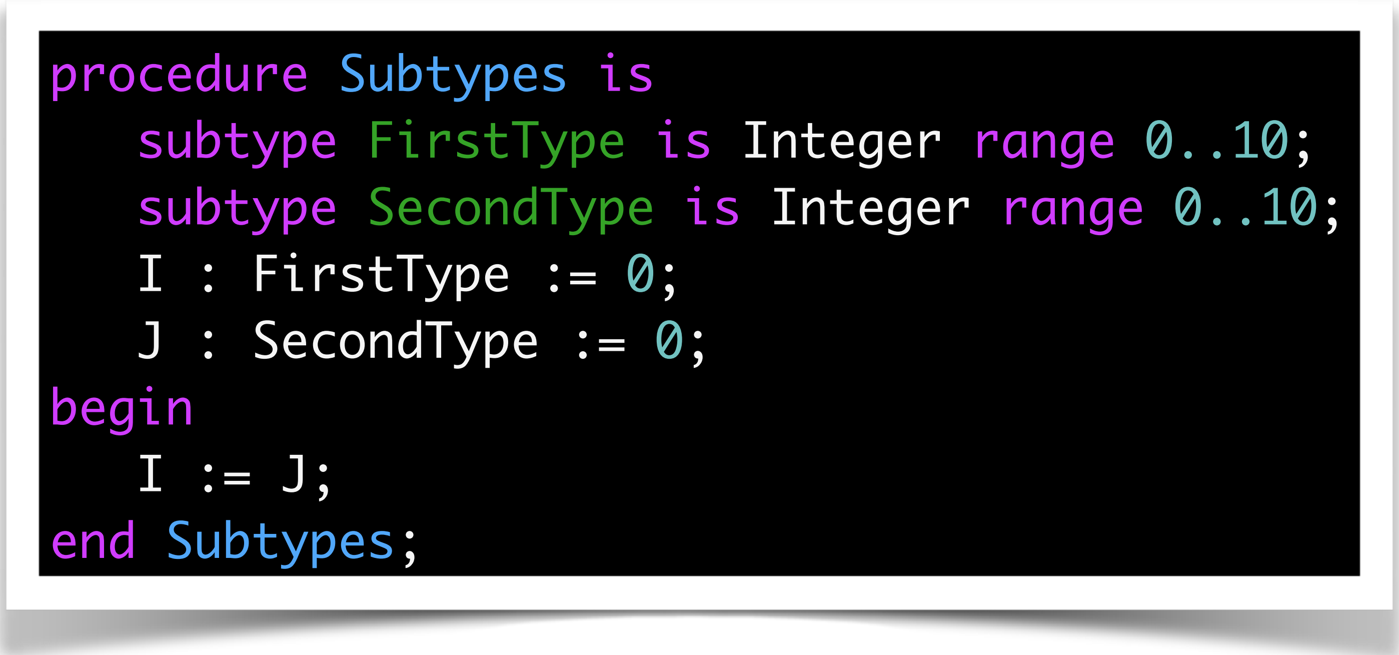
Subtypes



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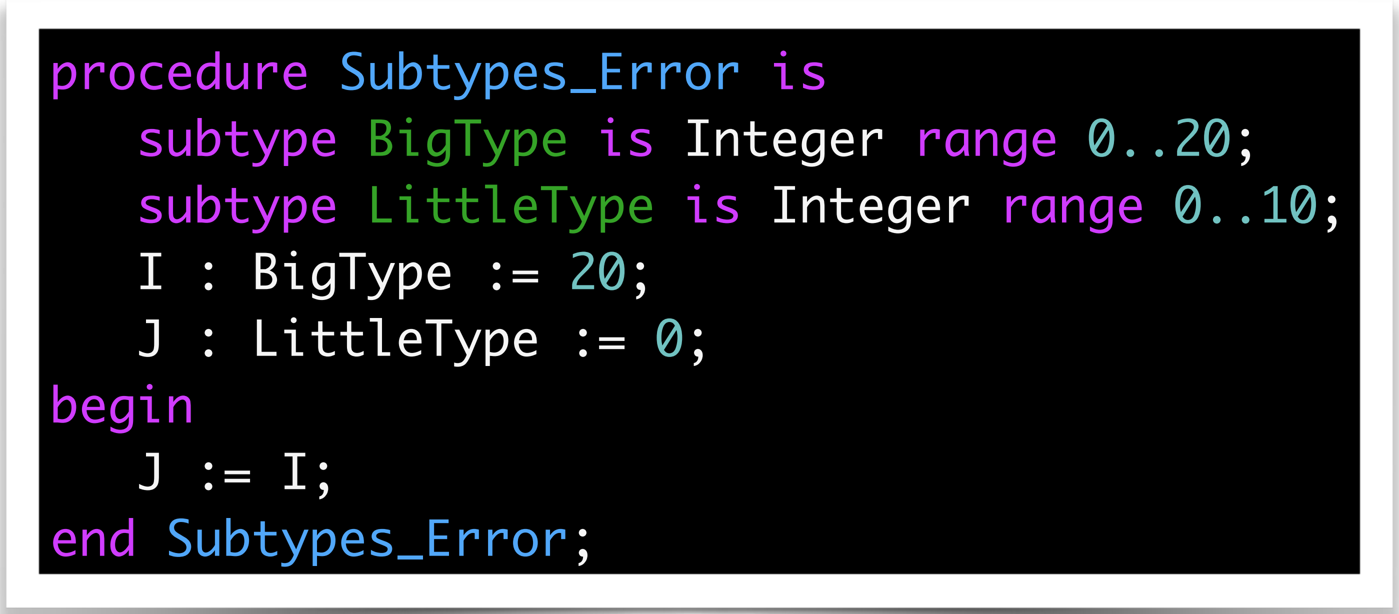
This compiles and executes with no errors.

Casting is effectively implicit between subtypes.

Subtypes



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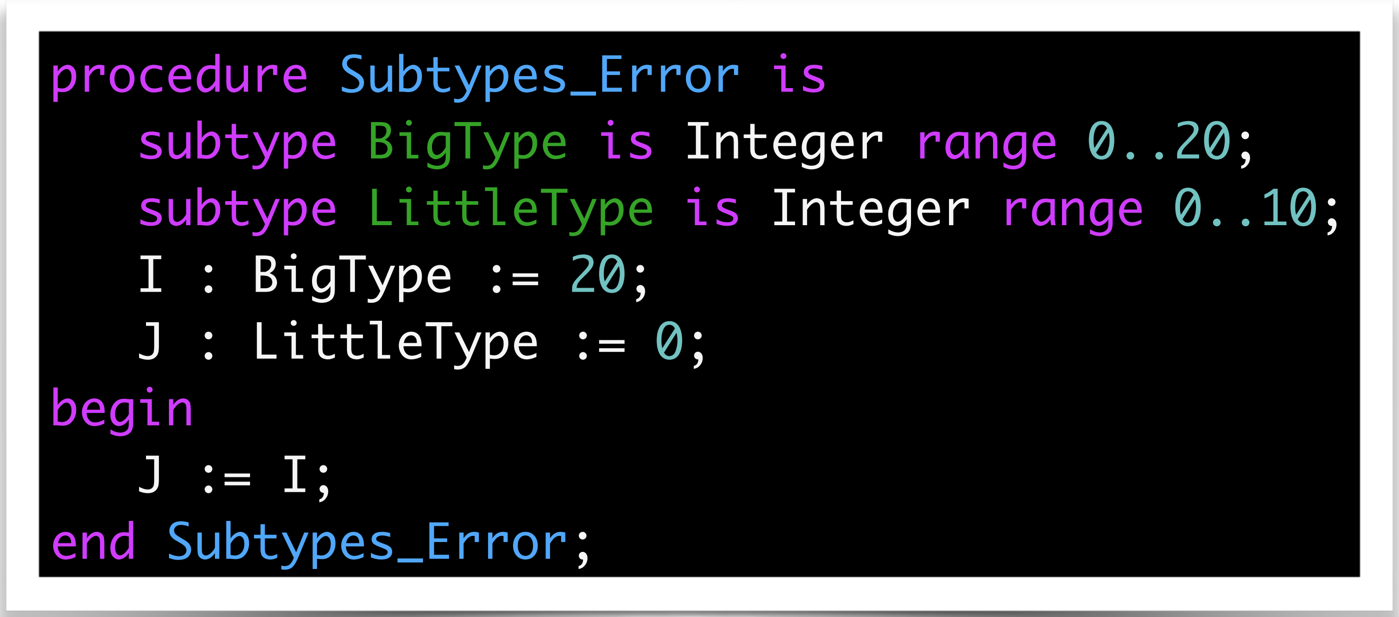
end Subtypes_Error;
```

What happens when we run this?

Subtypes



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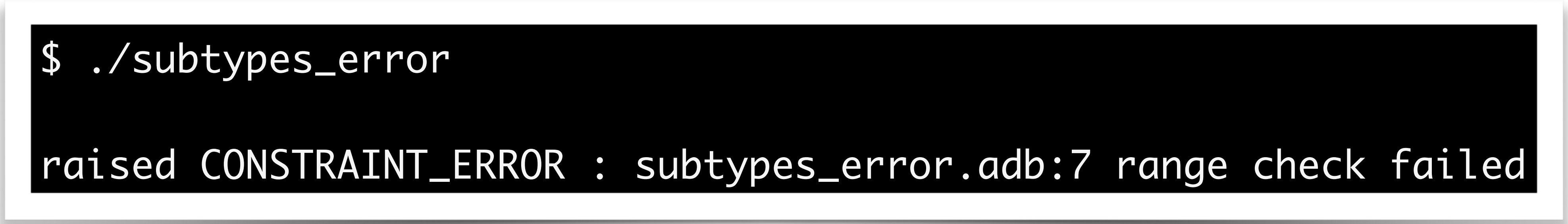

