Importance of OLAP in Business Intelligence

Debashis Rout
The Institute of Technology Blanchardstown

Abstract
The key element to success is the effective decision making through accurate information. The data is neither good nor useful if it does not provide accurate information. However, intelligent information is always required for analyzing data properly. Business intelligence is all about decisions made effectively with accurate information in timely manner. This thesis will provide a brief on how OLAP has importance in Business intelligence.
Keywords: *Business Intelligence (BI), Data Warehousing (DW), Extract-Transform-Load (ETL), On-Line Analytical Processing (OLAP), On-Line Transactional Processing (OLTP)*

Introduction

Data will not be good if we cannot get intelligent information from the same. Hence for proper analysis of data, intelligence is required. Due to the innovation of technology a new concept developed, named multi-dimensional data. This data replaced relational data through a conceptualizing process which brings the flavor of online analytical processing (OLAP). This OLAP tool helps BI system to look data in a different way rather than just summarizing and aggregating data. In this competitive world, day by day volume of transaction is increasing in every organization. Earlier SQL queries helped to generate various reports or normal BI tool could help. But now in today's business world, when millions of records are stored on daily basis into multiple databases which has made the process time much crucial factor.

Any organization will be benefited from appropriate, accurate, and latest information while making key decisions. However, there arise many business questions, for example:

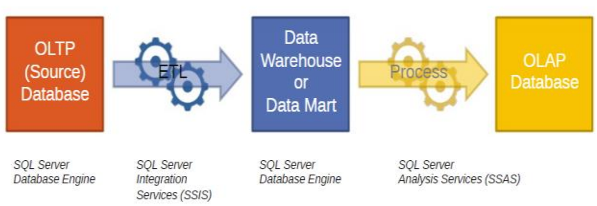
- How many new credit card customers joined in our bank during last month?
- What is the daily deposit in specific region?
- How many accounts closed during 2nd quarter?
- How many high risk customers closed their account during last month?
- How many personal Loan customers paid their last instalment during last month?
- What are the top five branches in term of deposits, no. of account, safe box, Personal loan and credit card earning?

For these simple questions, it is too difficult to execute multiple complex queries to get the results within few minutes. Hence, a BI system, having powerful techniques for processing, analyzing, and reporting on organization data, is required. It is achievable through historical data instead of real time data.

In the recent years, the Business Intelligence systems help people from different segments for making more positive business decisions to analyze information that is accumulated through company's huge transaction data from day-to-day operations (Gorbach, Berger and Melomed, 2009). Today most of business organizations use an online transaction processing (OLTP) system. This OLTP system provides facility to execute a large number of small transactions and reliable access to data stored in the result of the transactions. The volume of the data stored and processed for a single day by an OLTP system might be of several gigabytes. This volume may increase, over the time, up to the total volume of hundreds of terabytes. It would be difficult to store such large data but this challenge cannot be ignored as apart from being complex, the data is valuable for organization at the same time. This data can be very helpful to take any successful strategic decisions, as well as helpful to improve regular decision making.

Due to large volume, OLTP systems are not suitable for analyzing such data. A new concept which can provide more reliable and speedy access for analyzing a very large volume of data is called as online analytical processing (OLAP). OLAP helps senior management, executives, and data analysts while providing deeper study of data using fast, interactive, and consistent interfaces. For example, with OLAP solution, we can request information about company laptop sales in India over a period of years, then drill down to the sales in January, calculate year-to-date sales or compare sales figures with those for the same products sold in March, and then see a comparison of laptop sales in India in the same time period.

Online Analytical Processing (OLAP) databases help interactive analysis through a large volume of data as a part of business-intelligence queries. OLAP is a database technology that has been optimized for querying and reporting, instead of processing transactions (Support.office.com, 2016). The below diagram provide the relation between OLTP and OLAP.



