Interfaces.CPP

```
package Interfaces.CPP is

   type Vtable_Ptr is private;

private

   procedure Set_Vfunction_Address (...);
   function  Get_Vfunction_Address (...) return Address;
   procedure Set_Idepth (...);
   function  Get_Idepth (...)              return Natural;
   procedure Set_Ancestor_Vptrs (...);
   function  Get_Ancestor_Vptrs (...)     return Address;
   function  Vtable_Size (...) return Storage_Count;
   procedure Inherit_Vtable (...);
   function  CPP_Membership (...)         return Boolean;


  function Displaced_This (This : Address;
                           Vptr : Vtable_Ptr;
                            Pos  : Positive) return Address;

   type Vtable;
   type Vtable_Ptr is access all Vtable;


   pragma Inline (Get_Vfunction_Address);
   pragma Inline (...);

end Interfaces.CPP;
```

Same structure as Ada.Tags

to accomodate Multiple Inheritance

```
pragma CPP_Constructor (
  Entity     => Fname,
  Link_Name => "mangled name");
```

this function can only be used in declaration and allocation

```
pragma CPP_Destructor (
  Entity     => Fname,
  Link_Name => "mangled name");
```

this subprogram will be called on scope exit

```
pragma Import (
  Convention    => CPP,
  Entity        => Entity,
  External_Name => Whatever,
  Link_Name  => "mangled name");
```

no need to provide mangled name for disp. operations

The GNAT specific Pragmas

```
pragma CPP_Class (Entity => Typ);
```

} *Makes the type "limited" disable 'tag, aggregates, membership...*

```
pragma CPP_Vtable (
   Entity      => Typ,
   Vtable_Ptr  => Field_Name,
   Entry_Count => Static_Number);
```

} *tell the compiler where is the Vtable and its size*

```
pragma CPP_Virtual (
   Entity     => Subprogram,
   Vtable_Ptr => Field_Name,
   Position   => Static_Number)
```

} *tell the compiler where is the virtual func.tion in the Vtable*

To make it work

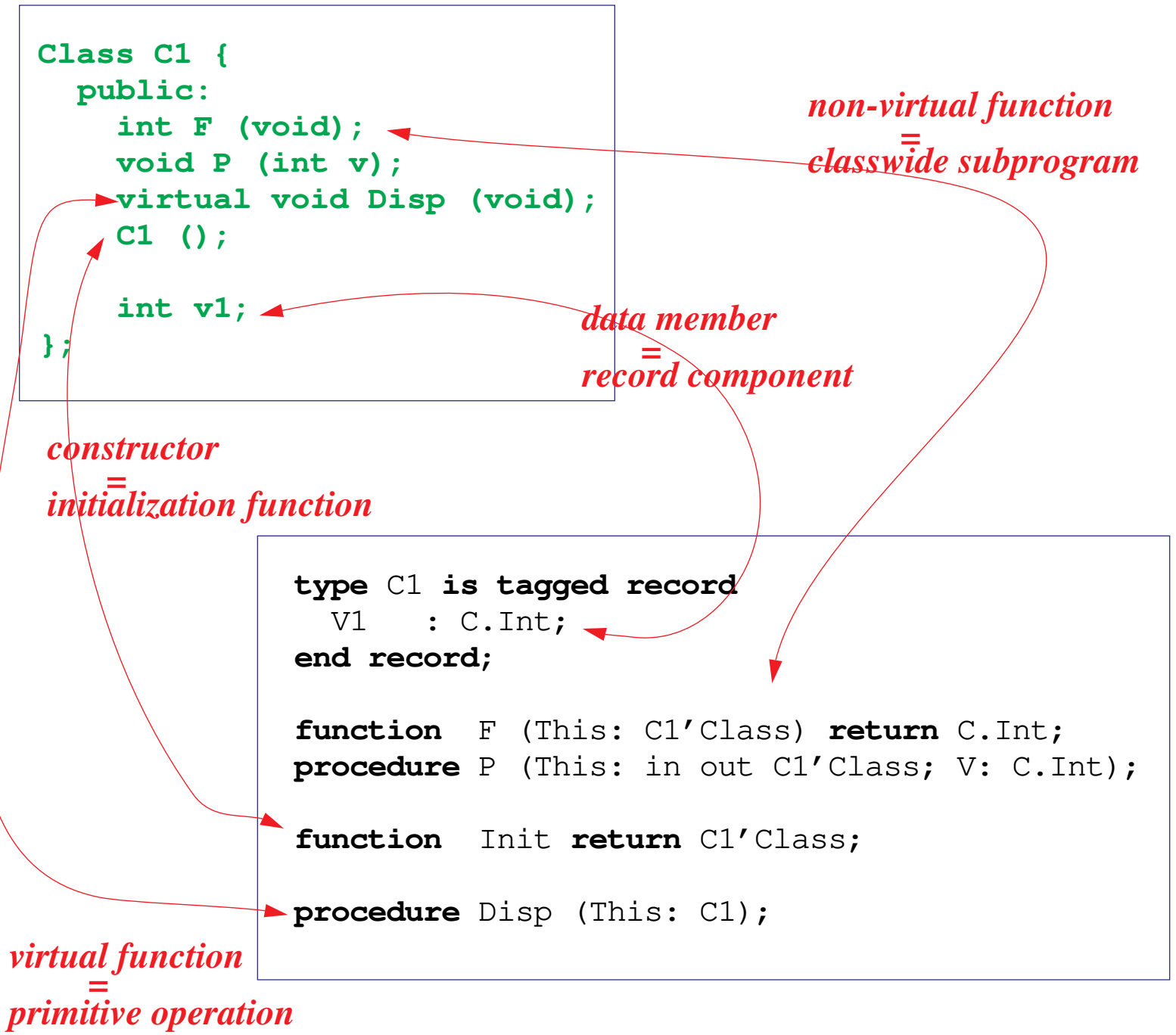
```
type C1 is tagged record
   V1   : C.Int;
   Vptr : CPP.Vtable_Ptr;
end record;
pragma CPP_Class (C1);
pragma Vtable (C1, Vptr, 1);

function  F (This: C1'Class) return C.Int;
pragma Import (CPP, F, "F", "f_3C1");

procedure P (This: in out C1'Class; V: C.Int);
pragma Import (CPP, P, "P", "p_3C1");

procedure Disp (This: C1);
pragma Import (CPP, Disp, "P", "p_3C1");
pragma CPP_Virtual (Disp, 1);

function  Init return C1'Class;
pragma CPP_Constructor (Init, "C1", "___3C1");
```

