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Good Practices and New Perspectives in Information Systems and Technologies

WorldCIST 2024, Volume 6

Springer

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Preface

This book contains a selection of papers accepted for presentation and discussion at the 2024 World Conference on Information Systems and Technologies (WorldCIST'24). This conference had the scientific support of the Lodz University of Technology, Information and Technology Management Association (ITMA), IEEE Systems, Man, and Cybernetics Society (IEEE SMC), Iberian Association for Information Systems and Technologies (AISTI), and Global Institute for IT Management (GIIM). It took place in Lodz city, Poland, 26–28 March 2024.

The World Conference on Information Systems and Technologies (WorldCIST) is a global forum for researchers and practitioners to present and discuss recent results and innovations, current trends, professional experiences, and challenges of modern Information Systems and Technologies research, technological development, and applications. One of its main aims is to strengthen the drive toward a holistic symbiosis between academy, society, and industry. WorldCIST'23 is built on the successes of: WorldCIST'13 held at Olhão, Algarve, Portugal; WorldCIST'14 held at Funchal, Madeira, Portugal; WorldCIST'15 held at São Miguel, Azores, Portugal; WorldCIST'16 held at Recife, Pernambuco, Brazil; WorldCIST'17 held at Porto Santo, Madeira, Portugal; WorldCIST'18 held at Naples, Italy; WorldCIST'19 held at La Toja, Spain; WorldCIST'20 held at Budva, Montenegro; WorldCIST'21 held at Terceira Island, Portugal; WorldCIST'22 held at Budva, Montenegro; and WorldCIST'23, which took place at Pisa, Italy.

The Program Committee of WorldCIST'24 was composed of a multidisciplinary group of 328 experts and those who are intimately concerned with Information Systems and Technologies. They have had the responsibility for evaluating, in a 'blind review' process, the papers received for each of the main themes proposed for the conference: A) Information and Knowledge Management; B) Organizational Models and Information Systems; C) Software and Systems Modeling; D) Software Systems, Architectures, Applications and Tools; E) Multimedia Systems and Applications; F) Computer Networks, Mobility and Pervasive Systems; G) Intelligent and Decision Support Systems; H) Big Data Analytics and Applications; I) Human-Computer Interaction; J) Ethics, Computers & Security; K) Health Informatics; L) Information Technologies in Education; M) Information Technologies in Radiocommunications; and N) Technologies for Biomedical Applications.

The conference also included workshop sessions taking place in parallel with the conference ones. Workshop sessions covered themes such as: ICT for Auditing & Accounting; Open Learning and Inclusive Education Through Information and Communication Technology; Digital Marketing and Communication, Technologies, and Applications; Advances in Deep Learning Methods and Evolutionary Computing for Health Care; Data Mining and Machine Learning in Smart Cities: The role of the technologies in the research of the migrations; Artificial Intelligence Models and Artifacts for Business Intelligence Applications; AI in Education; Environmental data analytics; Forest-Inspired

Computational Intelligence Methods and Applications; Railway Operations, Modeling and Safety; Technology Management in the Electrical Generation Industry: Capacity Building through Knowledge, Resources and Networks; Data Privacy and Protection in Modern Technologies; Strategies and Challenges in Modern NLP: From Argumentation to Ethical Deployment; and Enabling Software Engineering Practices Via Last Development Trends.

WorldCIST'24 and its workshops received about 400 contributions from 47 countries around the world. The papers accepted for oral presentation and discussion at the conference are published by Springer (this book) in four volumes and will be submitted for indexing by WoS, Scopus, EI-Compendex, DBLP, and/or Google Scholar, among others. Extended versions of selected best papers will be published in special or regular issues of leading and relevant journals, mainly JCR/SCI/SSCI and Scopus/EI-Compendex indexed journals.

We acknowledge all of those that contributed to the staging of WorldCIST'24 (authors, committees, workshop organizers, and sponsors). We deeply appreciate their involvement and support that was crucial for the success of WorldCIST'24.