On-line Transaction Processing (OLTP)

OLTP (On-line Transaction Processing) deals with operational data, which is data involved in the operation of a particular system and it is characterized by a large number of short on-line transactions like creation of new account, customer information update, PIN assignment, ATM transactions etc. The main emphasis of OLTP systems is faster processing, maintaining data integration in multi-access environments and an effectiveness measured by number of transactions per second. Also, in an OLTP system; the data is frequently updated and queried, to prevent data redundancy and prevent update anomalies; the database tables are normalized, which makes the writing of operation in the database tables more efficient.

Example: In a banking system, customer withdraw amount through an ATM, online money transfer, online household bill payment, Time deposit purchase etc. Then account Number, ATM PIN Number, Amount withdrawn/deposited by customer are few example of operational data attributes.

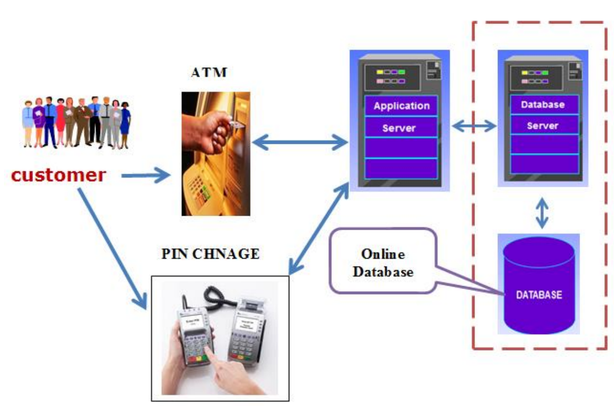


Figure 1-1: Online Transaction data – OLTP

It is true, the data generated and stored in OLTP systems is not easier to access by end users. It doesn't imply that OLTP system has any errors but it indicates that the OLTP systems are not for analysis purpose at end user's level. For making this possible, the transaction data needs to be moved out of the data warehouse and OLAP system should be used for analysis (Kenan, 2015). Data in the OLTP model is relational, and it is normalized according to database standards—such as the 3NF or 4NF. An important factor in the OLTP model is that data doesn't repeat in any fashion and hence it is arranged into more than one table. In this way, transactions involve fewer tables and columns, thus increasing performance. There are fewer indexes and more joins in this model, and the tables will hold the key information.

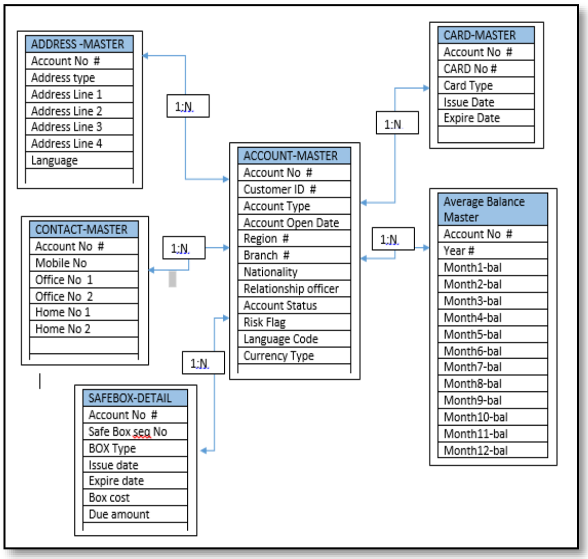


Figure 1-2 shows a basic OLTP system

From the figure below (figure 1-3), sample SQL query output can be seen. It is difficult to analyze further on specific customer's account. Even difficult to find the value in each columns. For any further details, we are required to write multiple queries with more SQL joint statements which might delay the process time. We can observe one more difficulty that the query length will increase depending on the increase in requirement.