```
$ ./subtypes_error

raised CONSTRAINT_ERROR : subtypes_error.adb:7 range check failed
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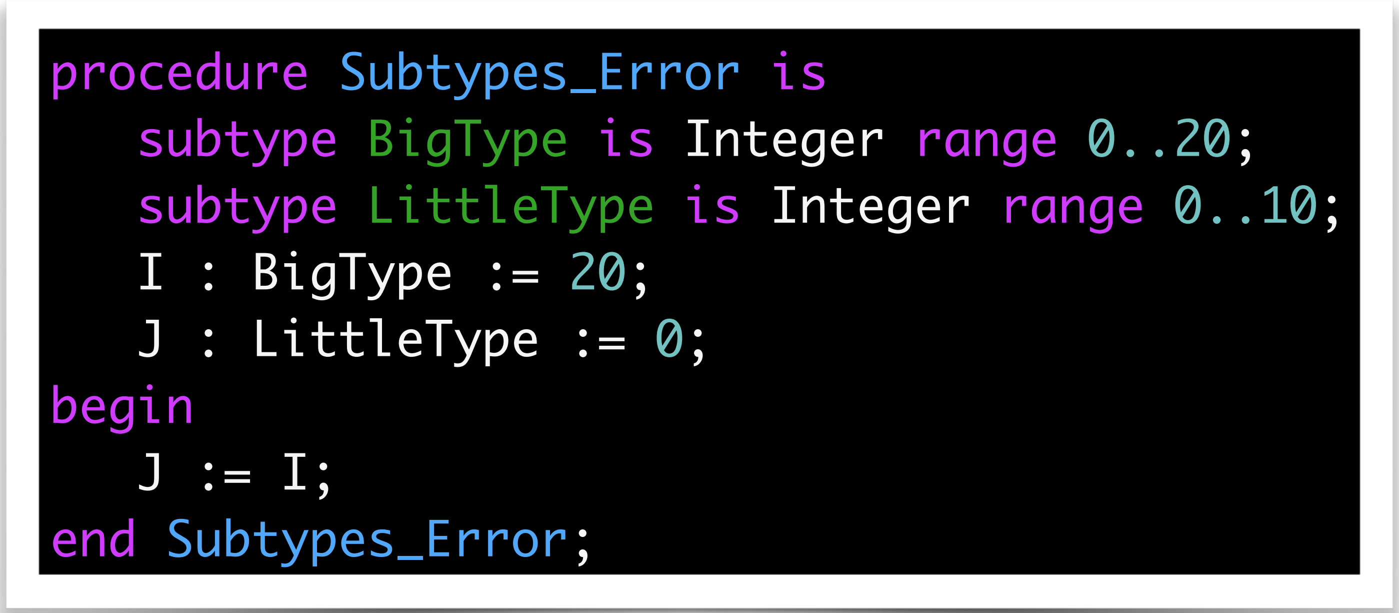
Subtypes



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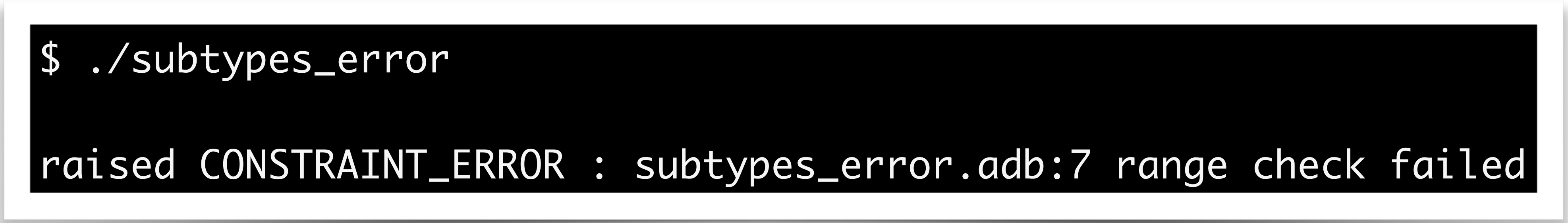

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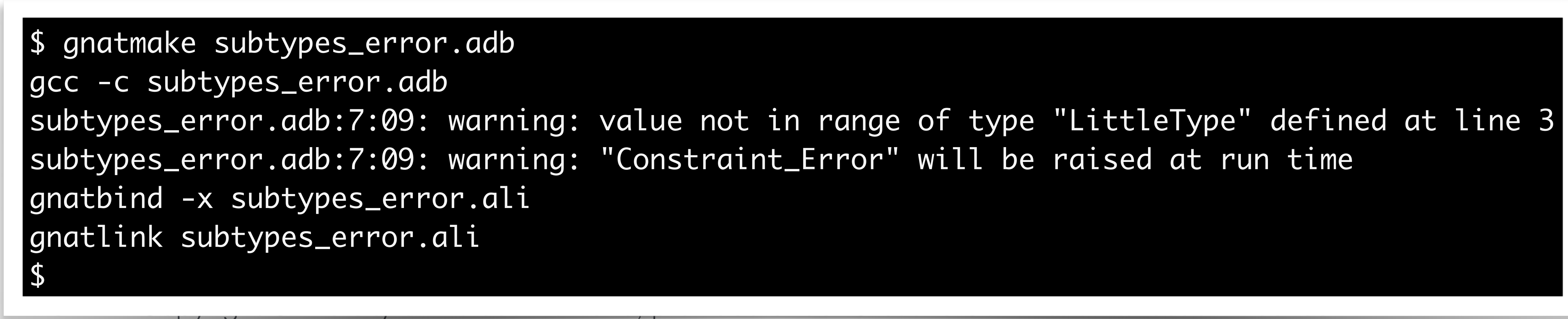
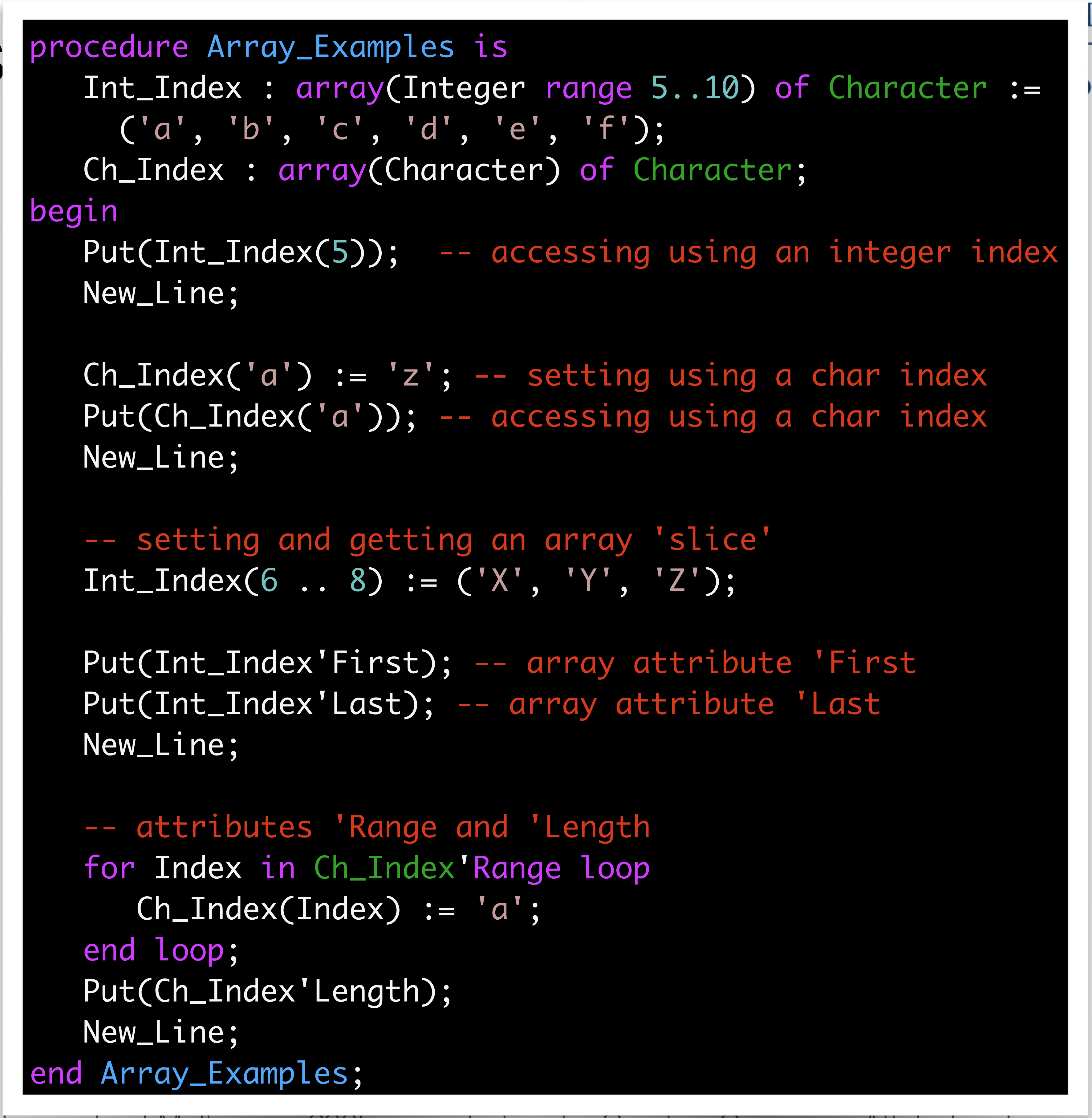
btw



```
$ gnatmake subtypes_error.adb
gcc -c subtypes_error.adb
subtypes_error.adb:7:09: warning: value not in range of type "LittleType" defined at line 3
subtypes_error.adb:7:09: warning: "Constraint_Error" will be raised at run time
gnatbind -x subtypes_error.ali
gnatlink subtypes_error.ali
$
```