March 2024

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Performance Analysis of the Data Aggregation in the Oracle Database

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Abstract. The amount of data for processing and evaluation is growing enormously. Temporal database monitoring object state evolution is an inseparable part of the analytics. Oracle Database provides a robust environment for treating complex datasets by offering indexing, partitioning, and other enhancements allowing to create scalable systems. Aggregate and analytic functions in SQL are associated with the data groups or partitions, characterizing the data set over which individual functions are evaluated. Commonly, groups are not defined only by the attributes, instead, function results and transformations form the groups. This paper deals with the performance of the group definition associated with the function calls, referenced by the pure definition or aliases, introduced in Oracle 23c.

Keywords: data analytics · aggregate functions · group definition · expression reference · column alias

1 Introduction

Data to be handled has enormously risen over the decades. The structure of the data became more complex, requiring storing the whole data evolution in the temporal database [9]. Database systems form the data layer holding the data, which are then evaluated by the aggregate and analytic functions. Relational databases are still most often used and widespread, because of the strict data structures, references, and integrity [5]. Database transactions ensure the data to be loaded pass the requirements defined by the data model, as well as all the constraints defined for the data [6]. Thus, the data are correct, ensured by consistency and integrity. Online transaction systems are mostly used for operational data, which are then grouped, evaluated, and shifted to warehouses for complex data analytics [5, 7, 12]. Autonomous data warehouses benefit from the ability to be deployed in the Oracle Cloud Infrastructure [1, 7, 12], so the whole maintenance and administration is left to the cloud vendor. Furthermore, it offers many enhancements allowing to optimize the data access by using auto-indexing features, dynamic partitioning, and scalability options.

Advanced analytics is required almost in every sphere. Intelligent information systems require temporal data to be evaluated by monitoring the changes [2, 3]. Intelligent

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decision-making systems [4] are based on complex data offering to predict the evolution using machine learning methods and AI [10, 11]. There are many tools for data analytics getting reports, charts, correlations, tables, or any other forms of the result representation. PowerBI, R, and Oracle Analytics are the most popular tools allowing to make reports and outputs easily using wizards, so the process does not need to be done by professionals. Whatever system is used, there are always data behind them to be acquired, processed, evaluated, and subsequently represented in the form defined by the user. Data and their representations are therefore critical.

This paper deals with the analytical and aggregate functions by defining the data set ranges – groups of data, which are processed by those functions. Well, typically, a group is not defined of only attributes, but also expressions and functions are used. In the past, it was impossible to use column aliases in the Where clause, as well as group definitions (Group by clause), forcing the system to process the function multiple times, even by calculating the output of the function several times, even with the same parameters, degrading the performance of the whole system.

Oracle Database 23c [14] offers the function result alias to be placed in almost all clauses of the SQL Select statement. Thanks to that, it can be directly referred to the function usage. This paper evaluates the impacts of using aliases in the Group by clause forming the groups for the data aggregations and analytics. Please note, that this paper focuses exclusively on the database system Oracle. The goal is not to compare individual implementations and features of multiple database systems and to provide a universal solution applicable in any environment. Instead, only the Oracle database is taken into consideration for multiple reasons. Oracle Database is the most complex and most powerful database type. It offers autonomous database types, so the administration, patching, and optimization are strongly reduced. Finally, this paper forms the output of the Erasmus + project EverGreen emphasizing green data analytics [13], in which Oracle Analytics Cloud forms the infrastructure.

2 SQL Statement Execution

To process an SQL statement and produce the results, the database system must perform the following steps:

- Parsing SQL statement
- Validating SQL statement
- Generating various execution plans and selecting the most suitable, based on the data statistics and heuristics.
- Executing the statement by using the selected access plan.

Besides, the database system collects many additional statistics to perform optimization and provides recommendations for using additional features, optimization, tuning, and extended numbers of statistics. The execution plan is identified by the hash value of the original statement and temporarily stored in the instance memory, so if it is executed multiple times, it is not necessary to process all the above steps, just the pre-calculated plan is taken.