provide information for dispatching

mangling is done by hand

Default constructor is automatically applied to CPP objects

Basic Mapping

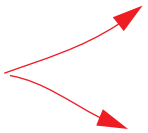


The Low-Level C++ Interface

Goals :

* Import and use C++ Classes as Tagged Types

* Derive from C++ Classes



dispatching accross languages

customizing C++ libraries

* Avoid coupling with a specific C++ compiler

Technical problems :

* Semantic differences

* Compatibility of the dispatch tables

* Mangling of names

* Run-time type information

* Layout of objects

Advantages of Black Box Dispatch Table Approach

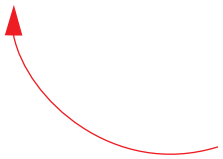
The user can modify Ada.Tags without changing the compiler in order to :

- customize the implementation of type **Tag** :

when dispatching is not needed

```
type Tag is null record;
```

```
type Tag is new Array_OF_DT_Index_Type;
```



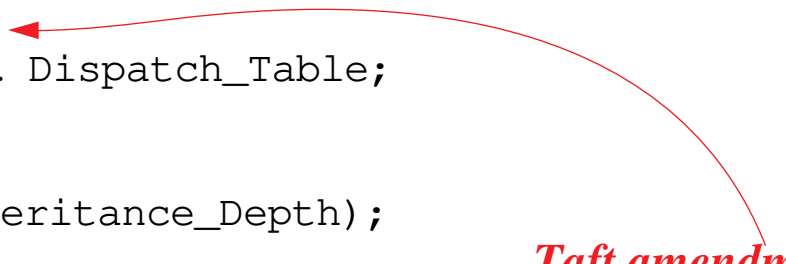
to trade efficiency for more compact objects

