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New PL/SQL Capabilities
in
Oracle Database 12c

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DATABASE 12^c

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Agenda

- Improved client <> PL/SQL <> SQL interoperability
- A new security capability
- Improved programmer usability
- Miscellaneous

Performance improvement for PL/SQL functions called from SQL

- *Example:* pretty-print an integer

```
select      PK,  
           Print(n1) "n1",  
           Print(n2) "n2",  
           Print(n3) "n3"  
from t
```

1	1 K	1 G	566 G
2	1 K	157 M	416 G
3	2 K	1 G	971 G
4	578 byte	1 G	1 T
5	2 K	1 G	220 G
6	1 K	2 G	1 T
7	48 byte	1 G	2 T
8	992 byte	42 M	3 T
9	794 byte	2 G	1 T
10	2 K	302 M	672 G

The “algorithm”

- Pretty-print an integer as a multiple of an appropriate power of 1024: plain, K, M, B, or T

```
function Print(n in integer) return varchar2 authid Definer is
  K constant number not null := 1024;
  M constant number not null := K*K;
  G constant number not null := M*K;
  T constant number not null := G*K;
begin
  return
    case
      when n <= K-1 then To_Char(n, '999999') || 'byte'
      when n/K <= K-1 then To_Char(n/K, '999999') || 'K'
      when n/M <= K-1 then To_Char(n/M, '999999') || 'M'
      when n/G <= K-1 then To_Char(n/G, '999999') || 'G'
      else
        To_Char(n/T, '999999') || 'T'
    end;
end Print;
```

Try it in pure SQL!

```
select
  PK,
  case
    when n1          <= 1023 then To_Char(n1,          '999999') || ' byte'
    when n1/1024     <= 1023 then To_Char(n1/1024,     '999999') || ' K'
    when n1/1048576  <= 1023 then To_Char(n1/1048576,  '999999') || ' M'
    when n1/1073741824 <= 1023 then To_Char(n1/1073741824, '999999') || ' G'
    else              To_Char(n1/1099511627776, '999999') || ' T'
  end
  "n1",
  case
    when n2          <= 1023 then To_Char(n2,          '999999') || ' byte'
    when n2/1024     <= 1023 then To_Char(n2/1024,     '999999') || ' K'
    when n2/1048576  <= 1023 then To_Char(n2/1048576,  '999999') || ' M'
    when n2/1073741824 <= 1023 then To_Char(n2/1073741824, '999999') || ' G'
    else              To_Char(n2/1099511627776, '999999') || ' T'
  end
  "n2",
  case
    when n3          <= 1023 then To_Char(n3,          '999999') || ' byte'
    when n3/1024     <= 1023 then To_Char(n3/1024,     '999999') || ' K'
    when n3/1048576  <= 1023 then To_Char(n3/1048576,  '999999') || ' M'
    when n3/1073741824 <= 1023 then To_Char(n3/1073741824, '999999') || ' G'
    else              To_Char(n3/1099511627776, '999999') || ' T'
  end
  "n3"
from t
```

Get the performance of SQL with the clarity and reusability of PL/SQL

```
function Print(n in integer) return varchar2 authid Definer is
  pragma UDF;
  K constant number not null := 1024;
  M constant number not null := K*K;
  G constant number not null := M*K;
  T constant number not null := G*K;
begin
  return
  case
    when n <= K-1 then To_Char(n, '999999')||'byte'
    when n/K <= K-1 then To_Char(n/K, '999999')||'K'
    when n/M <= K-1 then To_Char(n/M, '999999')||'M'
    when n/G <= K-1 then To_Char(n/G, '999999')||'G'
    else To_Char(n/T, '999999')||'T'
  end;
end Print;
```


Declare the PL/SQL function in the subquery's *with* clause

```
with
  function Print(n in integer) return varchar2 is
    K constant number not null := 1024;
    M constant number not null := K*K;
    G constant number not null := M*K;
    T constant number not null := G*K;
  begin
    return
      case
        when n <= K-1 then To_Char(n, '999999') || ' byte'
        when n/K <= K-1 then To_Char(n/K, '999999') || ' K'
        when n/M <= K-1 then To_Char(n/M, '999999') || ' M'
        when n/G <= K-1 then To_Char(n/G, '999999') || ' G'
        else
          To_Char(n/T, '999999') || ' T'
      end;
  end Print;
select PK,
  Print(n1) "n1",
  Print(n2) "n2",
  Print(n3) "n3"
from t
```