account_no	account_type	currency_code	acc_open_date	branch_code	region_code
0000000400	10	0	Mar 8 2006 12:00AM	216	1
0000000400	10	0	Mar 8 2006 12:00AM	216	1
0000000400	10	0	Mar 8 2006 12:00AM	216	1
0000000400	10	0	Mar 8 2006 12:00AM	216	1
0000000400	10	0	Mar 8 2006 12:00AM	216	1
0000000400	10	0	Mar 8 2006 12:00AM	216	1
0000000930	10	0	Mar 16 2008 12:00AM	203	1
0000003522	20	0	Mar 30 1981 12:00AM	214	1
0000003522	20	0	Mar 30 1981 12:00AM	214	1

account_status	initial_deposit	acct_shortname	language_cd
R	0.00	(null)	0
R	0.00	(null)	0
R	0.00	(null)	0
R	0.00	(null)	0
R	0.00	(null)	0
R	0.00	(null)	0
R	0.00	(null)	1
R	0.00	(null)	0
R	0.00	(null)	0

cardtype	expirydate	mon1_avgbal	mon2_avgbal
0100	Dec 1 2013 12:00AM	62,169,803.67	62,202,562.39
0100	Dec 1 2013 12:00AM	62,169,803.67	62,202,562.39
0100	Dec 1 2013 12:00AM	62,169,803.67	62,202,562.39
0100	Dec 1 2013 12:00AM	62,169,803.67	62,202,562.39
0100	Dec 1 2013 12:00AM	62,169,803.67	62,202,562.39
0100	Dec 1 2013 12:00AM	62,169,803.67	62,202,562.39
0920	Mar 1 2014 12:00AM	2,326,464.06	2,516,631.48
0100	Jun 1 2017 12:00AM	197,904.49	193,199.47
0100	Jun 1 2017 12:00AM	197,904.49	193,199.47

mon3_avgbal	mon4_avgbal	mon5_avgbal
62,230,464.13	62,286,329.20	62,299,108.35
62,230,464.13	62,286,329.20	62,299,108.35
62,230,464.13	62,286,329.20	62,299,108.35
62,230,464.13	62,286,329.20	62,299,108.35
62,230,464.13	62,286,329.20	62,299,108.35
62,230,464.13	62,286,329.20	62,299,108.35
3,119,668.38	3,956,292.83	4,120,515.41
234,733.61	232,630.93	220,459.70
234,733.61	232,630.93	220,459.70

SQL QUERY:

```
select a.account_no,a.account_type, a.currency_code,a.acc_open_date,a.branch_code,a.region_code,
a.account_status,a.initial_deposit,a.acct_shortname,a.language_cd ,d.cardtype ,d.expirydate,
b.mon1_avgbal ,b.mon2_avgbal,b.mon3_avgbal,b.mon4_avgbal,b.mon5_avgbal,b.mon5_avgbal
from baccount a , bmainhist b , sm_relation c , bcards d
where a.account_no = b.account_no
and b.year = 2015
and a.account_no = c.cust_acct_no
and '000000000'+a.account_no = d.primaryacct
and b.mon1_avgbal > 10000
and b.mon2_avgbal > 20000
and b.mon3_avgbal > 30000
and b.mon4_avgbal > 40000
and b.mon5_avgbal > 50000
and b.mon6_avgbal > 90000
order by 1,2,5,6
```

Figure 1-3: SQL Query

From below query processing report, we noticed that the query is taking too much time due to voluminous data so we tried to join query using de-normalized table. But we noticed the physical IO (figure 1-4) is too high due to complexity of the query as well as index was not found for this de-normalized table. If we create more indexes then it needs more space in database also.

```
Total estimated I/O cost for statement 1 (at line 1): 1854268.
Parse and Compile Time 0.
Adaptive Server cpu time: 0 ms.

Query cancelled by User

Execution Time 166.
Adaptive Server cpu time: 17002 ms.  Adaptive Server elapsed time: 87332 ms.

QUERY PLAN FOR STATEMENT 1 (at line 1).
```

Figure 1-4: Example on Physical IO process during execution of the SQL Query.

From above example, we observe if a complex query will be executed in online system then it might take longer time and major impact on daily transaction or block online operation.

