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Implementation of Privacy Preservation of N-D Algorithms for Online Analytical Processing

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ABSTRACT: Online analytical processing (OLAP) is one of the most popular decision support and knowledge discovery techniques in business-intelligence systems.There are issues related to the protection of private information in Online Analytical Processing (OLAP) systems, where a major privacy concern is the adversarial inference of private information from OLAP query answers. This inference problem cannot be fully addressed by access control and data sanitization techniques.

KEYWORDS: preservation, analytical, problem, privacy.

I. INTRODUCTION

In computing, **online analytical processing**, or **OLAP** is one of the most popular decision support and knowledge discovery techniques in business-intelligence systems. It is an approach to swiftly answer multi-dimensional analytical queries. OLAP is part of the broader category of business intelligence, which also encompasses relational reporting and data mining.

We address issues related to the protection of private information in Online Analytical Processing (OLAP) systems, where a major privacy concern is the adversarial inference of private information from OLAP query answers. Most previous work on privacy preserving OLAP focuses on a single aggregate function and/or addresses only exact disclosure, which eliminates from consideration an important class of privacy breaches where partial information, but not exact values, of private data is disclosed (i.e., partial disclosure). We address privacy protection against both exact and partial disclosure in OLAP systems with mixed aggregate functions.

Typical applications of OLAP include business reporting for sales, marketing, management reporting, business process management, budgeting and forecasting, financial reporting and similar areas, with new applications coming up, such as agriculture. The term *OLAP* was created as a slight modification of the traditional database term OLTP (Online Transaction Processing).

In particular, we propose an information-theoretic inference control approach that supports a combination of common according to its communication aggregate functions (e.g., COUNT, SUM, MIN, MAX, and MEDIAN) and guarantees the level of privacy disclosure not to exceed thresholds predetermined by the data owners. We demonstrate that our approach is efficient and can be implemented in existing OLAP systems with little modification. It also satisfies the simulate able auditing model and leaks no private information through query rejections.

Through performance analysis, we show that compared with previous approaches, our approach provides more effective privacy protection while maintaining a higher level of query-answer availability.

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II. WHY PRIVACY PRESERVATION IS REQUIRED FOR OLAP?

The data warehouse server holds private data, and is supposed to answer OLAP queries issued by users on the multidimensional aggregates of private data. However, it is a challenge to enable OLAP on private data without violating the data owners' privacy.

A user may not have the right to access all individual data points in the data warehouse, but might be allowed to issue OLAP queries on the aggregates of data for which it has no right to access.

In an OLAP system, a privacy breach occurs if a user can infer certain information about a private data point for which it has no right to access from the query answers it receives as well as the data that it has the right to access. Such privacy breach is referred to as the **inference problem**.

Example:

In a hospital system, the accounting department (as a user) can access each patient's financial data, but not the patients' medical records.
Nonetheless, the accounting department may query aggregate information related to the medical records, such as the total expense for patients with Alzheimer's disease.

III. INFERENCE PROBLEM

In an OLAP system, a **privacy breach** occurs if a user can infer certain information about a private data point for which it has no right to access from the query answers it receives as well as the data that it has the right to access.

Such privacy breach is referred to as the **inference problem.** If owner of the cube makes Attribute Y of collection 1 as sensitive cell, then users do not have access to that sensitive cell, but they can request aggregate queries.

Suppose a user asks 2 queries:

1. What is the total no. of items in collection1?
2. What is the value of attribute X in collection 1?

Answer 1. 47
Answer 2. 7

Inference: The no. of items of Y in collection1 is 47-7=40.

	April	May	June	July	Sum
Book	10	12	15	7	$q_5 = 47$
CD	20	23	27	N/A	$q_6 = 70$
DVD	23	35	16	36	$q_7 = 110$
Game	N/A	25	30	14	$q_8 = 69$
Sum	$q_1 = 53$	$q_2 = 95$	$q_3 = 88$	$q_4 = 57$	

Example of Inference Problem

So the user is able to get the value of sensitive cell for which it has no access by requesting aggregate queries on the data.
So "**Privacy Breaching**" as user should not get value of sensitive cell but here it can be inferred.