Arrays



```
procedure Array_Examples is
   Int_Index : array(Integer range 5..10) of Character :=
     ('a', 'b', 'c', 'd', 'e', 'f');
   Ch_Index : array(Character) of Character;
begin
   Put(Int_Index(5));  -- accessing using an integer index
   New_Line;

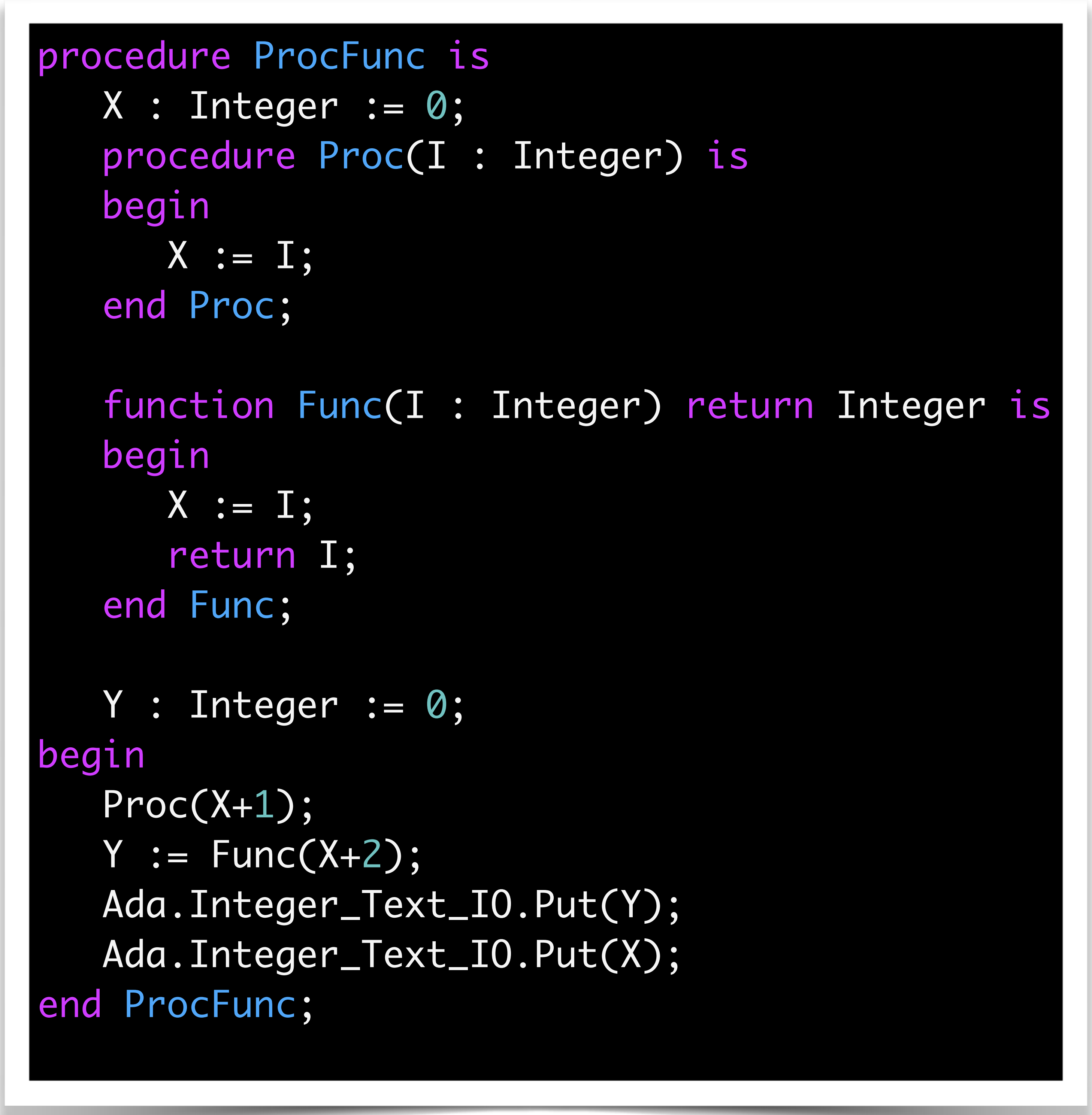
   Ch_Index('a') := 'z'; -- setting using a char index
   Put(Ch_Index('a')); -- accessing using a char index
   New_Line;

   -- setting and getting an array 'slice'
   Int_Index(6 .. 8) := ('X', 'Y', 'Z');

   Put(Int_Index'First); -- array attribute 'First
   Put(Int_Index'Last); -- array attribute 'Last
   New_Line;

   -- attributes 'Range and 'Length
   for Index in Ch_Index'Range loop
      Ch_Index(Index) := 'a';
   end loop;
   Put(Ch_Index'Length);
   New_Line;
end Array_Examples;
```

Procedures and Functions



```
procedure ProcFunc is
   X : Integer := 0;
   procedure Proc(I : Integer) is
   begin
      X := I;
   end Proc;

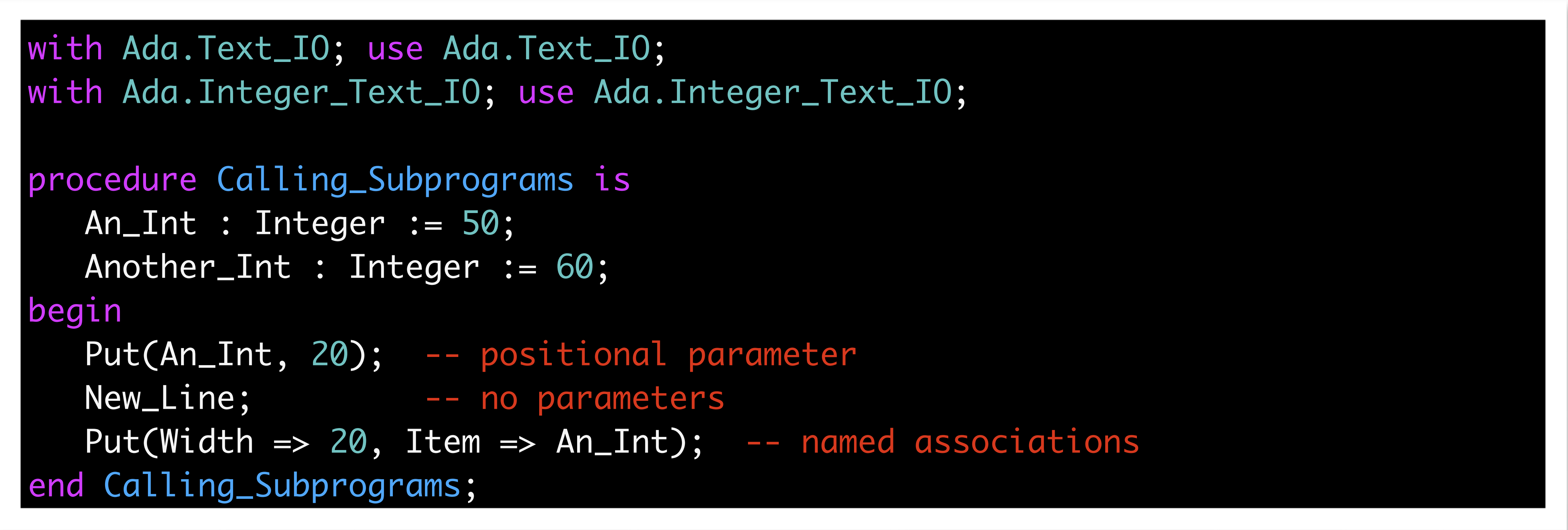
   function Func(I : Integer) return Integer is
   begin
      X := I;
      return I;
   end Func;

   Y : Integer := 0;
begin
   Proc(X+1);
   Y := Func(X+2);
   Ada.Integer_Text_IO.Put(Y);
   Ada.Integer_Text_IO.Put(X);
end ProcFunc;
```

Nesting, static scope

Functions with side-effects (disallowed in SPARK)