Online Analytical Processing (OLAP) System

To analyze data, it is required to have a process which can make it feasible to drill down, run an analysis, and understand the data. This result can provide huge benefits in making major decisions at various management level. It will also help to see data in a different window. As we know, the process to extract intelligence from organization's data is BI. However, it requires a system which has major role in driving the process called OLAP system, the Online Analytical Processing system. An OLAP deals with historical data and it is characterized by relatively low volume of transactions. The frequency of update is less as compared to OLTP. In addition, the queries needed for these systems are often very complex and involve aggregations; as for OLAP systems, the response time is an effectiveness measure. It helps users to analyze database information from multiple databases at same time. The most important property of OLTP is that the data is stored in multidimensional databases.

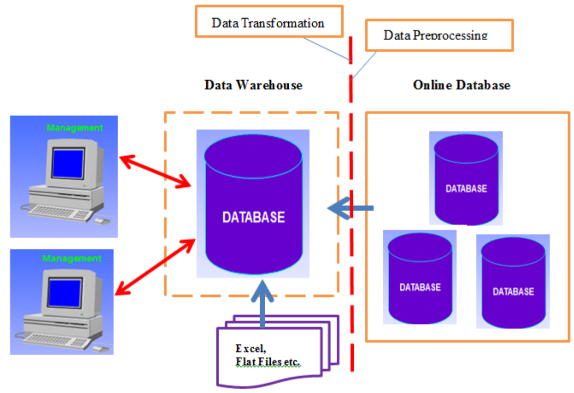


Figure 1-5: Data storage in multi-dimensional databases

Example: When we collect data for a short period like 2-4 months then it will not give out a proper trend to analyze but when we collect data for 5-8 years for specific area then it will give meaningful information. Let's say we collect data on Indian civil service candidates who have appeared in this prestigious examination. This data through analysis is able to provide crucial information as described below:

- What educational background students mostly appearing in this exam have?
- What age group of students mostly succeed in the exam?
- What family income mostly the candidates possess?
- Which state has maximum students appearing in this exam?
- Which state has minimum % of successful candidates during the last 5 years?

These are few analytical questions that arise when we have a large volume of qualified data. It requires the analytical system named OLAP for analysis and to generate various reports or graphs as needed by management within a limited time duration. OLAP is the base for a diversified business application areas like marketing, finance, budgeting, education, sales, planning etc. (Han, 2000 & The OLAP Report). In contrast with OLTP, OLAP information is considered historical, which means that though there may be batch additions to the data, it is not considered up-to-the-second data. Data is completely isolated and is meant for performing various tasks, such as drilldown and the like. Information is stored in fewer tables and so queries perform much faster since they involve fewer joins (Han and Kamber, 2000).

OLAP Architecture

It describes the basic model, where the OLAP server works as an interface between the data warehouse and the reporting tool. OLAP is a software technology which helps managers to gain insight into data through fast, accurate, interactive access to a wide variety of possible views of information that has been transferred from raw data to reflect dimensionality of the organization as accepted by the user (Gupta, 2012).

OLAP Server

It is a data manipulation engine which is used for OLAP operations on multidimensional data. We need to remember, dimensional modeling is the logical modeling to develop data warehouses (Pudi and Krishna, 2009). There are two different structures of OLAP servers available named ROLAP (Relational OLAP) and MOLAP (Multidimensional OLAP). The below figure describes where OLAP server provide role for BI.