Select statements can consist of multiple clauses defining the data set and processing, which significantly influence the processing steps. The following clauses can be used, Select and From clauses are mandatory [5]:

- *Select* clause defining the list of values produced in the result set.
- *From* clause defining the data sources and methods for interconnecting them.
- *Where* clause specifying conditions limiting the data set.
- *Group by* clause defining data groups and splits used for the aggregate and analytic function calculations.
- *Having* clause for specifying conditions based on aggregate functions and analytics (window functions).
- *Order by* clause offering to sort the result data set. Generally, the data are not sorted at all, defined by the order in which individual results were obtained
- *Limit* (*Fetch*) clause allowing to get only a portion of data, instead of the full result set, based on the evaluation and conditions.

Figure 1 shows the process of the execution and statement evaluation. First, source tables are extracted, joined, and merged, followed by applying conditions specified in the Where clause attempting to reduce the amount of data for further steps. Data are filtered, so it´s time to group by the data, optionally reduced by the Having clause specifying conditions based on the aggregate functions and analytics. Then, the Select clause is treated, and enhanced by the column, expression or function call aliases. Finally, the pre-prepared result set is ordered, or limit & offset can be applied.

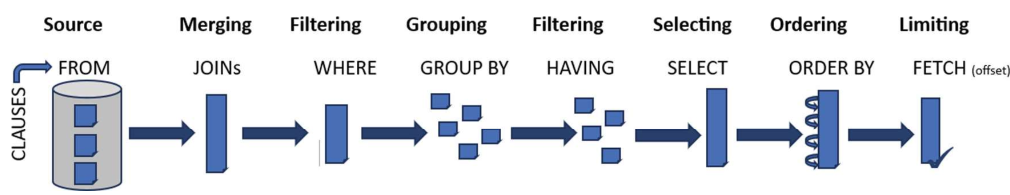

Fig. 1. SQL query execution order

The order of individual steps is significant. It is always preferred to reduce the cardinality as much as possible. Thus, if there are multiple conditions, the order of their execution is defined by the reduction factor - the ratio between the original input and the expected output from the point of view of the data amount. Aliases are defined in the Select clause. As evident, Where conditions and group definitions are considered before attempting to process Select clause. Consequently, SQL norm does not allow to use column, expression, and function aliases in the Group by and Where clauses of the same Select statements. The limiting factor of the performance is defined in the next section.

3 Problem

Aliases defined in the Select clause are primarily used for specifying column references in the provided output. As stated, they cannot be used in other clauses of the same statement, because they are not known at those stages, except for the Order by clause, which is evaluated at the end of the processing, in which the data set itself and the contained data in it are clear. In principle, the Group by clause must state all data attributes from the Select statement clause, except of the aggregate function. Additional data attributes can be stated, mostly determined by the primary keys. Furthermore, function calls can be present in Select, Where, and Group by clause (Order by clause can be also enhanced by the function calls, but it is not significant from the data access processing point of view). By digging deeper into SQL tuning and performance accelerations, the impossibility of using function call aliases brings additional costs and processing time. One function is evaluated multiple times. Even caching the function results does not provide sufficient power, while the function must be explicitly stated as deterministic, and obtaining the result from the memory cache also requires some time and resources. Figure 2 shows the problem by determining one function in three positions. The same function is called in multiple positions and thus evaluated multiple times. Furthermore, calling the PL/SQL function requires a context switch. Even optimization of the function for the SQL calls (by using User Defined Function (UDF) pragma) does not provide relevant improvement.

```
select FUNC(params) as function_result, agg_function
 from table_list+joining
   where FUNC(params) > limit_val
     group by FUNC(params)
       [order by FUNC(params)];
```

Fig. 2. Function calls in a Select statement

In conclusion, the inability to use function call aliases impact and limit the performance of the query. In the current standard, aliases cannot be used in the clauses part of the same statement, as specified. Proposed solutions, techniques, and workarounds, compared to the Oracle 23c enhancement are discussed in the next section.