Parameter Passing

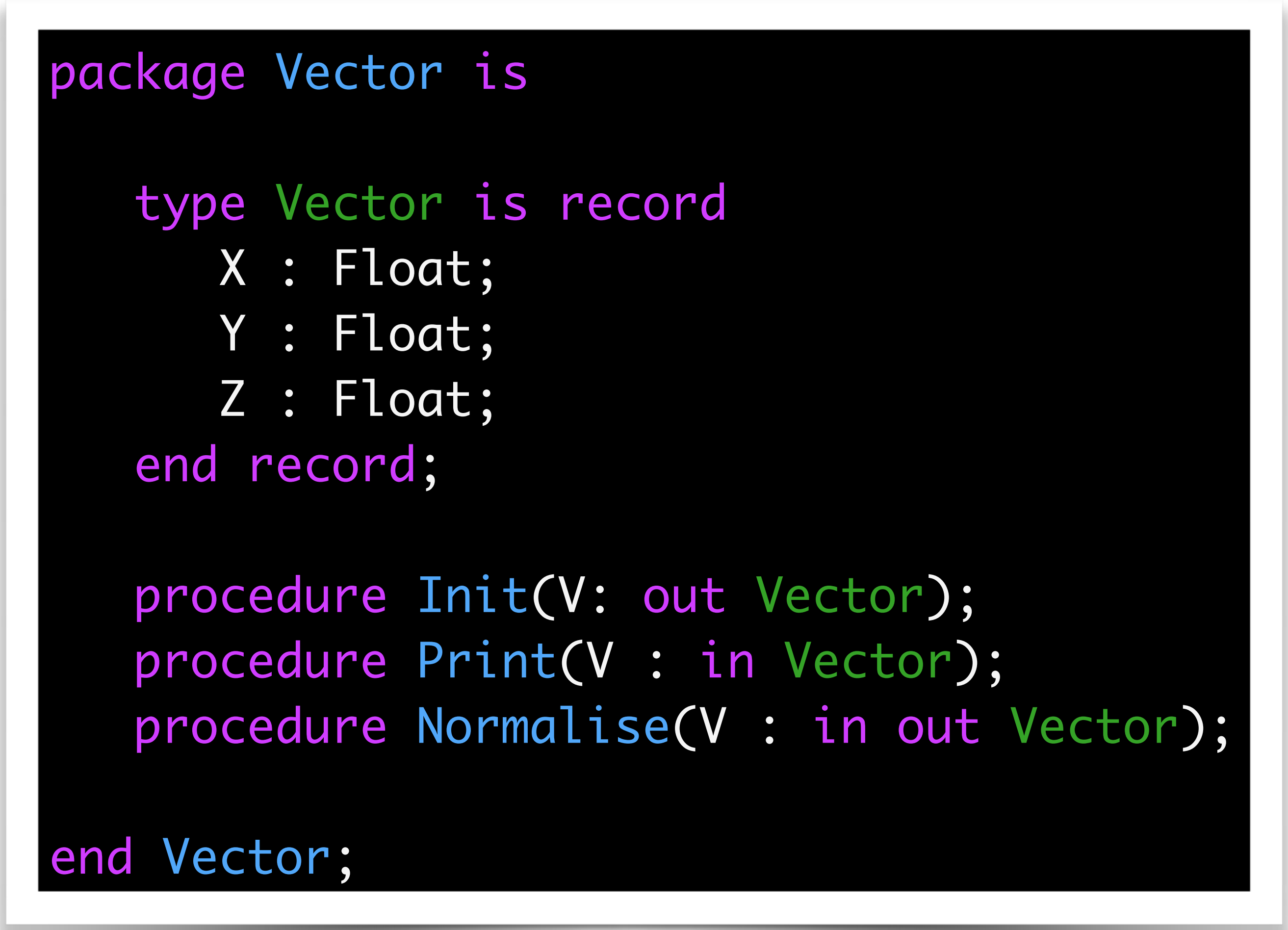


```
with Ada.Text_IO; use Ada.Text_IO;
with Ada.Integer_Text_IO; use Ada.Integer_Text_IO;

procedure Calling_Subprograms is
   An_Int : Integer := 50;
   Another_Int : Integer := 60;
begin
   Put(An_Int, 20);   -- positional parameter
   New_Line;          -- no parameters
   Put(Width => 20, Item => An_Int);   -- named associations
end Calling_Subprograms;
```

names come from names of **formal parameters** (which is why they must match between package spec and body)

Parameter Modes



```
package Vector is

   type Vector is record
      X : Float;
      Y : Float;
      Z : Float;
   end record;

   procedure Init(V: out Vector);
   procedure Print(V : in Vector);
   procedure Normalise(V : in out Vector);

end Vector;
```

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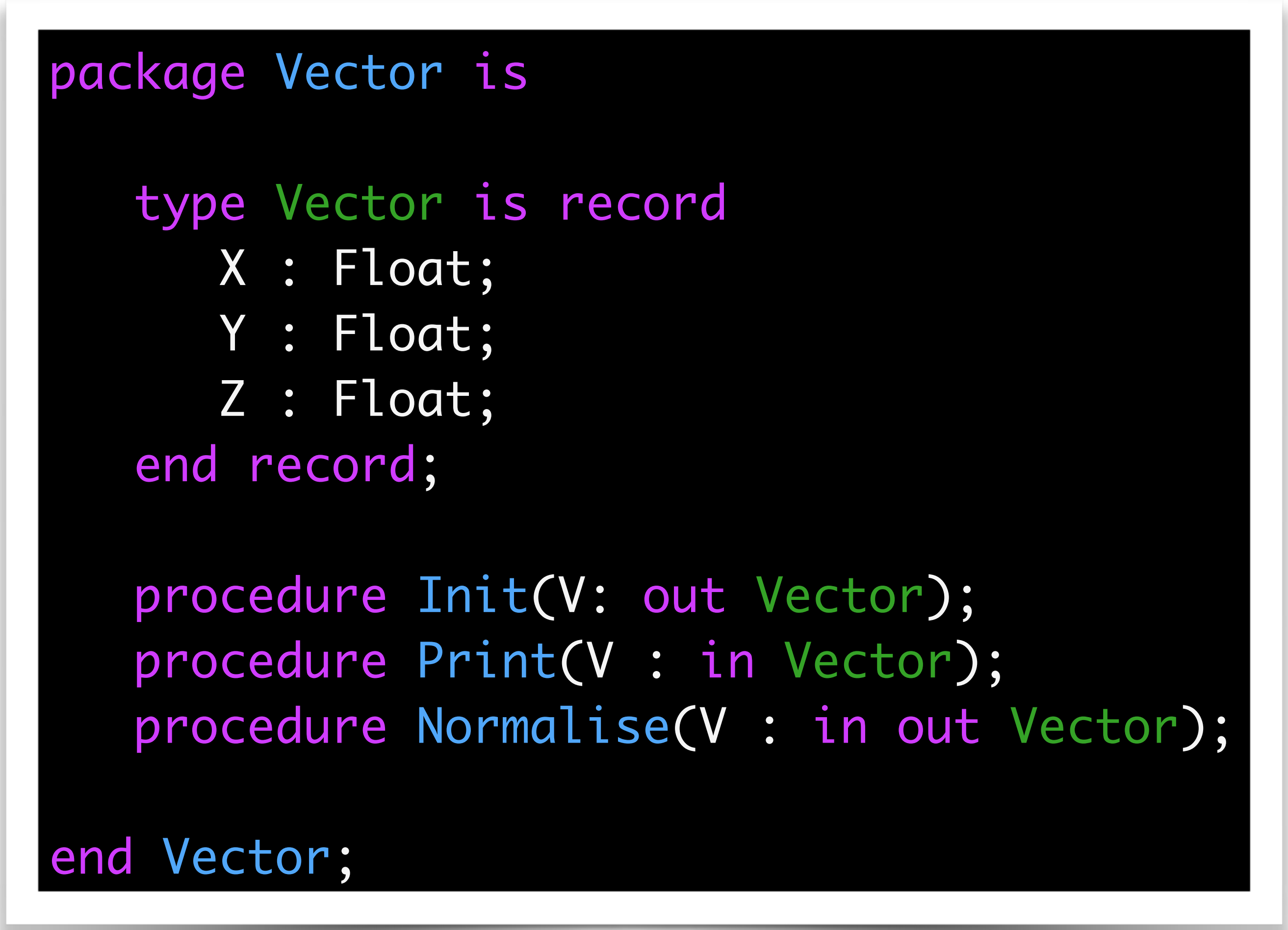

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in: read only
out: write only
in out: read/write

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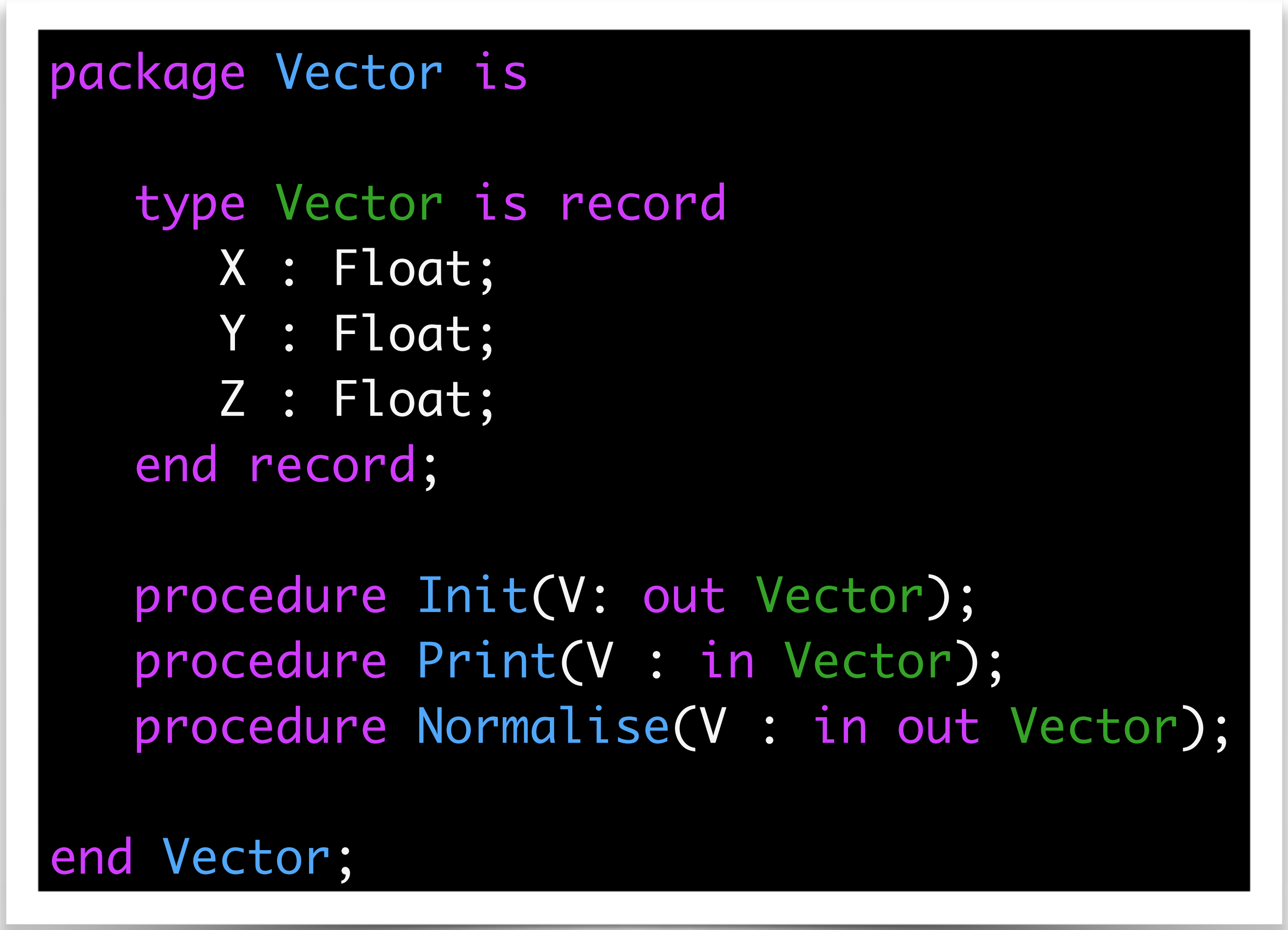