- modify the format of the Dispatch Table

  * to match a **foreign** Dispatch Table **format**

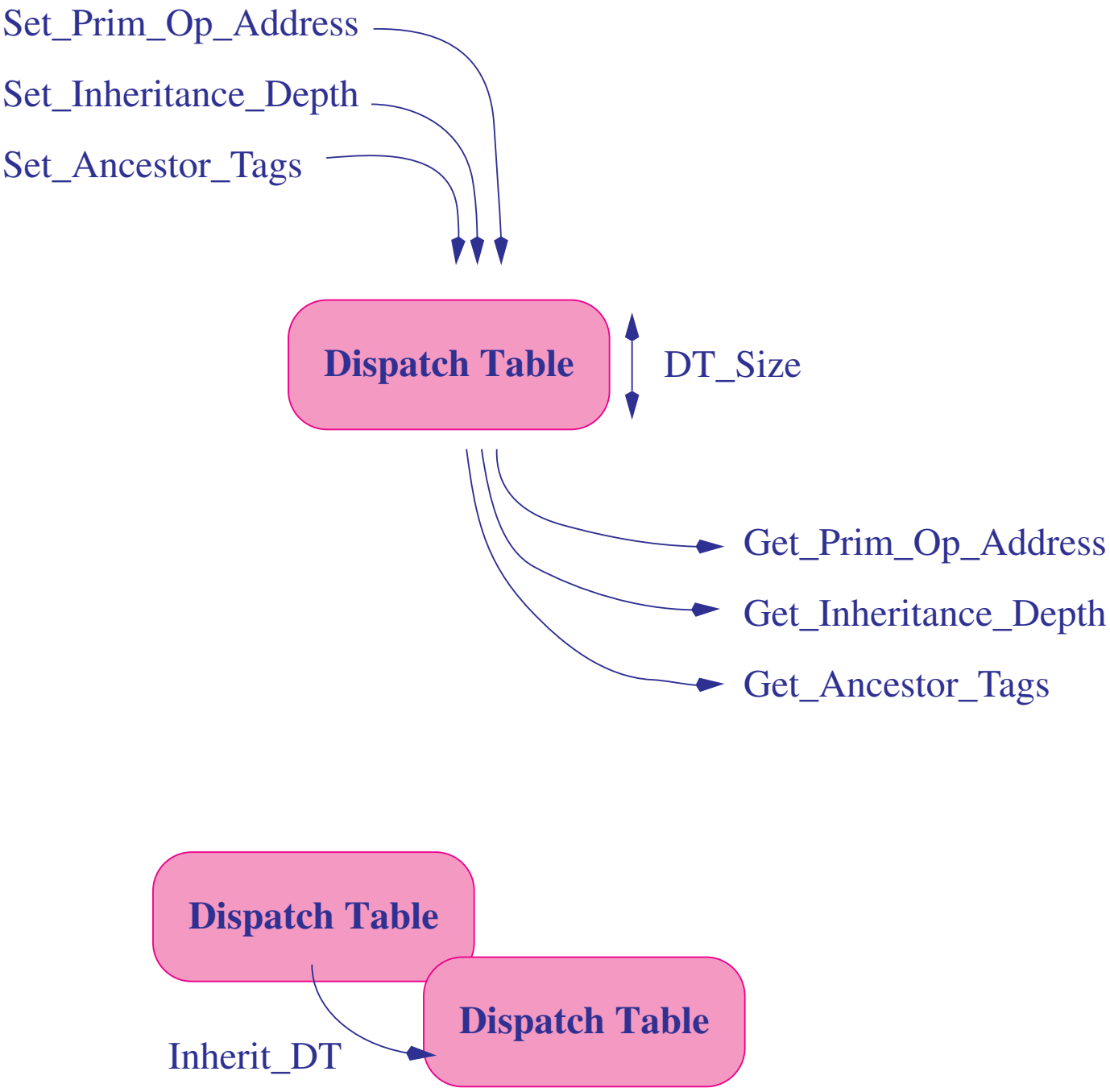
  * to take advantage of a specific architecture

```
package Ada.Tags is

   type Tag is private;

   ...

private

   procedure Set_Prim_Op_Addr (T: Tag; P: Pos; V: Address);
   function  Get_Prim_Op_Addr (T: Tag; P: Pos) return Address;

   procedure Set_Inheritance_Depth (T : Tag; V    : Natural);
   function  Get_Inheritance_Depth (T : Tag) return Natural;

   procedure Set_Ancestor_Tags (T : Tag; V    : Address);
   function  Get_Ancestor_Tags (T : Tag) return Address;

   function DT_Size (C : Natural) return Storage_Count;

   procedure Inherit_DT (OldT, NewT: Tag; C: Natural);

   function CW_Membership (ObjT, TypT : Tag) return Boolean;

   type Dispatch_Table;
   type Tag is access all Dispatch_Table;


   Pragma Inline (Get_Inheritance_Depth);
   Pragma Inline (...);
end Ada.Tags;
```