4 Proposed Solutions and Enhancements

In this paper, three new solutions and enhancements are discussed, denoted by the SOL1-SOL3 display marks. The reference solution (marked as REF) uses the original approach defined by the SQL norm, which does not use aliases, and a particular function is listed in each clause separately.

- **REF** – Original solution calling a function multiple times. The improvement of this reference method lies in the optimization of the called method for SQL language usage through the UDF pragma usage (REF_UDF).
- **SOL1** - Nested statement – This solution is based on calculating the function results in the first phase by forming a nested query. Then, the function result is called in the outer query, referred to by the aliases specified in the inner query. Thanks to that, a particular function is called only once for each row/group and stored temporarily in the inline view.

- **SOL2** - Pre-processing using dynamic view – With clause extensions have been introduced in Oracle Database 12c Release allowing to use of subquery factoring clause enhancements, like PRAGMA UDF, deterministic hint, and subquery caching.
- **SOL3** - Direct usage of the alias specified in the Select clause is offered in the Oracle Database 23c. Groups can be enhanced by the function calls defined in the same statement and referenced by the aliases. The extended Select statement evaluation process is depicted in Fig. 3.

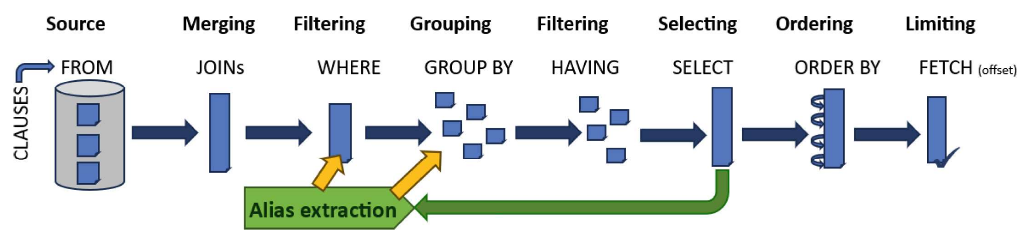

Fig. 3. Function calls (alias) extraction module

The next section deals with the computational study using environmental data impact analysis.

5 Computational Study

The computational study was run on the server with the following parameters:

- Processing unit: AMD Ryzen 5 PRO 5650U, 2.30 GHz, Radeon Graphics
- Memory: Kingston, DDR4 type, 2x 32 GB, 3200 MHz, CL20
- Storage: 2 TB, NVMe disc type, PCIe Gen3 x 4, 3500 MB/s for read/write operations
- Operating system: Windows Server 2022, x64
- Database system: Oracle Database 23c, release bundle Oracle 23c Free, Developer Release Version 23.2.0.0.0.

European region flight monitoring data set was used to determine environmental data by treating planned and real routes of the airplanes, compared to the optimal plans reducing the environmental impacts and emissions [8]. Flight companies attempt to reduce costs by using regions, which are cheaper and avoid expensive territories. This results in longer journeys, greater fuel consumption, and thus greater consequences for the environment and climate. For each flight, location data were monitored, delimited by the 50 parameters monitoring the flight and temporal assignment to the flight information regions (FIR). These provided values were compared to the planned routes and calculated journey optimized for reducing environmental burdens. The whole data set consisted of 5 million rows for the positional data and 1000 of rows for the FIR assignment. The structural data example of the FIR assignment is in Fig. 4. Each flight is identified by the ECTRL_ID. Individual FIR assignments (identified by the AUA_ID) are sequentially referenced (Sequence_number) over the timeline (Entry_time, Exit_time).

```
"ECTRL ID","Sequence Number","AUA ID","Entry Time","Exit Time"
"186858226","1","EGGXOCA","01-06-2015 04:55:00","01-06-2015 05:57:51"
"186858226","2","EISNCTA","01-06-2015 05:57:51","01-06-2015 06:28:00"
"186858226","3","EGTTCTA","01-06-2015 06:28:00","01-06-2015 07:00:44"
"186858226","4","EGTTTCTA","01-06-2015 07:00:44","01-06-2015 07:11:45"
"186858226","5","EGTTICTA","01-06-2015 07:11:45","01-06-2015 07:15:55"
```

Fig. 4. FIR assignment data [8]

The computational study deals with the costs of the processing and processing time.