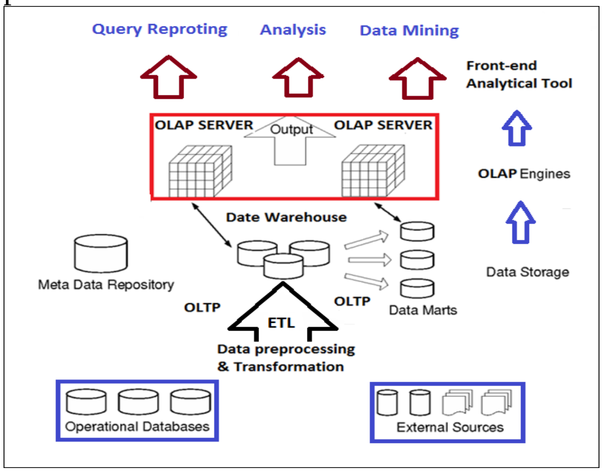


Figure 1-6: Major component - BI Life Cycle

Relational OLAP

It does not pull data from the underlying relational database source to the OLAP cube server rather both cube detail data and aggregation stay at the relational database source. The cube is mapped to a set of base tables as fact table and dimension tables.

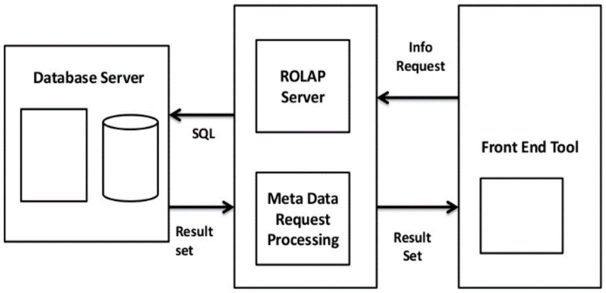


Figure 1-7: (Saranya, 2013)

In order to study more details on OLAP how it helps BI, we need to know following types of schema as used in OLAP server.

Star Schema

It consists of one central fact table which is mostly a large transactional table and surrounded by small tables named as dimension table. All these dimensional tables are linked to fact table through foreign key. Due to non-normalized form, these dimensional tables require less time to provide output for a given query. However, they occupy large space due to non-normalized form. In star schema, least number of tables are linked, hence, joining tables' complexity is minimum which lowers the complexity of query.

Example of a Star Schema used in OLAP system as below

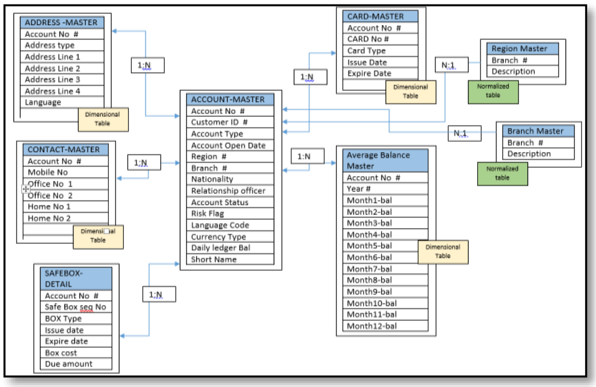


Figure 1-8: Star schema

Snowflake Schema

The snow flake schema consists of fully normalized dimension tables in such a way that gives a shape of snow flake. Here, the advantage is less space needed in comparison to star schema due to available normalized dimensional tables, however, the query processing time will be more due to complex join conditions. In star schema, sometimes the process of query id slow due to deformalized dimension table, hence, snowflake schema is more efficient.

We discussed about schema because dimensional modeling depends on selection of schema as per organization's requirement. We need to remember, dimensional modeling is the logical modeling to develop data warehouses (Pudi and Krishna, 2009).