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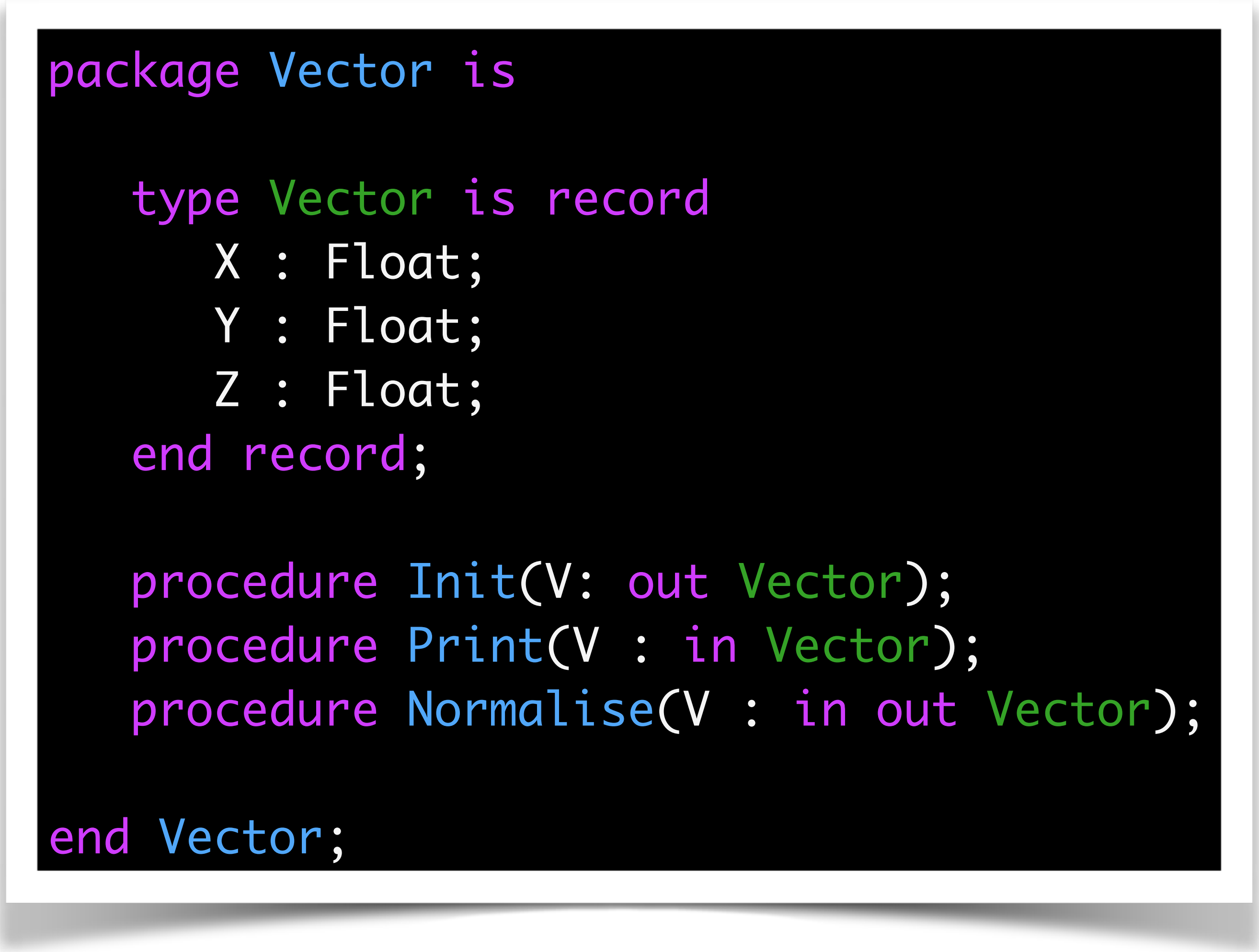
Checked statically by the type system

Parameter Modes



```
package Vector is

   type Vector is record
      X : Float;
      Y : Float;
      Z : Float;
   end record;

   procedure Init(V: out Vector);
   procedure Print(V : in Vector);
   procedure Normalise(V : in out Vector);

end Vector;
```

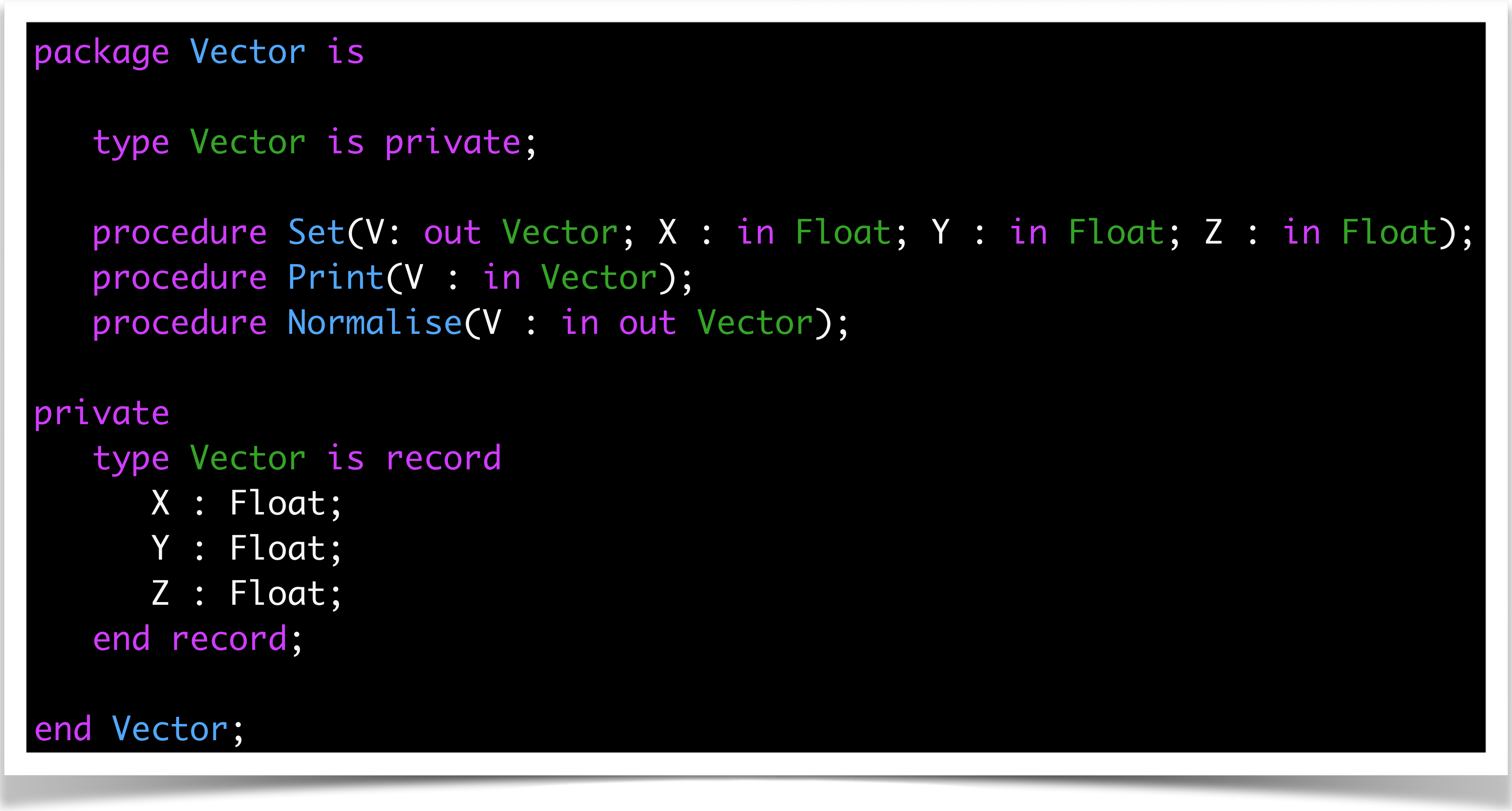
in: read only
out: write only
in out: read/write

Checked statically by the type system

Allows e.g. all records to be passed by pointer if the compiler desires.