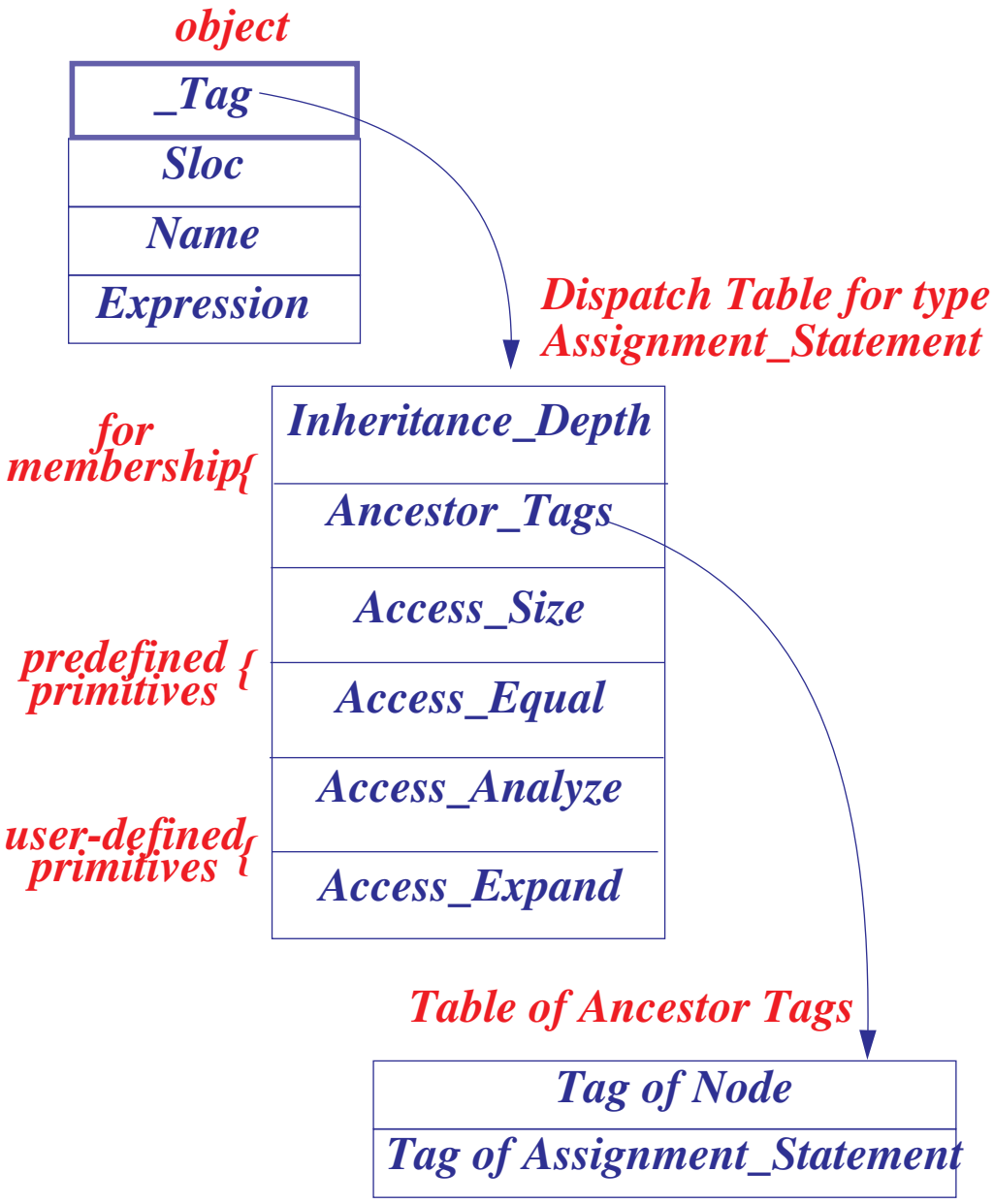


Taft amendment type

The Procedural Interface to the Dispatch

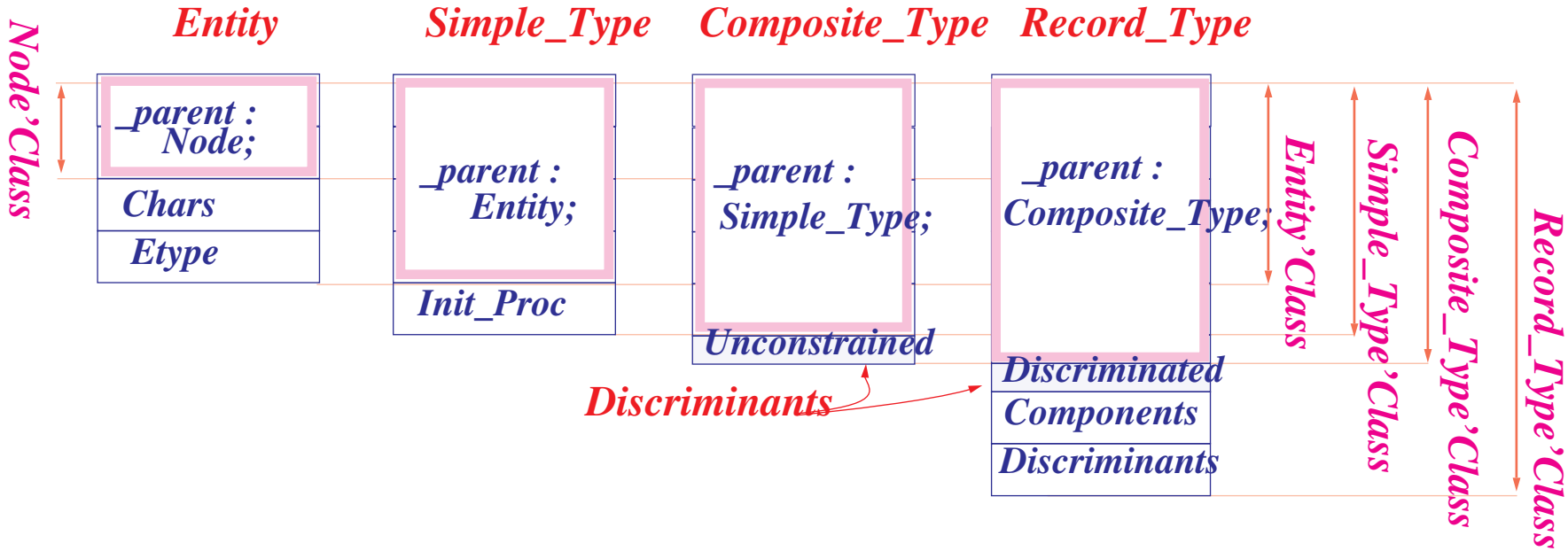


The Strongly Typed View of the Dispatch



Layouts of root tagged types

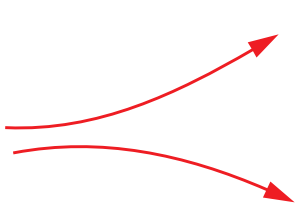
Layouts of extensions



3. Basic Implementation Techniques

Problems that had to be solved:

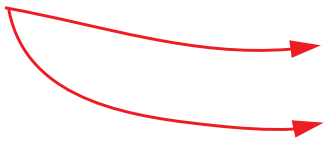
* Layout of objects



where to put the new discriminants

how to allocate classwide objects

* Structure of the Dispatch Table



The strongly typed approach

The black box approach

* Membership Test

* Visibility issues with private extensions and primitives

GNAT messages

```
package Error3 is

   type Node is tagged null record;
   type Node_Id is access all Node'Class;
   Empty: constant Node_Id := new Node'(null record);
```

warning: no primitive operations for "Node" after this line

```
   procedure Analyze (N : access Node);
```

this primitive operation is declared too late

```
   type Expr is abstract new Node with null record;
   type Op_Add is new Expr with null record;
```

warning: no primitive operations for "Expr" after this line

```
   procedure Analyze (N : access Expr) is abstract;
```

this primitive operation is declared too late

```
   procedure Analyze (N : access Op_Add);
```

The problematic notion of Freezing

RM 13.14

> ...A noninstance body causes freezing ...
>
> ...The occurence of an object_declaration... causes freezing...
>
> ...The declaration of a record extention causes freezing ...
>
> ...At the place where an allocator causes freezing, the designated subtype of its type is frozen

where are the mistakes???

```
package Error3 is

   type Node is tagged null record;
   type Node_Id is access all Node'Class;
   Empty: constant Node_Id := new Node'(null record);
   procedure Analyze (N : access Node);

   type Expr is abstract new Node with null record;
   type Op_Add is new Expr with null record;
   procedure Analyze (N : access Expr) is abstract;
   procedure Analyze (N : access Op_Add);

end Error3;
```

What you could have got

```
package body Error2 is

   type Ctrl is new Controlled with null record;
   procedure Finalize (Obj : in out Ctrl) is
                     |
 "Finalization" conflicts with declaration at line 3
```

GNAT message

```
package body Error2 is

   type Ctrl is new Controlled with null record;
   procedure Finalize (Obj : in out Ctrl) is
                     |
overriding too late (subprogram spec should appear immediately after type)

   begin
      ...
   end Finalize;
end Error2;
```

case2

```
package body Error2 is

   type Ctrl is new Controlled with null record;
   procedure Finalize (Obj : in out Ctrl) is
   begin
       ...
   end Finalize;
end Error2;
```

althrough RM 3.2.3 (7) says :

> The primitive subprograms of a specific type are defined as follows: ... For a specific type declared outside a package_Specification, any subprograms that are explicitly declared immediately within the same declarative region and that override other implicitly declared subprograms of the type

it also says somewhere else (RM 13.14 (15))

> The explicit declaration of a primitive subprogram of a tagged type shall occur before the type is frozen.

and RM 13.14 (4)

> A noninstance body causes freezing of each entity declared before it within the same declarative_part..

What you could have got

```
   Analyze (N);
               |
type 'access to Node' expected, found Node_Id

end Error1;
```

The warning is only issued when an error occurs later

GNAT message

```
procedure Error1 is

   type Node is tagged null record;
   type Node_Id is access all Node'Class;
   procedure Analyze (N : access Node) is separate;
                      |
warning: not a dispatching operation (must be defined in a package spec)

   N : Node_Id;

begin
    Analyze (N);
             |
access to class-wide argument not allowed here
"Analyze" is not a primitive operation of "Node"
```

2. Dealing With Common User Mistakes

Find the Mistake ???

case1

```
procedure Error1 is

   type Node is tagged null record;
   type Node_Id is access all Node'Class;
   procedure Analyze (N : access Node) is separate;
   N : Node_Id;

begin
   ...
   Analyze (N);
end Error1;
```

Hints : RM 3.9.2 (9)

> if the expected type of an expression or name is some specific tagged type, then the expression shall not be dynamically tagged unless it is a controlling operand in a call on a dispatching operation

RM 3.2.3

> The primitive subprograms of a specific type are defined as follows: ... For a specific type declared immediately within a package_Specification, any subprogram that are explicitly declared immediately within the same packag-e_specification and that operate on the type...