Performance comparison

- Pure SQL is fastest 5.0x
- Schema-level function with pragma UDF is close 3.9x
- Function in the with clause is similar 3.8x
- Pre-12.1 ordinary schema-level function is very much the slowest 1.0 – the baseline

Binding values of PL/SQL-only datatypes into SQL statements

- Before 12.1, you could bind only values of SQL datatypes
- In 12.1, you can bind PL/SQL index-by-pls_integer tables (of records) and booleans
 - **from** client-side programs – OCI or both flavors of JDBC – and from PL/SQL
 - **to** anonymous blocks, statements using functions, or statements using the *table* operator

Binding a PL/SQL index-by table to SQL

- Before 12.1, you could invoke a function with a collection actual, or select from a collection, but
 - The type had to be defined at schema-level
 - Therefore it had to be a nested table or a varray
 - A non-scalar payload had to be an ADT
- New in 12.1
 - The type can be defined in a package spec – can be *index by pls_integer* table
 - The payload can be a record – but the fields must still be SQL datatypes

The collection

```
package Pkg authid Definer is
  type r is record(n integer, v varchar2(10));
  type t is table of r index by pls_integer;
  x t;
end Pkg;
```

Example: binding an IBPI to a PL/SQL function in SQL

```
function f(x in Pkg.t) return varchar2 authid Definer is
  r varchar2(80);
begin
  for j in 1..x.Count() loop
    r := r||...;
  end loop;
  return r;
end f;
```

```
procedure Bind_IBPI_To_Fn_In_SQL authid Definer is
  v varchar2(80);
begin
  select f(Pkg.x) into v from Dual;
  ...
  execute immediate 'select f(:b) from Dual' into v
    using Pkg.x;
end Bind_IBPI_To_Fn_In_SQL;
```

Example: binding to the operand of the *table* operator

```
procedure Select_From_IBPI authid Definer is
  y Pkg.t;
begin
  for j in (select n, v from table(Pkg.x)) loop
    ...
  end loop;

  execute immediate 'select n, v from table(:b) '
  bulk collect into y
  using Pkg.x;
  for j in 1..y.Count() loop
    ...
  end loop;
end Select_From_IBPI;
```

Example: binding an IBPI to an anonymous block

```
procedure p1(x in Pkg.t) authid Definer is
begin
  for j in 1..x.Count() loop
    ...;
  end loop;
end p1;
```

```
procedure Bind_IBPI_To_Anon_Block authid Definer is
begin
  execute immediate 'begin p1(:b); end;' using Pkg.x;
end Bind_IBPI_To_Anon_Block;
```


Example: binding a boolean to an anonymous block

```
procedure p2(b in boolean) authid Definer is
begin
  DBMS_Output.Put_Line(case b
                        when true  then 'True'
                        when false then 'False'
                        else       'Null'
                        end);
end p2;
```

```
procedure Bind_Boolean_To_Anon_Block authid Definer is
  Nil constant boolean := null; -- workaround for existing bug
begin
  execute immediate 'begin p2(:b); end;' using true;
  execute immediate 'begin p2(:b); end;' using false;
  execute immediate 'begin p2(:b); end;' using Nil;
end Bind_Boolean_To_Anon_Block;
```

Binding PL/SQL types in JDBC

- Before 12.1
 - Generate a schema level object type to mirror the structure of the non-SQL package type
 - Populate and bind the object into a custom PL/SQL wrapper around the desired PL/SQL subprogram
 - Convert the object to the package type in the wrapper and call the PL/SQL subprogram with the package type

Binding PL/SQL types in JDBC

- New in 12.1
 - PL/SQL package types supported as binds in JDBC
 - Can now execute PL/SQL subprograms with non-SQL types
 - Supported types include *records*, *index-by tables*, *nested tables* and *varrays*
 - *Table%rowtype*, *view%rowtype* and package defined *cursor%rowtype* also supported. They're technically record types

Example 1: Bind a single record from Java into a PL/SQL procedure, modify it, and bind it back out to Java

```
package Emp_Info is
  type employee is record(First_Name   Employees.First_Name%type,
                          Last_Name    Employees.Last_Name%type,
                          Employee_Id  Employees.Employee_Id%type,
                          Is_CEO       boolean);

  procedure Get_Emp_Name(Emp_p in out Employee);
end;
```

Example 1:

- Use the *EmpinfoEmployee* class, generated by JPub, to implement the *Employee* formal parameter

```
{ ...
    EmpinfoEmployee Employee = new EmpinfoEmployee();
    Employee.setEmployeeId(new java.math.BigDecimal(100)); // Use Employee ID 100

    // Call Get_Emp_Name() with the Employee object
    OracleCallableStatement cstmt =
        (OracleCallableStatement)conn.prepareCall("call EmpInfo.Get_Emp_Name(?)");
    cstmt.setObject(1, Employee, OracleTypes.STRUCT);

    // Use "PACKAGE.TYPE NAME" as the type name
    cstmt.registerOutParameter(1, OracleTypes.STRUCT, "EMPINFO.EMPLOYEE");
    cstmt.execute();

    // Get and print the contents of the Employee object
    EmpinfoEmployee oraData =
        (EmpinfoEmployee)cstmt.getORADData(1, EmpinfoEmployee.getORADDataFactory());
    System.out.println("Employee: " + oraData.getFirstName() + " " + oraData.getLastName());
    System.out.println("Is the CEO? " + oraData.getIsceo());
}
```

Example 2: populate a collection of *table%rowtype* using a bulk collect statement, and pass the collection as an *out* parameter back to the caller

```
package EmpRow is
  type Table_of_Emp is table of Employees%Rowtype;
  procedure GetEmps(Out_Rows out Table_of_Emp);
end;
```

```
package Body EmpRow is
  procedure GetEmps(Out_Rows out Table_of_Emp) is
  begin
    select *
    bulk collect into Out_Rows
    from Employees;
  end;
end;
```

Example 2:

```
{ ...
  // Call GetEmps() to get the ARRAY of table row data objects
  CallableStatement cstmt = conn.prepareCall("call EmpRow.GetEmps(?)");

  // Use "PACKAGE.COLLECTION NAME" as the type name
  cstmt.registerOutParameter(1, OracleTypes.ARRAY, "EMPROW.TABLE_OF_EMP");
  cstmt.execute();

  // Print the Employee Table rows
  Array a = cstmt.getArray(1);
  String s = Debug.printArray ((ARRAY)a, "",
                              ((ARRAY)a).getSQLTypeName () +"( ", conn);

  System.out.println(s);
}
```

Binding PL/SQL-only datatypes into SQL statements: restrictions

- The PL/SQL-only datatypes must be declared in a package spec
- The record fields of the IBPI must be SQL datatypes
- Only IBPI, not index-by-varchar2
- Cannot bind into *insert*, *update*, *delete*, or *merge*
- Cannot bind using DBMS_Sql

Agenda

- Improved client <> PL/SQL <> SQL interoperability
- **A new security capability**
- Improved programmer usability
- Miscellaneous

Granting a role to a PL/SQL unit

- Consider this best practice
 - Give access to an application's data only via PL/SQL subprograms
 - Reinforce this by having end-user sessions authorize as a different database owner than the one that owns the application's artifacts
 - Arrange this by using definer's rights units in a single schema or a couple of schemas. Then grant Execute on these to end-users – but don't grant privileges on the tables to end-users
- This means that each unit can access very many tables because the owner of the units can

Granting a role to a PL/SQL unit

- 12.1 lets us have a fine-grained scheme where each unit with the same owner can have different privileges on the owner's tables
 - The end-user is low-privileged, just as in the old scheme
 - The units are invoker's rights, so "as is" would not allow end-users to access the data
 - The privilege for each unit is elevated for exactly and only that unit's purpose by granting a role that has the appropriate privileges to the unit. Such a role cannot be disabled.
 - The unit's owner must already have that same role (but it need not be enabled)

Granting a role to a PL/SQL unit

- This scenario lets us illustrate the idea
 - There are two users *App* and *Client*
 - There are two tables *App.t1* and *App.t2*
 - There are two IR procedures *App.Show_t1* and *App.Show_t2* to run *select* statements against the tables
 - Client has *Execute* on *App.Show_t1* and *App.Show_t2*
 - *App* creates two roles *r_Show_t1* and *r_Show_t2*
 - *App* grants *Select* on *App.t1* to *r_Show_t1* – and similar for ~2
 - *App* grants *r_Show_t1* to *App.Show_t1* – and similar for ~2