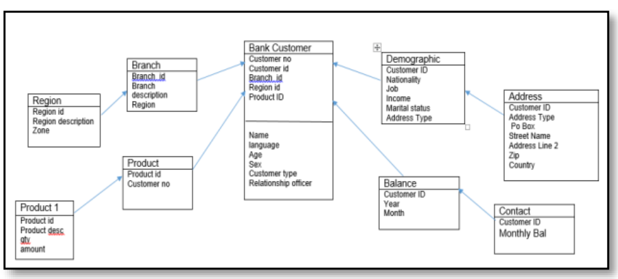
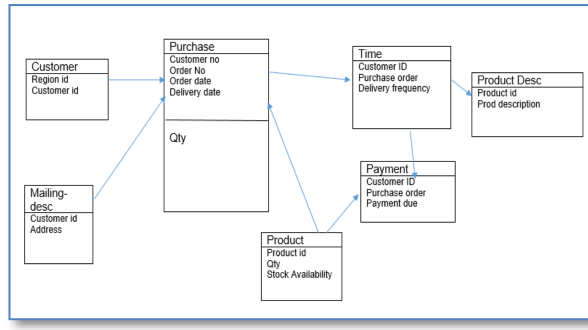


Figure 1-9: Snowflake Schema (Pujari, 2013)

Star flake Schema

A star flake schema is a combination of star schema and snowflake schema. In many design issues, the best solution is mostly between the two boundaries as star schema and snowflake schema.



We need to know all these schema as they all have same data and support same queries. The only difference is the format of queries that depends on the dimensions used.

Multi-Dimensional OLAP

In this mode, when the cube process, the source data is retrieved from the relational store and the required aggregation is performed. Finally, the data is stored in a compressed and optimized multidimensional format. Finally, OLAP is performed through random access of array (Pujari, 2013). Unlike ROLAP where nonzero facts are only stored, in MOLAP major disadvantage is that in the multidimensional array many unimportant cells are stored.

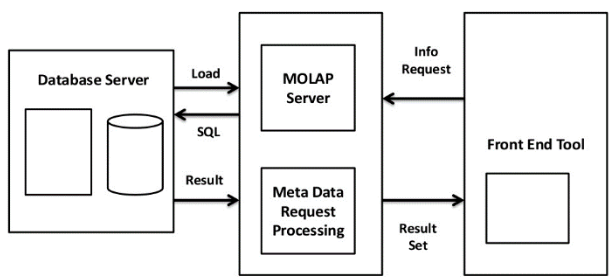


Figure 1-10: (Saranya, 2013)

It is necessary to know the time consumed by sequential access to array which depends on the order of access of dimensions. There is a process called Chunking which divides an n-dimensional array to smaller hypercube-shaped sub-arrays named as chunks. The process saves each chunk in a page in the secondary storage; it is also called as tiles.

Chunking

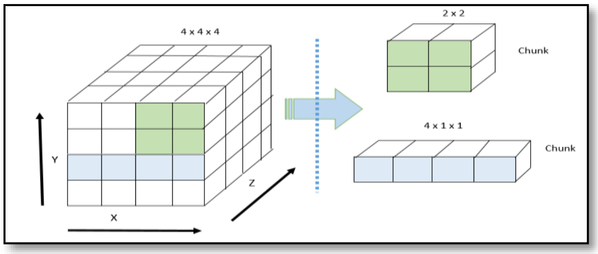


Figure 1-11: (Chunking of cuboid)

Here, the base cuboid XYZ is 4 x 4 x 4 size, and two-dimensional cuboids have chunks of size 2 x 2 and 4 x. Hence, to compute cuboid XZ from the given array XYZ as per the available rule.

$$\frac{(|d_1| \times |d_2| \times |d_3| \times \ldots \times |d_p|) \times ch_{j(p+1)} \, X \, ch_{j(p+2)} \, X \ldots X \, ch_{j(n-1)}}{ch_{i1} \, X \, ch_{i2} \, X \, ch_{i3} \, X \ldots ch_{i(n-1)} z}$$

Source: (Pujari, 2013)

As per this above rule regarding chunk usage at single time, we found maximum (4 x 2)/ (2 x 2) = 2 chunks will be active in the working memory at given time.

Hybrid OLAP

It is a hybrid of MOLAP and ROLAP that attempts to provide the greater data capacity of ROLAP and the fast processing and high query performance of MOLAP. In the HOLAP storage mode, the cube detail data remains in the underlying relational data store and the aggregations are stored on the OLAP cube server (agarwal, 2014).