The evaluation study is divided into two parts. In the first experiment, the groups are defined by the pure attributes, however, they are referred to by the aliases to highlight the additional workload of extracting and translating aliases into the original definition. The aim is to calculate the flight efficiency, delimited by the FIR references comparing optimal and real routes, while external circumstances like weather are taken into consideration. The efficiency is calculated for each flight separately, so the group is formed by the flight identifiers – ECTRL_ID attribute. Table 1 shows the results.

Table 1. Results considering attribute alias

	REF	SOL1	SOL2	SOL3
Costs	3660 (24% CPU)			
Processing time (ss. ff)	23.25	27.33	21.78	18.24

The worst solution was obtained by the nested query, it is caused by the execution plan calculation necessity. By transforming the nested query to the dynamic view, a 20.31% improvement was detected, caused by the optimization, pre-fetching, and data optimization, offered by the parallelism options. Using aliases references lowers the processing time demands to 18.24 s, which refers to a 21.55% improvement compared to the REF. Furthermore, it does not require any query nesting. Compared to SOL1, it provides a 33.26% improvement and 16.25% for SOL2. Figure 5 shows the processing time demand results graphically.

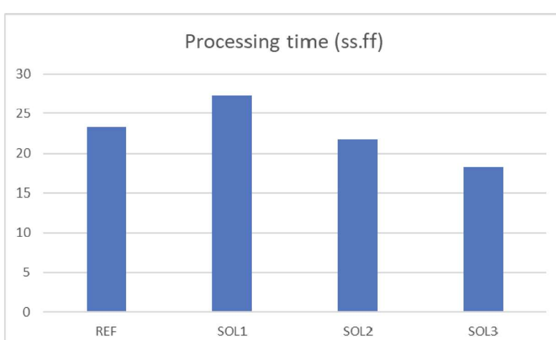

Fig. 5. Results – group definition by attributes

The second experiment deals with the function calls, which are to be calculated only once and consecutively referenced by the internal views, nested query, or pointed by the function result aliases. In this case, efficiency is calculated across all flights together. The month and year extractions are considered as the forming values for the groups. Each flight refers to the takeoff, as long as the flight is at the border of the months. Standard function to_char, bundled in the Standard package is used, optimized for the SQL calls. The main advantage of that function is that it can treat multiple date and time elements in one call, compared to the extract function, which is also available, however, such a function can proceed only one temporal element, consequencing in the necessity to call it twice – once for getting the month and once for year element. Table 2 shows the results. The first part deals with the to_char function usage, and the second part highlights extract function usage.

Table 2. Results considering function references

	REF	SOL1	SOL2	SOL3	Used function
Costs	3660 (24% CPU)				to_char
Processing time (ss. ff)	23.05	26.12	20.46	17.01	
Costs	3660 (24% CPU)				extract
Processing time (ss. ff)	23.67	26.41	21.03	16.46	

The number of functions defining the groups does not play a significant role. On the one hand, we have the to_char function, which processes both elements in one call, but it results in a more complex output in string format. Opposite, there is an extract function, which needs to be called twice, once for the month and the second time for the year components. Thus, the results are indeed two values, but in numerical format, which reduces the cost of further processing. So, summarizing, in both cases, the achieved results are almost identical from the time requirements point of view. The number of groups also impacts the performance. Namely, too many groups can cause tiny data frames and a small amount of data. Although the groups can be processed in parallel, it is impossible to establish separate threads for each group, if the number is too high. Reflecting on the results, the function alias is the most beneficial and reduces the processing time demands by 26.20% for the to_char function and 30.46% for the extract function (referencing REF). Similarly to the previous results obtained in experiment 1, the most demanding solution is based on query nesting (SOL1) (Fig. 6).