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IV. OLAP SYSTEM MODEL

Consider OLAP as a system where the data warehouse server stores data in an n-dimensional data cube, in order to support aggregate queries on an attribute-of-interest over selected data.
We refer to such attribute-of-interest as the **measure attribute**. Besides the measure attribute, there are n **dimension attributes**, each of which is represented by a dimension of the data cube.
Each (base) cell of the data cube is the value of the measure attribute for the corresponding value combination of dimension attributes.

	April	May	June	July	Sum
Book	10	Known	15	Known	$q_5 = 25$
CD	20	Known	27	Known	$q_6 = 47$
DVD	Known	35	16	36	$q_7 = 87$
Game	Known	25	Known	14	$q_8 = 39$
Sum	$q_1 = 30$	$q_2 = 60$	$q_3 = 58$	$q_4 = 50$	

For example
Table shows a two-dimensional data cube with a **measure attribute** of **sales** and two **dimension attributes** of **product** and **time**.

Each cell of the data cube in Table is the sales amount (i.e., measure attribute) of a product (e.g., Book) in a month (e.g., April). As in real cases, some cells in the data cube can be missing or not applicable.

V. INFERENCE CONTROL

There are two types of methods that have been proposed to prevent inference problems from happening in OLAP systems:

1. Inference Control
2. Input/output perturbation.

1. Inference control:
In the inference control approach, after receiving a query from a user, the data warehouse server determines whether answering the query may lead to an inference problem, and then either rejects the query or answers it precisely.

2. Input/output Perturbation:
The input/output perturbation approach either perturbs (input) data stored in the data warehouse server with random noise and answers every query with estimation, or adds random noise to the (output) query answers in order to preserve privacy
But for decision making precise or exact answer is required, therefore inference control is better way for privacy information.

VI. IMPLEMENTATION AND RESULTS

1. INFERENCE CONTROL ALGORITHM (for n-d Arbitrary Distribution

Require: h-dimensional query q on sub-cube ($a_1 \ldots a_{n-h}$, ALL… ALL), $l_o = 0$.
1: {When a query q is received.}
2: if function of q is MIN-like then

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3: $l_0 \leftarrow f_{max}$ (q, |q|)/H(x).
4: else if function of q is SUM-like then
5: for i← 1 to n - h do
6: $\Theta_i \leftarrow (a_1, a_{i-1}, ALL, a_{i+1}. . . a_{n-h}, ALL, . . . , ALL)$.
7: Find $T_i \leftarrow \{\Theta' | \Theta' \epsilon\ \Theta_k^s, \Theta'$ is subset of $\Theta_i\}$
8: $\mu \leftarrow \min(\min\{\mu k\ (\Theta') | \Theta' \epsilon\ T_i\}, d_i + d_{n-h+1} + d_{n-h+2} + \ldots\ldots + d_n - |T_i|, d_{i/2}, d_{n-h+1/2}, \ldots\ldots d_{n/2})$.
9: t← max(the maximum integer that satisfies $\sum \{\sigma_k(\Theta')\ (h-1/h)\ (1/h)\ |\Theta' \in T_i\} \geq t\ (d_i-\mu) + (t)\ (\mu-1)(d_1+d_2+\ldots.. + d_h - h\ (t)), 0)$ assuming 0 , (0) =1.
10: $n_0 \leftarrow |q| - r_k(q) - t$.
11: $l_0 \leftarrow \max(l_0, (1 - l_p)x\ (f_{max}(q, n_0) - f_{min}(q, n_0 - 1))/H(x))$
12: end for
13: end if
14: if $l_p + l_0 \geq \min(l_k, l(q))$ then
15: return Ø. {Reject query q}
16: else
17: if function of q is SUM-like then
18: $\mu_k(\Theta) \leftarrow \mu(\Theta)$
19: $T \leftarrow \{\Theta' | \Theta' \epsilon\ \Theta_k^s, \Theta' \subseteq \Theta\}$.
20: $\sigma_k(\Theta) \leftarrow \sigma(\Theta) - \sum_{\Theta' \in T}\ \sigma_k(\Theta')$
21: $\Theta_k^s \leftarrow \Theta_k^s\ U\ (\Theta, \mu_k(\Theta), \sigma_k(\Theta))$
22: end if
23: lk← min $(l_k, l(q))$.
24: $l_p \leftarrow l_p + l_0$.
25: return q. {Answer query q correctly}
26: end if