Note: Strong typing *improving* performance over e.g. C

Implementation Hiding



```ada
package Vector is

   type Vector is private;

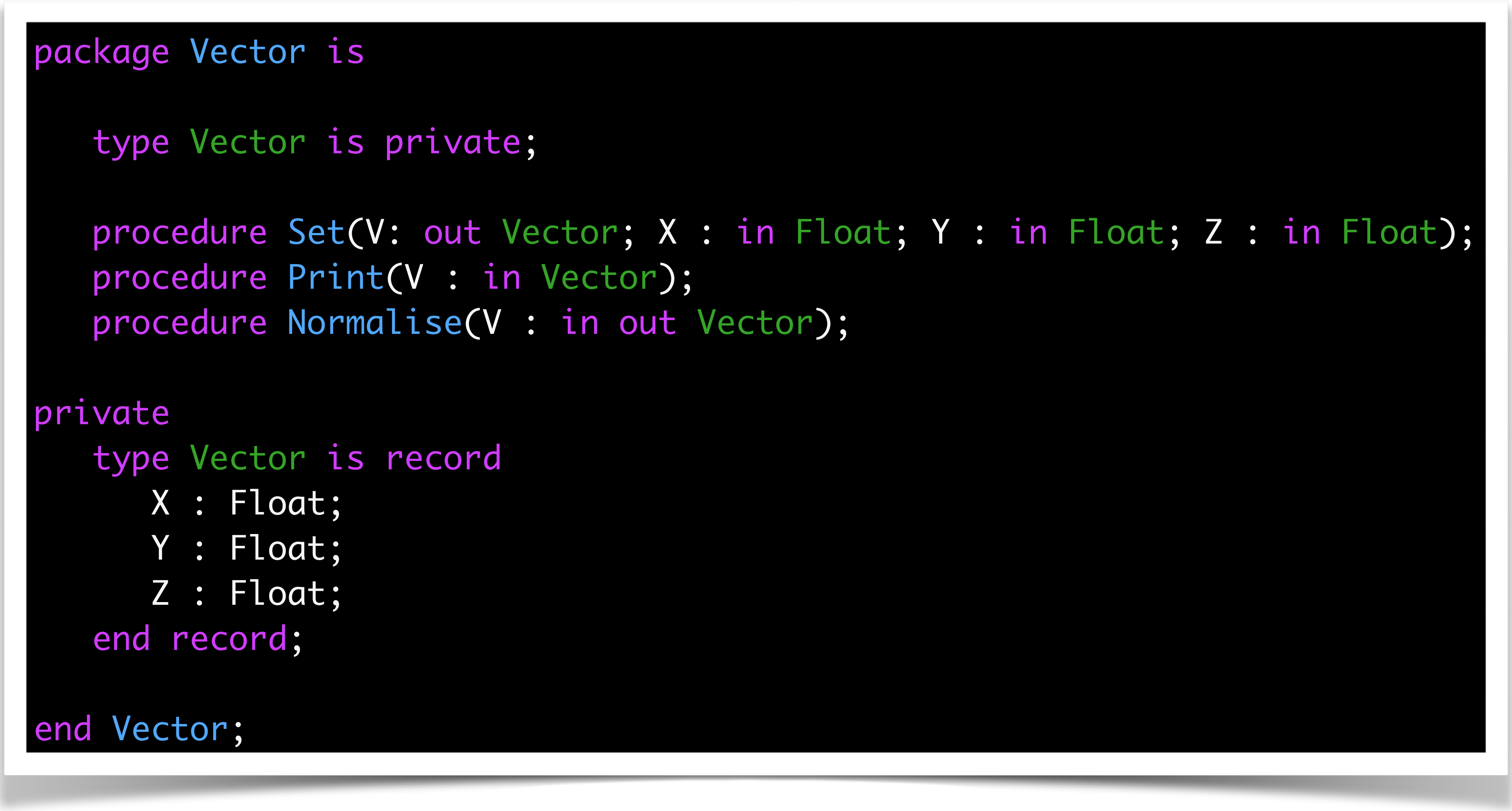
   procedure Set(V: out Vector; X : in Float; Y : in Float; Z : in Float);
   procedure Print(V : in Vector);
   procedure Normalise(V : in out Vector);

private
   type Vector is record
      X : Float;
      Y : Float;
      Z : Float;
   end record;

end Vector;
```

Vector’s fields can’t be accessed outside the package.

Private



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package Vector is

   type Vector is private;

   procedure Set(V: out Vector; X : in Float; Y : in Float; Z : in Float);
   procedure Print(V : in Vector);
   procedure Normalise(V : in out Vector);

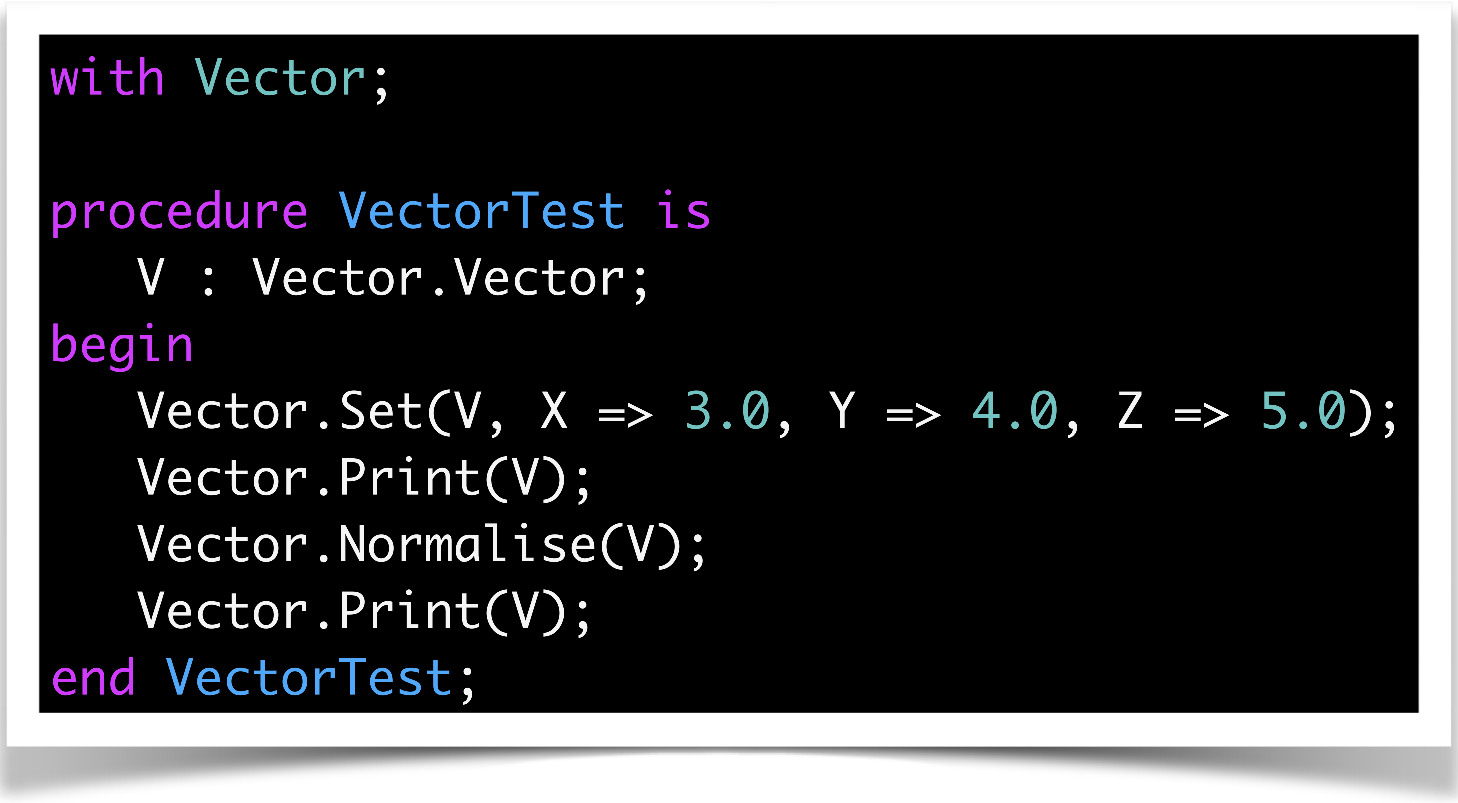
private
   type Vector is record
      X : Float;
      Y : Float;
      Z : Float;
   end record;