Private Extensions and New Discriminants

new discriminant

```
type Composite_Type (Unconstrained : Boolean) is
   abstract new Simple_Type with null record;
```

discriminant renaming

```
type Record_Type (Discriminated : Boolean) is
   new Composite_Type (Unconstrained => Discriminated)
      with private;
.
.
.
```

private extension

```
type Tagged_Type is new Record_Type with
   record
      Dispatch_Table : Entity_Id;
      Is_Controlled  : Boolean;
   end record;
.
private
```

discriminant inheritance

```
type Record_Type (Discriminated : Boolean) is
   new Composite_Type (Unconstrained => Discriminated)
with
      record
         Components : Entity_List;
         case Discriminated is
            when True  => Discriminants : Entity_List;
            when False => null;
         end case;
      end record;
```

Record and Extension Aggregates

```
Rec_Variable.Field := Funct (X) + 1;
```

Record Aggregate

```
Assign_Stmt_Ptr : Node_Id :=

  new Assignement_Statement'(
    Sloc       => Current_Location,
    Name       => new Selected_Component,
    Expression =>

     new Op_Add'(Node with
       Etype      => Standard_Integer,
       Left_Opnd  => new Function_Call,
       Right_Opnd => new Universal_Integer'(Expr with 1)));
```

Extension Aggregates

Syntax

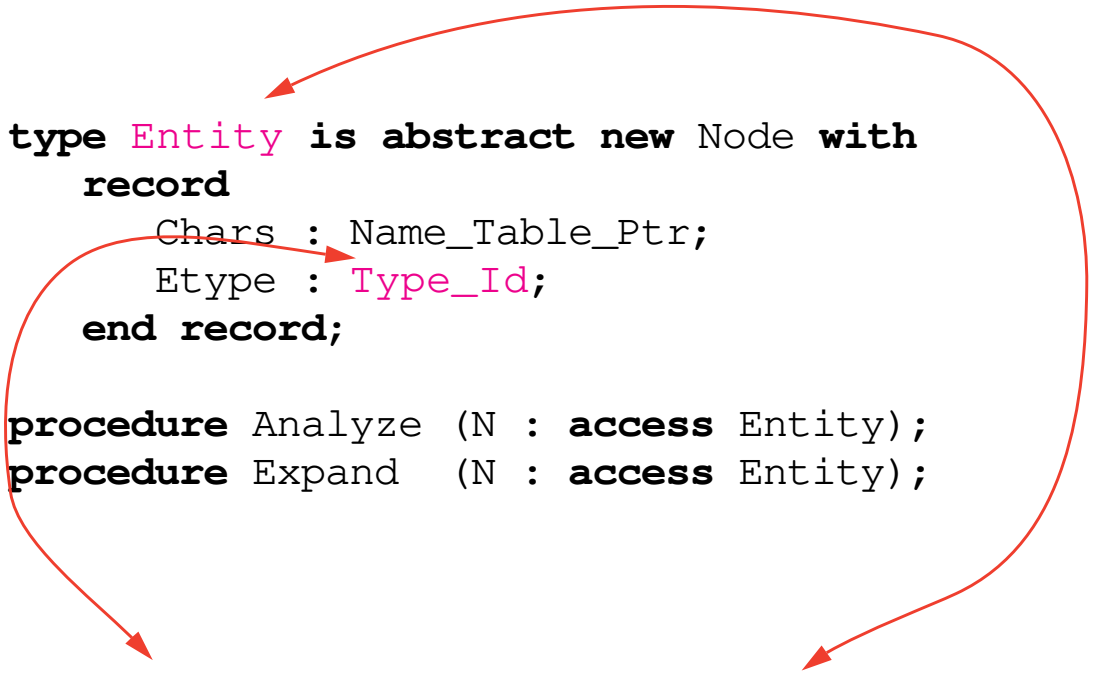
can be of a private type

```
(Ancestor_Expression with [comp_associations])

(Ancestor_Type       with [comp_associations])
```