2. IMPLEMENTATION

Let $r_k(q)$ be the number of cells in q that belong to G_k (i.e., known by C_k as preknowledge).

|q| is the number of all cells in q.

Let Q_k^s be the set of SUM-like queries in the query history Qk, and $|Q_k^s|$ be the number of queries in Q_k^s

Let σ_k be the number of preknown cells covered by at least one query in Q_k^s.

That is, $\sigma_k = |\{x | x \in G_k, 3q \in Q_k^s$ such that x ϵq$\}|$.

Let μ_k be the minimum number of sensitive cells covered by a SUM-like query in the query history:

$$\mu_k = \min(|q| - r_k(q)) \quad q: q \in Q_k^s$$

In the algorithm, we use l_p denote the current upper-bound estimate on $l_{max}(Q_k)$.

When $Q_k = \emptyset$, the initial values of the parameters are μ_k =infinity, $\sigma_k = 0$, and $l_p = 0$.

With the algorithm, when a new query q is received, the data warehouse server computes an upper-bound estimate on $l_{max}(q | Q_k)$ as l_0, and answers the query if and only if $l_p + l_o$ is less than the owner-specified threshold l.

If $l_p + l_o < l$ (i.e., query answer q can be issued to user C_k), then the data warehouse server updates the values of μ_k, σ_k, $|Q_k^s|$, and l_p in Steps 12-17.

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As we can see, only l_p needs to be updated for MIN-like queries while all four parameters are updated for SUM-like ones.
In the starting we are using "Analytical Workspace Manager" to analyze the data cube and to map the dimensions of data cube on corresponding tables of database. Then, these tables are used in program for query evaluation and query answering.

Here, instead of maintaining μ_k and σ_k values for each user, we are maintaining μ_k and σ_k values for each sub cube of query history.

3. ASSUMPTIONS

1) The algorithm is for n-dimensions.
2) The query must be entered in a special manner
   a) After every word space has to be given.
   b) First word of the query belongs to the aggregate function
   c) All the words except the first one are names of dimensions.
   d) Each query gives the value of measure attribute. e.g.- sum april
3) Our implementation gives whether the query must be answered or not.

Modification made in the algorithm

In line 9 of algorithm B (query evaluation of SUM like queries) we have modified the evaluation of 't' such that
9. t← the maximum integer that satisfies $\sum \{\sigma_k (\Theta') (h-1) / h (1/h) |\Theta' \in T_i\} \geq t (d_i-\mu) + (t) (\mu-1) (d_1+d_2+\ldots. +d_h - h (t)$ assuming 0 (0) =1.

9.1. $t_{prev} = t$;

9.2. $t_m = \max(t_{prev}, 0)$;

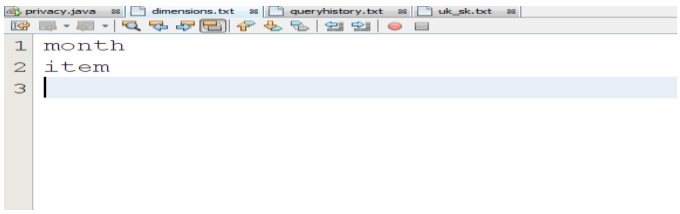
where, t_{prev} is t as calculated in the paper. t_m is modified t.