Granting a role to a PL/SQL unit

```
create procedure Show_t1 authid Current_User is
begin
  for j in (select Fact from App.t1 order by 1) loop -- Notice the schema-qualification
    ...
  end loop;
end Show_t1;
/
grant Execute on App.Show_t1 to Client
/
-- this has the side-effect of granting the role to App with Admin option
-- other non-schema object types like directories and editions behave the same
create role r_Show_t1
/
grant select on t1 to r_Show_t1
/
grant r_Show_t1 to procedure Show_t1
/
```

```
select Object_Name, Object_Type, Role
from User_Code_Role_Privs
/
```

```
.....      .....      .....
SHOW_T1      PROCEDURE   R_SHOW_T1
```

Granting a role to a PL/SQL unit

- When *Client* invokes *App.Show_t1*, then no matter what careless mistakes the programmer of the procedure might later make, its power is limited to just what the role confers.

Granting a role to a PL/SQL unit

- This new feature has no effect on static references at PL/SQL compilation time

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Improved call stack introspection

- Before 12.1, you used three functions in the *DBMS_Utility* package
 - *Format_Call_Stack()*
 - *Format_Error_Stack()*
 - *Format_Error_Backtrace()*
- New in 12.1
 - The package *UTL_Call_Stack* solves the same problem properly

Code to be introspected

```
package body Pkg is
  procedure p is
    procedure q is
      procedure r is
        procedure p is
          begin
            Print_Call_Stack();
          end p;
        begin
          p();
        end r;
      begin
        r();
      end q;
    begin
      q();
    end p;
  end Pkg;
```

Pre 12.1 Print_Call_Stack()

```
procedure Print_Call_Stack authid Definer is
begin
  DBMS_Output.Put_Line(DBMS_Utility.Format_Call_Stack());
end;
```

```
----- PL/SQL Call Stack -----
 object      line  object
 handle      number name
0x631f6e88    12  procedure USR.PRINT_CALL_STACK
0x68587700     7  package body USR.PKG
0x68587700    10  package body USR.PKG
0x68587700    13  package body USR.PKG
0x68587700    16  package body USR.PKG
0x69253ca8     1  anonymous block
```

- See bug 2769809 filed by BLLEWELL Jan 2003

12.1 Print_Call_Stack()

```
procedure Print_Call_Stack authid Definer is
  Depth pls_integer := UTL_Call_Stack.Dynamic_Depth();
begin
  for j in reverse 2..Depth loop
    DBMS_Output.Put_Line(
      (j - 1)||
      To_Char(UTL_Call_Stack.Unit_Line(j), '99')||
      UTL_Call_Stack.Concatenate_Subprogram(UTL_Call_Stack.Subprogram(j)));
  end loop;
end;
```

```
5  1  __anonymous_block
4  16  PKG.P
3  13  PKG.P.Q
2  10  PKG.P.Q.R
1   7  PKG.P.Q.R.P
```

Improved call stack introspection

- Symmetrical subprograms for error stack and backtrace
- Plus
 - Owner(Depth)
 - Current_Edition(Depth)
 - Lexical_Depth(Depth)

Whitelist

- You can declare that a particular unit may be referenced only by other listed units
- You cannot list the anonymous block and so a whitelisted unit cannot be called dynamically and cannot be invoked from outside of the database

accessible by clause

```
package Helper authid Definer accessible by (Good_Unit, Bad_Unit)
is
  procedure p;
end Helper;
```

```
package body Good_Unit is
  procedure p is
  begin
    Helper.p();
    ...
  end p;
end Good_Guy;
```

```
package body Bad_Unit is
  procedure p is
  begin
    Helper.p();
    ...
  end p;
end Bad_Guy;
```

PLS-00904: insufficient privilege to access object HELPER

Agenda

- Improved client <> PL/SQL <> SQL interoperability
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Other enhancements brought by 12.1

- You can now result-cache an invoker's rights function (the current user becomes part of the cache lookup key)
- Safe callouts (implemented via *extproc*) are faster (motivated by Oracle R Enterprise – which saw a 20x speedup)
- Edition-based redefinition can now be adopted without needing to change how objects are disposed among schemas – so no reason at all for you not to use EBR for every patch that changes only PL/SQL, views, or synonyms

Other enhancements brought by 12.1

- *pga_aggregate_limit* – exceeding, e.g. by allowing a collection to become too big, it causes a fatal error
- *DBMS_Scheduler* has new *Job_Types*:
 - *Sql_Script*
 - *Backup_Script*
- Controlled by a new use of a credential
 - encapsulates database username, password, and role – e.g. AS SYSDBA, AS SYSBACKUP

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