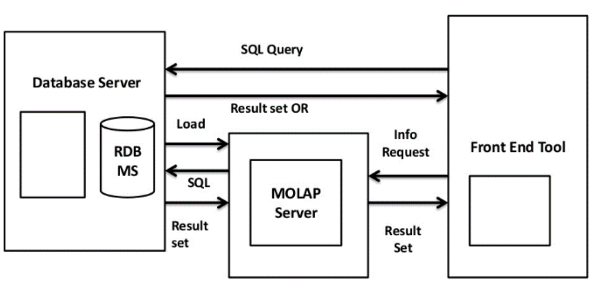


Figure 1-12: (Saranya, 2013)

OLAP & ATTRIBUTES

OLAP is a multidimensional structure that makes data available for analytics. Technically, OLAP pre-calculates, summarizes, and stores the data in compressed form; this makes the reporting and predictive analysis fast and interactive exploration of aggregated data from different perspective possible by using various tools, such as Business Objects, IBM Cognos, SQL Server Analysis Services, MicroStrategy, etc. The key terminologies for OLAP system designing are as below:

Data Cubes

A cube contains a whole set of data that is required while becoming a single source of truth for analysis. It's multidimensional in nature and has two main elements: Dimensions and Facts. In cubes, data (measures) are categorized by dimensions and cubes are pre-summarized across dimensions to drastically improve query time over relational databases. Also, cubes are designed for analytical purposes, so that they can report on millions of records at a time.

The aspect of reducing the total workload of aggregation for reducing the concern on space and time is the major concern of cube computation or cubing technique. There are various cubing techniques such as below:

- Full Cube
- Iceberg Cube
- Skycube
- Shell Cube
- Bottom-Up Cube
- Condensed Cube
- Star Cube
- Quotient Cube
- Dwarf

Dimensions

Dimensions are objects that reside in a cube and have a collection of related attributes to provide information about data (measure). They provide a base for data analysis on stored data (measures) and can be related to one or more measures of groups in the cube. Also, Dimensions define the structure of the cube that helps to slice and dice the data. A dimension table contains more number of columns than rows.

One Dimensional Data

Let us take the example of data available branch wise, total Accounts in Delhi central Zone.

Table 1.1 - One Dimensional Table

Branch	Account
Delhi – Central	32000
Delhi- CP	11000
KarolBagh	23000
GK Part 1	32011
GK Part 2	21890
Total Account	119901

Sometime this same data is projected in different projections for different analysis like shown in table below:

Customer Age range	Account
Below 25	25050
>25 and < 40	45001
40-50	14050
50-60	23000
60 and above	12900
Total Account	119901

Two Dimensional Data

Using same data business expect number of account segregated into individual and corporate on branch wise.

Table 1.2: Two Dimensional Data

Branch	Individual A/C	Corporate A/C	Number of Account
Delhi – Central	22000	10000	32000
Delhi- CP	8000	3000	11000
KarolBagh	17000	6000	23000
GK Part 1	28010	4001	32011
GK Part 2	19000	1890	21890
		Total Account	119901

Here in this two-dimensional data, it will help to analyze in dimensions what you can say geometrical coordinate. Now let's suppose that business wants to see data across all regions, then, this two dimensional data cannot fulfill the requirement. Hence, it requires three dimensional data (shown in table below).