end Vector;
```

Why does the **Vector** record need to be defined in the spec?

Private: A Hint

Why does the **Vector** record need to be defined in the spec?

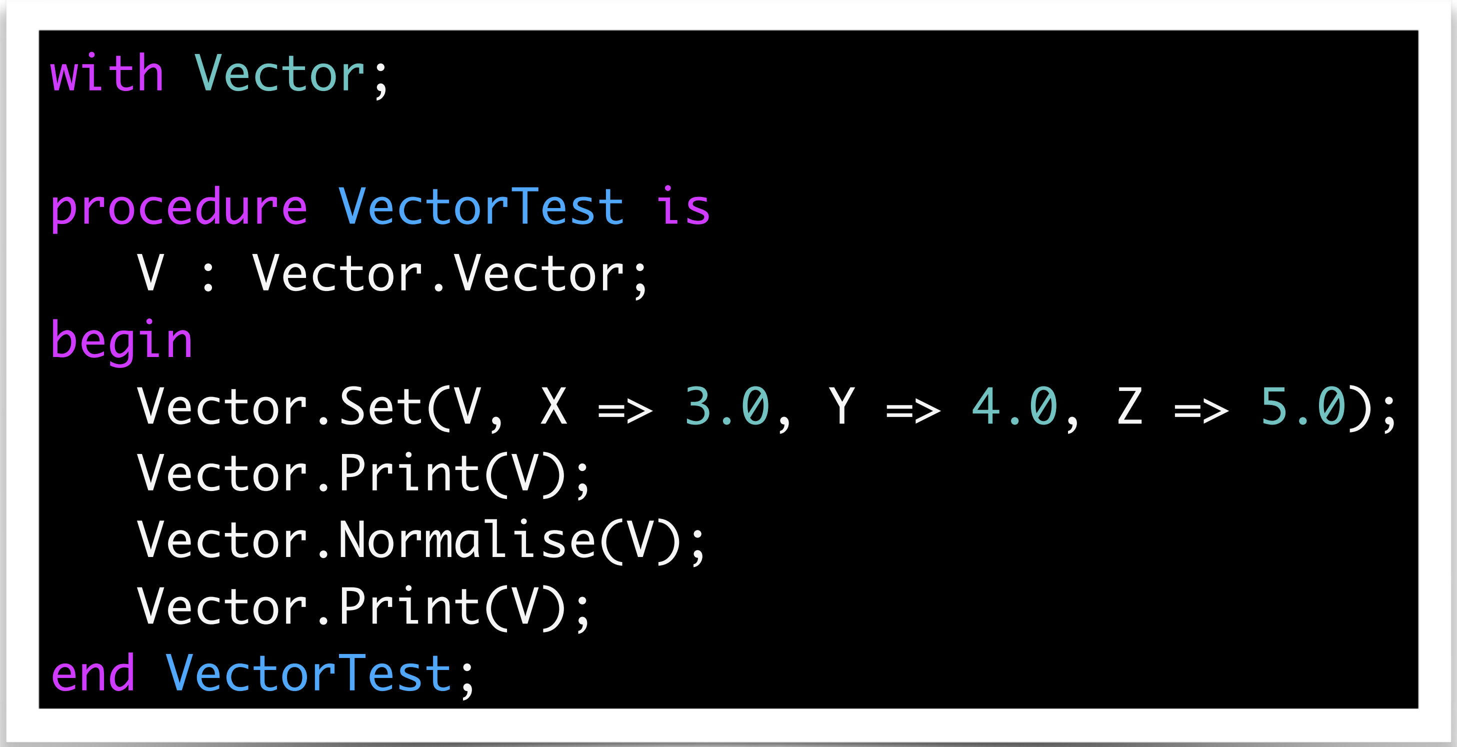


```ada
with Vector;

procedure VectorTest is
   V : Vector.Vector;
begin
   Vector.Set(V, X => 3.0, Y => 4.0, Z => 5.0);
   Vector.Print(V);
   Vector.Normalise(V);
   Vector.Print(V);
end VectorTest;
```

Private: A Hint

Why does the **Vector** record need to be defined in the spec?



```
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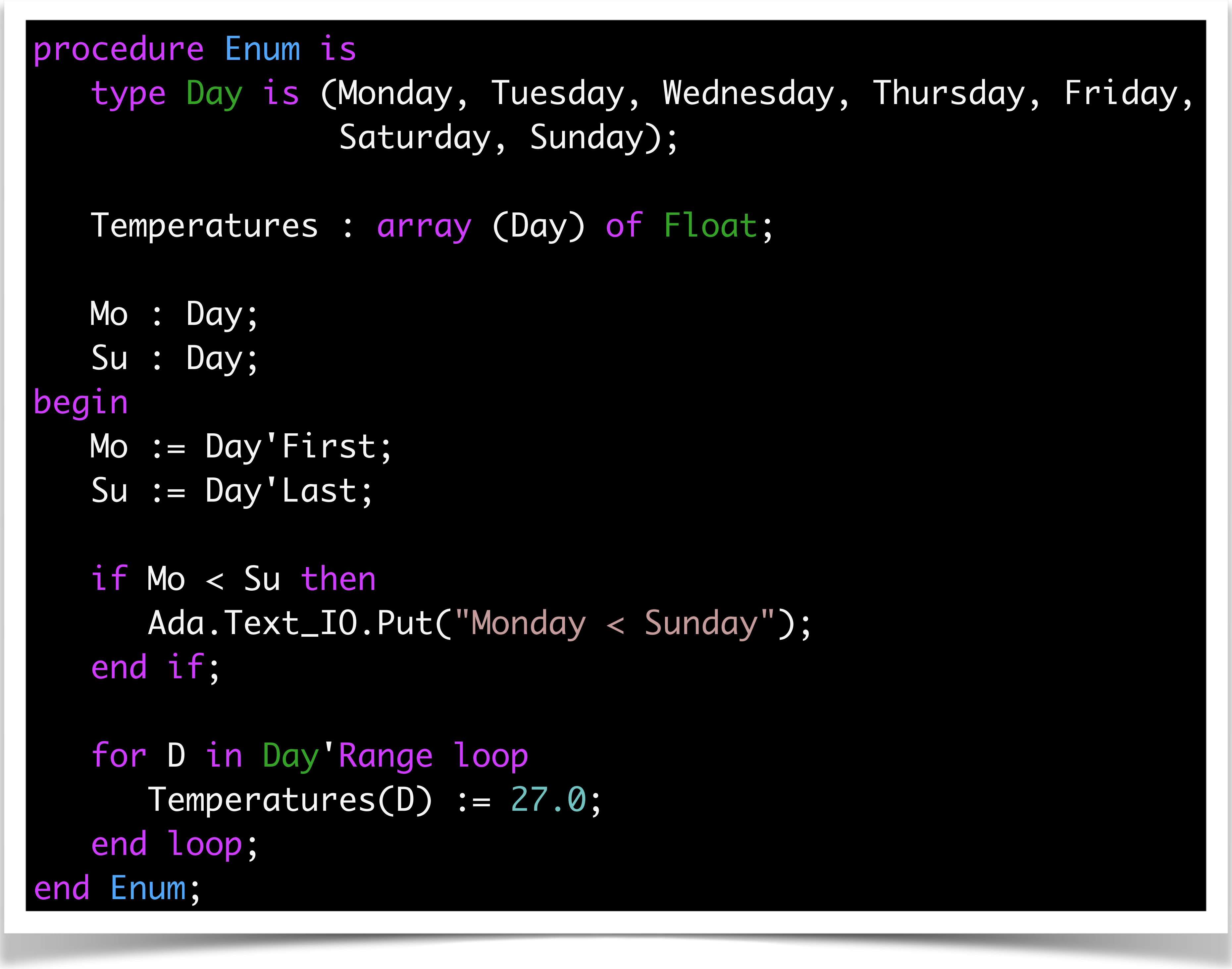
   V : Vector.Vector;
begin
   Vector.Set(V, X => 3.0, Y => 4.0, Z => 5.0);
   Vector.Print(V);
   Vector.Normalise(V);
   Vector.Print(V);
end VectorTest;
```

Because the compiler needs to know how big a **Vector** is when it compiles client code that uses **Vector**s

Enumerations



```
procedure Enum is
   type Day is (Monday, Tuesday, Wednesday, Thursday, Friday,
                Saturday, Sunday);

   Temperatures : array (Day) of Float;

   Mo : Day;
   Su : Day;
begin
   Mo := Day'First;
   Su := Day'Last;

   if Mo < Su then
      Ada.Text_IO.Put("Monday < Sunday");
   end if;

   for D in Day'Range loop
      Temperatures(D) := 27.0;
   end loop;
end Enum;
```

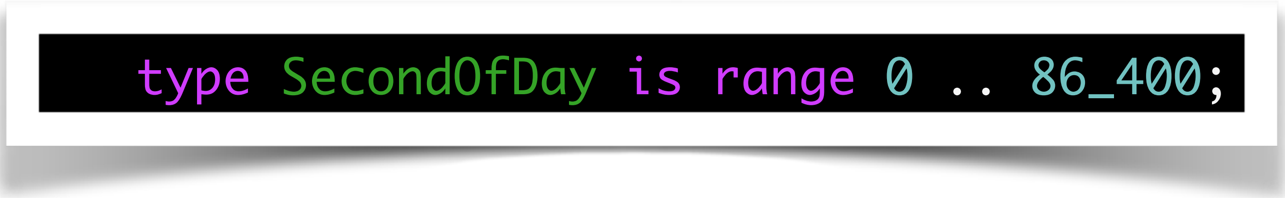
attributes

comparison

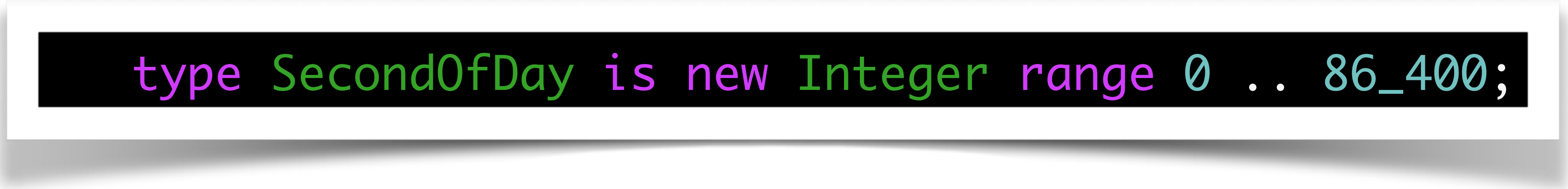
array
indexed by
enums

A Note on Standard Types

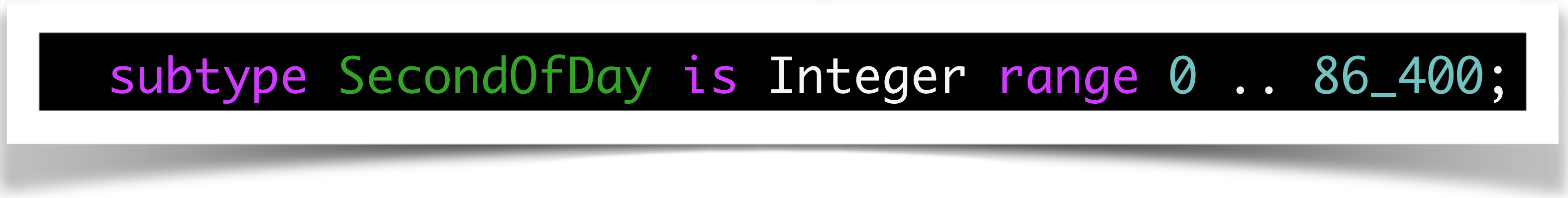
Which is best?