can be an abstract type

Example of recursive definition

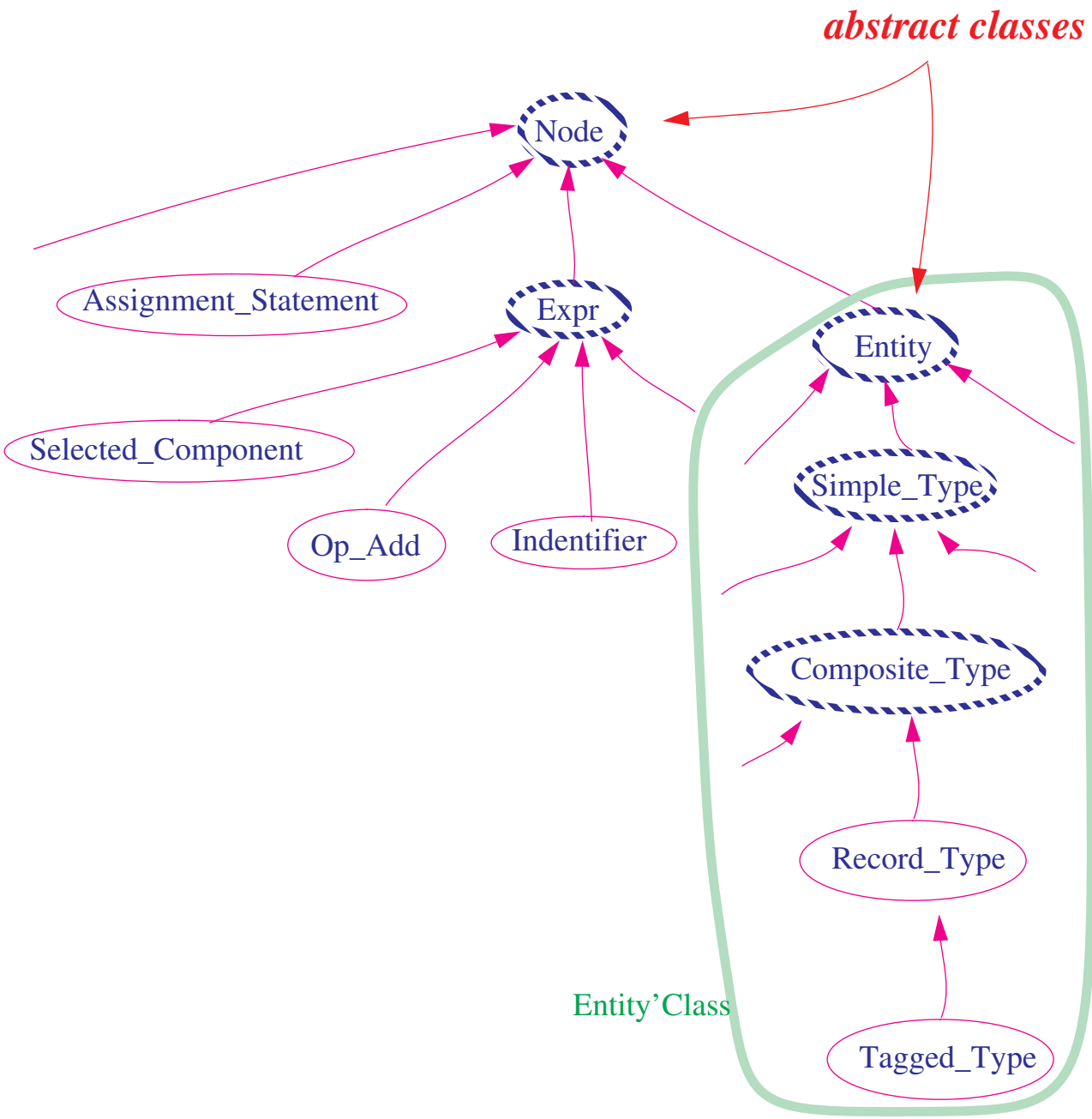
```
type Entity;
type Entity_Id is access Entity'Class;
```



```
type Entity is abstract new Node with
   record
      Chars : Name_Table_Ptr;
      Etype : Type_Id;
   end record;

procedure Analyze (N : access Entity);
procedure Expand  (N : access Entity);
```

```
type Simple_Type is abstract new Entity with
   record
      Init_Proc : Entity_Id;
   end record;
```

Hierarchy of Tagged Types



Primitive Operations versus Operations on Classwide Types

This is a general algorithm, valid for all Nodes

```
procedure Analyze_Node (N : Node_Id) is
begin
   Analyze (N);
   if Code_Generation
    and then N.all not in Expr'Class
   then
      Expand (N);
   end if;
end Analyze_Node;
```

Dispatching Calls:
the formal has a specific tagged type
the actual has a classwide type

```
procedure Analyze (N : access Assignment_Statement) is
   Typ : Type_Id;
begin
   Analyze_Node (N.Name);
   Analyze_Node (N.Expression);
   Typ := Find_Matching_Type (N.Name, N.Expression);
   Resolve_Expr (N.Name, Typ);
   Resolve_Expr (N.Expression, Typ);
end Analyze;
```

This is the specific algorithm for analyzing Assignments

concrete type extension

```
type Assignment_Statement is new Node with
   record
      Name       : Expr_Id;
      Expression : Expr_Id;
   end record;
```

```
procedure Analyze (N : access Assignment_Statement);
procedure Expand  (N : access Assignment_Statement);
```

Overriding of primitive operations

class of an incomplete type

```
type Simple_Type;
type Type_Id is access Simple_Type'Class;
```

```
type Expr is abstract new Node with
   record
      Etype : Type_Id;
   end record;
```

abstract type extension

```
-- Inherited:
--  procedure Analyze (N : access Expr) is abstract;
--  procedure Expand  (N : access Expr) is abstract;
```

inheritance

```
procedure Resolve_Expr (E : Expr_Id; Typ : Type_Id);
procedure Resolve  (E : access Expr; Typ : Type_Id)
  is abstract;
```