4. INITIAL SETUP AND RESULTS

1. Sample Database used to show results for Algorithm.

[Fig.4.1: Database details]

2.It is maintaining 3 text files-
   a) "dimensions.txt"- It is a text file containing the names of tables (dimensions) to be accessed by our program.



[Fig.4.2: Dimensions details]

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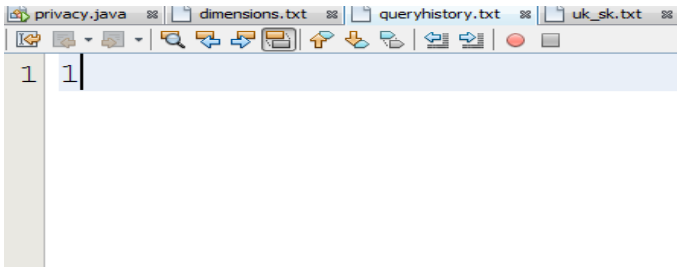
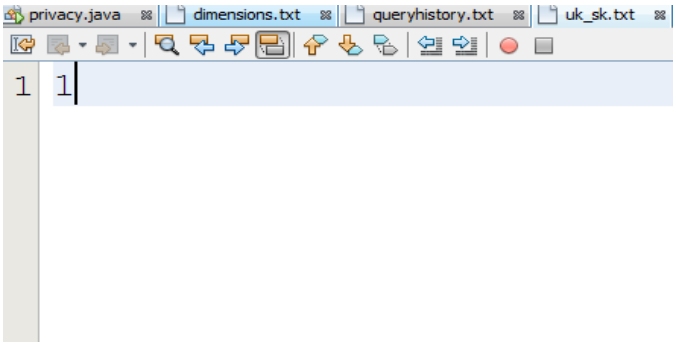
b) "queryhistory.txt"- It is a text file containing the sub cubes of answered queries



[Fig.4.3: Query History Details]

c) "u_k_s_k.txt"- It is a text file containing corresponding μ_k,σ_k and l_p values.



[Fig.4.4 : u_k_s_k details]

3. Program Details:

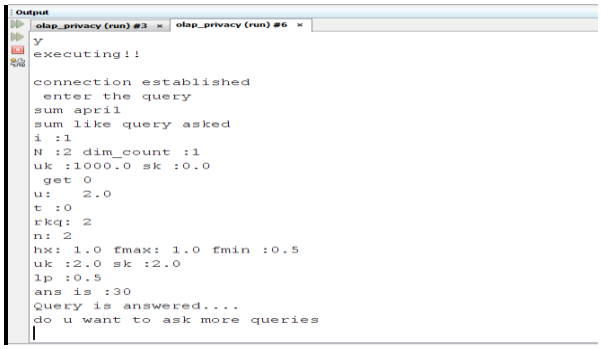
a) As soon as the program starts, db_data_retrival() establishes connection with database and get_queryinfo() takes query from the user and classifies it into "MIN like" or "SUM like" query.

b) transfer2() and transfer() functions transfer corresponding μ_k,σ_k and l_p values of each subcube and subcube history into related data structures.

c) Depending on type of query, query_evaluate() evaluates the query and answers it if l_o+$_p$p< l where l_o = information accessed by the query, l_p=information accessed earlier l=level at which privacy breach takes place.

4.

a) Query asked: sum april
Output: Query is answered



[Fig.4.5: Query Result]