```
type SecondOfDay is range 0 .. 86_400;
```



```
type SecondOfDay is new Integer range 0 .. 86_400;
```

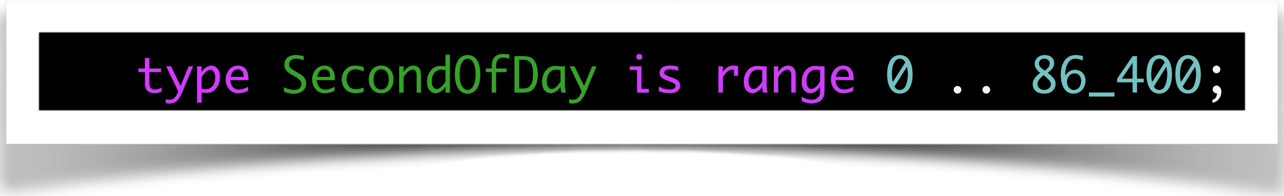


```
subtype SecondOfDay is Integer range 0 .. 86_400;
```

A Note on Standard Types

Which is best?

This one:



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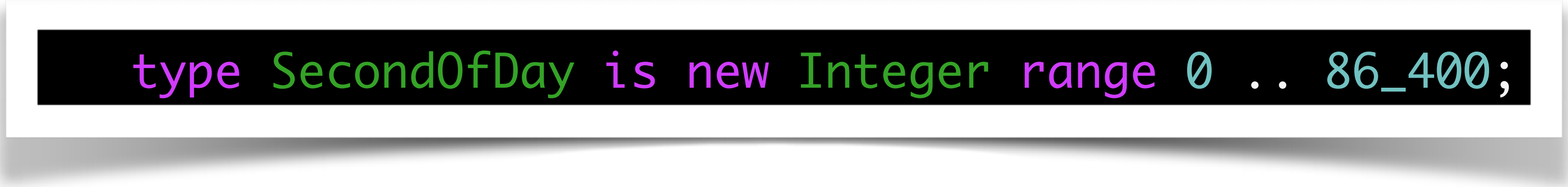
```



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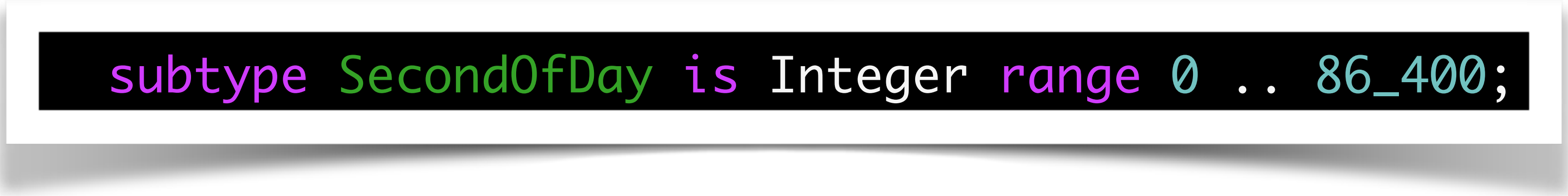

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A Note on Standard Types

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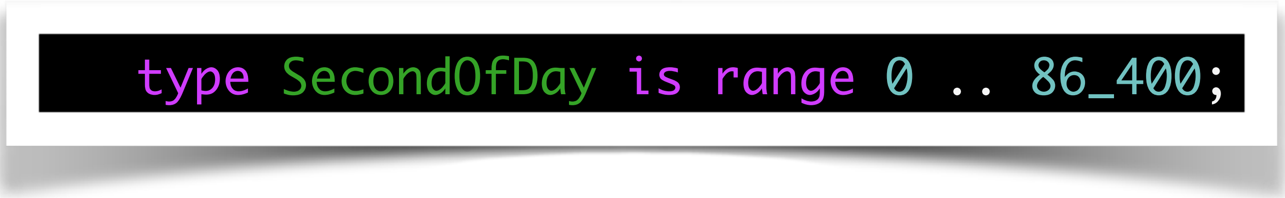

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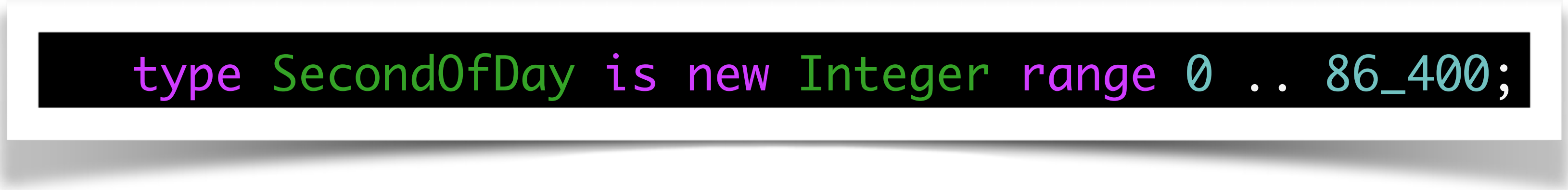
More portable than this:



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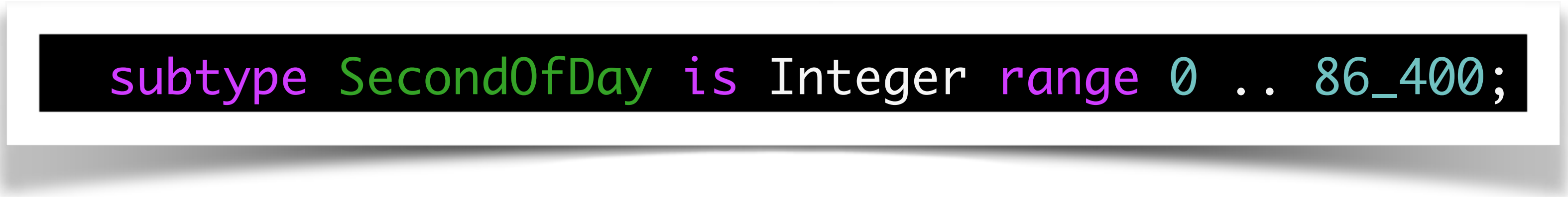

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A Note on Standard Types

Which is best?

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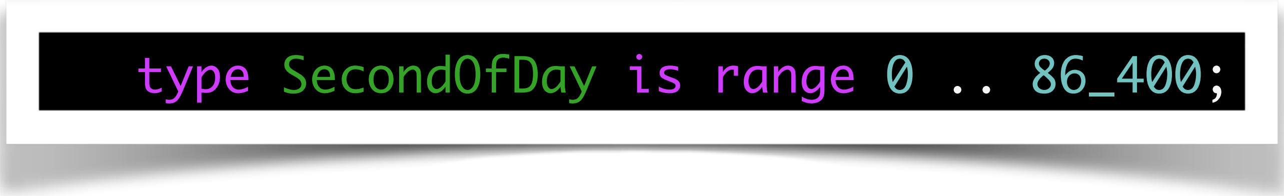

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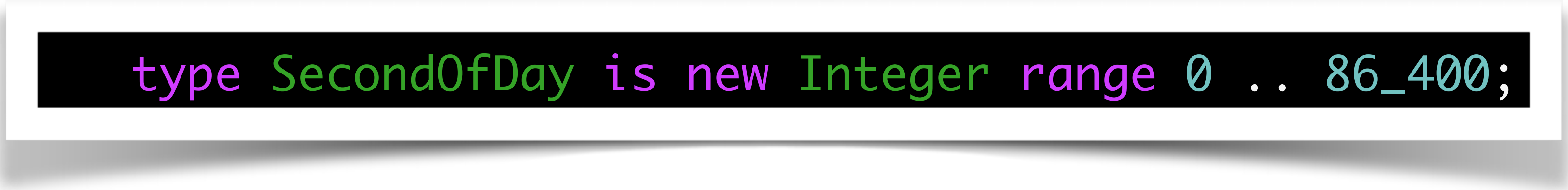
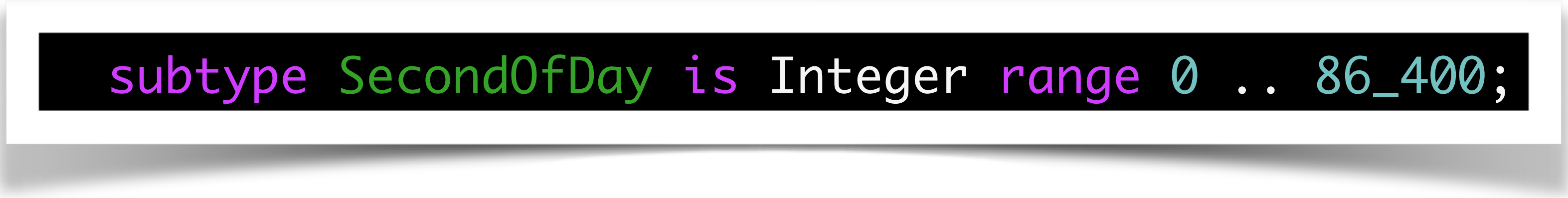


```
type SecondOfDay is new Integer range 0 .. 86_400;
```

More static checking than this:



```
subtype SecondOfDay is Integer range 0 .. 86_400;
```

Resources

Ada 2012 Reference Manual:
http://www.ada-auth.org/standards/rm12_w_tc1/html/RM-TTL.html

(including what's in the standard library,
plus all the language features we don't cover:
dynamic memory, variant records,
OO, concurrency, etc.)

Ada Quality and Style Guide:
https://en.wikibooks.org/wiki/Ada_Style_Guide