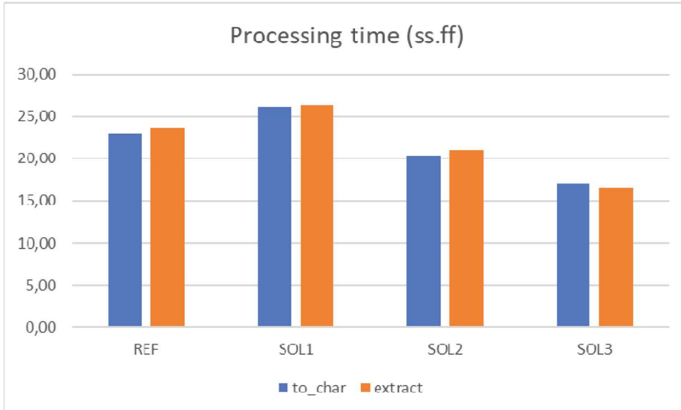

Fig. 6. Results – group definition by functions

6 Results and Conclusions

Data aggregation is a core element and prerequisite of the analysis by shifting the data from the transaction-oriented databases into data warehouses, marts, lakes, etc. To calculate aggregated data, it is necessary to form the groups, for which the aggregate functions are calculated, followed by the analytic function calls defined by the partitions. The groups can be formed by an unlimited number of attributes, expressions, and functions. Generally, function calls can be present in any clause of the Select statement. By emphasizing the execution plan and order of individual clause processing, it is evident that the Where clause, Data set merging, and Group by definitions are processed before evaluating the Select clause, which can consist of the expressions and function calls, enhanced by the aliases. In the past, column aliases were mostly intended for the definition and naming of the attributes of the output set, for hiding the definition and easier expression of the results. Users had to be aware of the aliases and their visibility across the definition, forcing the system to nest queries to make them more complicated, or to refer to the same expressions multiple times. If something had to be changed in the definition, it had to be applied in multiple places, which could potentially introduce errors. Later, the queries became more and more complex, so they were necessary for consecutive references in the outer queries. Data analytics is a typical example of defining complex queries. Oracle Database 23c brought significant change in terms of alias management. Namely, individual aliases are identified and extracted in the first phase making them referencable in any clause of the statement. It brings not only simplification of the code, better readability, but as shown in this paper, it also brings improvement of performance characteristics and reduction of costs and processing time.

In this paper, four solutions are referenced and compared. REF solution is a reference, which does not use any alias to focus on the impacts. Usage of the nested query brings additional demands, caused by the result set fetching and loading necessity for the inner query. This fact can have a significant impact on the instance memory, whereas the data need to be placed there, for the consecutive processing by the outer queries. If the result set is huge and does not fit the available instance memory, the problem is even huge, because of the disc-swapping necessity. For the discussed environment, nested querying processing time demands are higher by 4.08 s, which expresses an additional

17.55%. Vice versa, using a function alias lowers the demands compared to the referenced (REF) solution by 5.01 s, just because of the function reference extraction and reducing content switches. Namely, even if the function call parameters differ, they can always be processed in bulk, instead of separating them for each statement clause separately. Pre-calculation of the function results is also appropriate because the dynamic view already contains the results of the function calls, which are treated as stored results. Thus, in the data analysis itself, the functions are no longer called, they only use the calculated results in the previous phase.

The limitation of the discussed alias extraction module is its strict interconnection with the Select statement and reference to the steps of the execution plan. Therefore, individual clauses can be executed only if there is no not yet processed alias. Otherwise, the processing has to wait.

In further research, we will focus on our own extended extraction methods of columns, expressions, and functions aliases and their placement in a collection defined in the form of an index, instead of the flat structure, that is currently used. Thanks to that, complex queries will benefit, because the validity of the alias will be for the entire processing, not only a specific block and its nested subqueries.

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