Basic Syntax and Concepts

```
package Definitions is

   type Node is abstract tagged
      record
         Sloc : Source_Ptr;
      end record;

   type Node_Id is access Node'Class;

   procedure Analyze_Node (N : Node_Id);

   procedure Analyze (N : access Node) is abstract;
   procedure Expand  (N : access Node) is abstract;
```

abstract tagged type

The corresponding classwide type

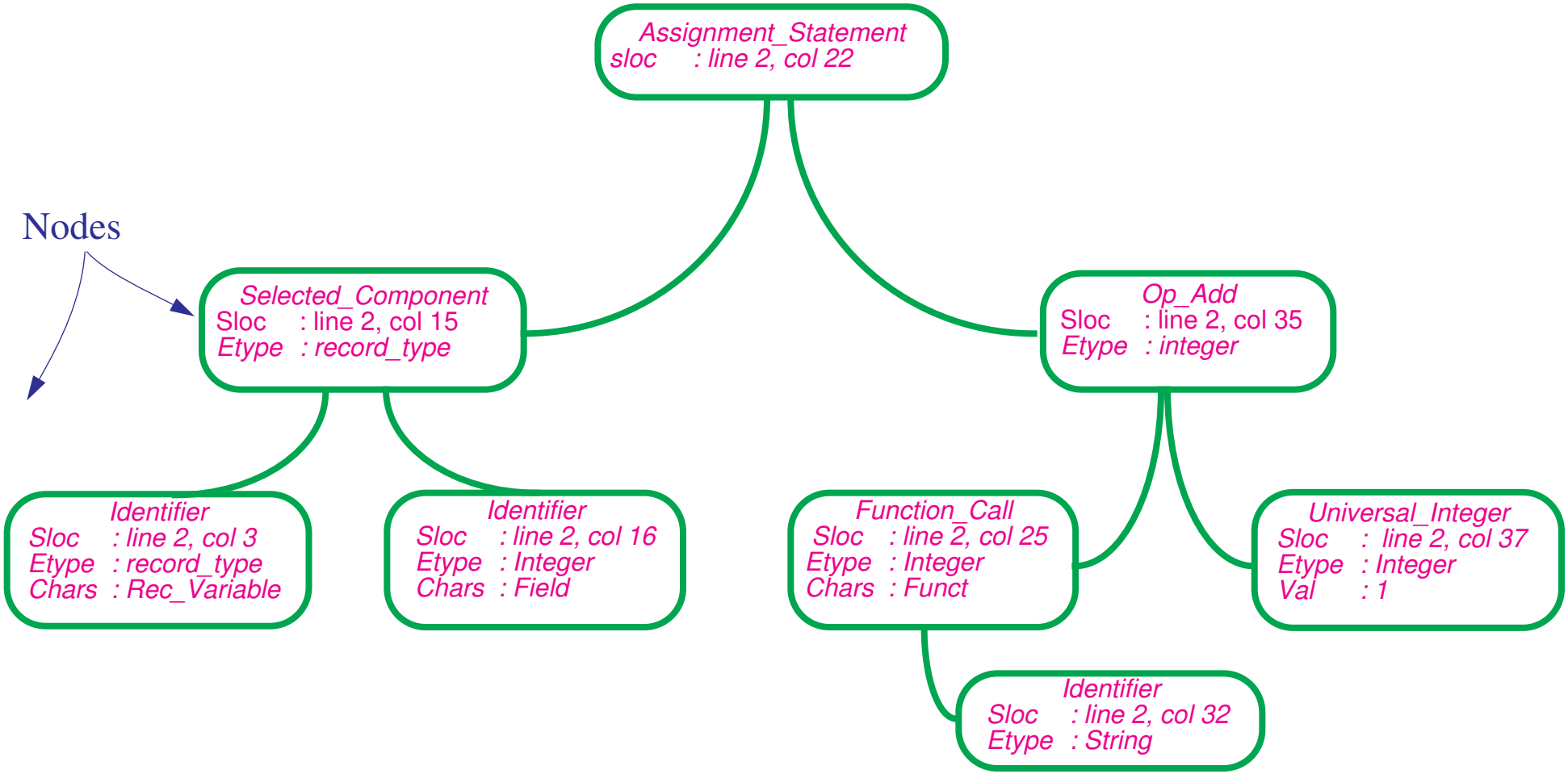
polymorphic pointer

classwide operation

primitive operations

a GNAT tree for

```
Rec_Variable.Field := Funct (X) + 1;
```



OUTLINE

1. Ada 9x Object-Oriented Concepts Through An Example

- The main GNAT Data-Structures with Tagged Types
- Extending and Dispatching

2. Dealing With Common User Mistakes

- Tagged types outside Package Specs.
- Freezing point Issues

3. Basic Implementation Techniques

- Layout of Tagged Objects
- Structure of the Dispatch Table

4. The Low-Level C++ Interface

- Goals and Limitations
- The Gnat-specific Pragmas supporting the interface

Ada 9x Tagged Types

and their Implementation

in GNAT

Cyrille Comar & Brett Porter

Gnat Project