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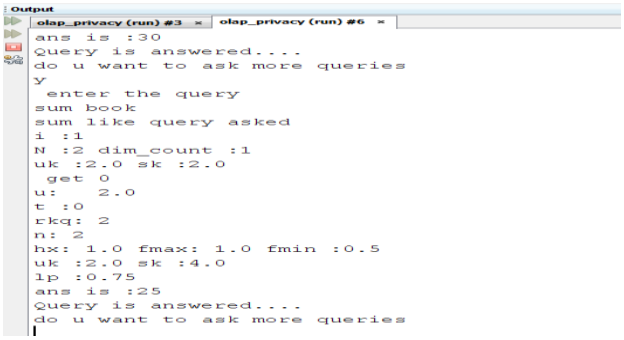
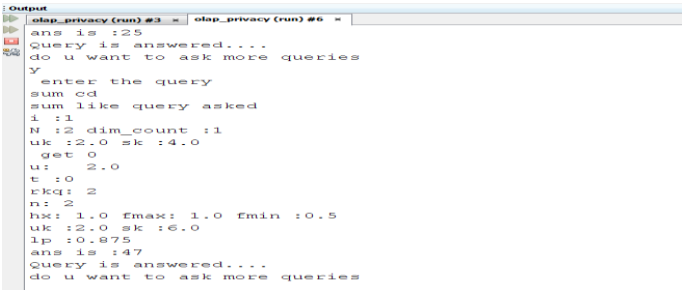
b) Query asked: sum book
Output: Query is answered



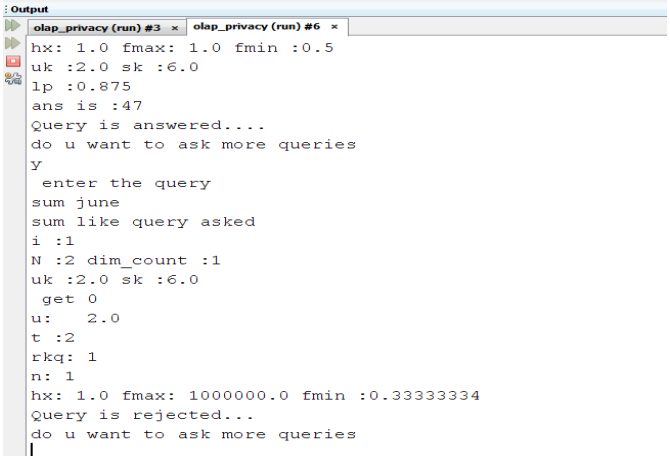
[Fig.4.6: Query Result]

c) Query asked: sum cd
Output: Query is answered.



[Fig.4.7: Query Result]

d) Query asked: sum june
Output: Query is rejected



[Fig.4.8: Query Result]

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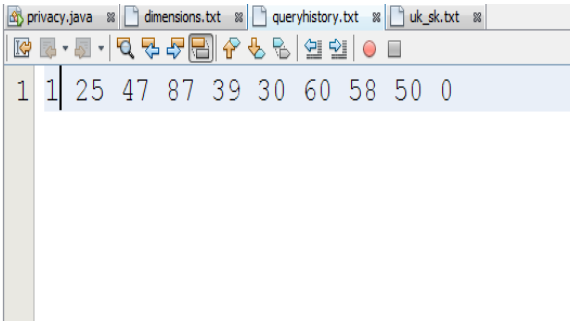
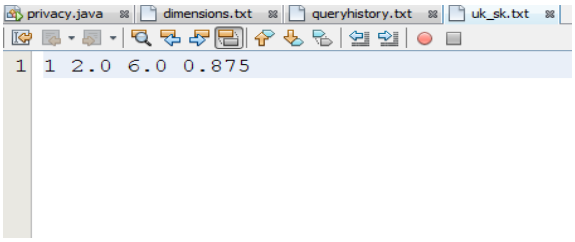
5. Updated text files are
   a) "Queryhistory.txt"- containing the subcube of answered queries.



[Fig.4.9 : Query History]

   b) "u_k_s_k.txt" –containing the corresponding μ_k,σ_k and l_p values of answered query's subcube



[Fig.4.10: u_k_s_k Details]

V. CONCLUSION

For implementing Inference Control Algorithm (A Generic n-d Algorithm), we have used "Analytical Workspace Manager" for building, analysing and mapping values. We have used Oracle 11g for database and mapped values on database tables with the help of "Analytical Workspace Manager".

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BIOGRAPHY

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