Table 1.3: Three Dimensional Data

. Region	Branch	Individual A/C	Corporate A/C	Number of Account
North	Delhi – Central	22000	10000	32000
	Delhi- CP	8000	3000	11000
	KarolBagh	17000	6000	23000
	GK Part 1	28010	4001	32011
	GK Part 2	19000	1890	21890
West	Rohini	4200	200	4400
	Pritampura	12000	2000	14000
	Keshavepuram	2300	100	2400
	Ashok Vihar	45000	2000	47000
	Utam nagar	20000	2000	22000
South	AIIMS	10000	100	11000
	GreenPark	32000	1000	33000
	Meheroli	21000	900	30000
	IIT	2000	10	2010
East				
	Kamalnagar	21001	30001	24001

There is no limit in dimensions but it is necessary to know that how business users are6 able to view data with minimum efforts. We should remember multidimensional data almost always because it has a logical hierarchy with multiple levels. Multidimensional databases are also very good at storing data at various consolidation levels (by department, by division, by company) and drilling up and down through the data. For these types of actions, a multidimensional database is both easier and faster to use than a relational database (Kenan, 2015).

Facts

Another type of objects residing in a cube which store the data to be analyzed by dimension data, is called measure. Related measures reside in one table known as a Fact table. As with dimensions, there are many types of facts which can be available in cubes. They are as follows:

- Additive: Those facts which can be used across all dimensions
- Semi-additive: Selectively used in specific dimensions, example - time

• Non-additive: The fact which cannot be used in any dimension, example Unit price of a product

Cube Storage

An OLAP system has three storage approaches; we need to choose any one of the storage strategies based on the data availability and the need for successful implementation of a BI system.

OLAP Operations

Let us discuss about OLAP operations in multidimensional data. The Multidimensional data model catered by fact or dimension structure is suitable for interactive analysis of large volume of data for decision making. The list of OLAP operations includes:

- Roll-up
- Drill-down
- Slice and dice
- Pivot (rotate)

Roll-up

Roll-up performs aggregation on a data cube in any of the following ways:

- By climbing up a concept hierarchy for a dimension
- By dimension reduction

The following diagram illustrates how roll-up works.

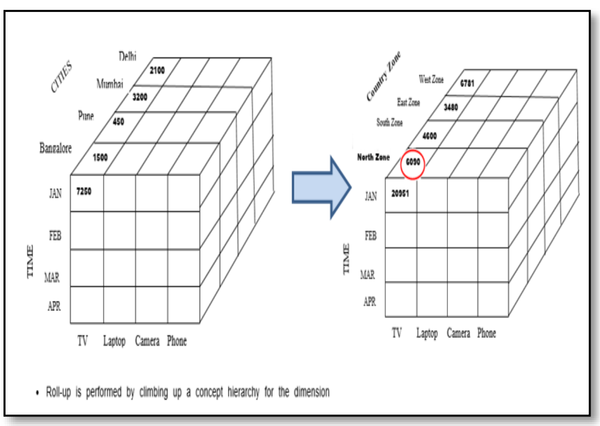


Figure 1-13: Roll-up from City to Zone in India

On rolling up, the data is aggregated by ascending the location hierarchy from the level of city to Zone of a country. Also as the roll-up is performed, dimensions from the data cube are reduced.

Drill-Down

Drill-down is the reverse operation of roll-up. It is performed in either of the following ways (Rathod, 2012):

- By stepping down a concept hierarchy for a dimension
- By introducing a new dimension.

The following diagram illustrates how drill-down works:

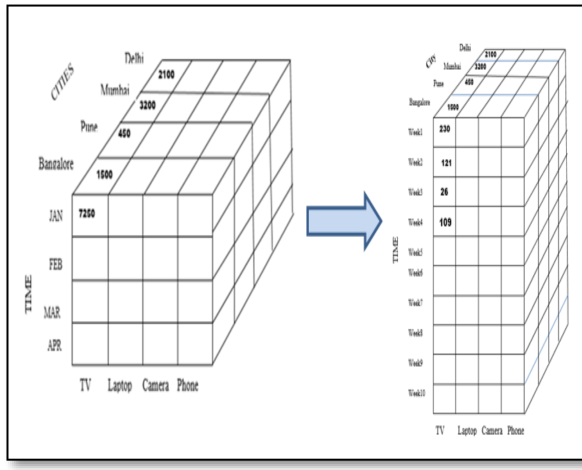


Figure 1-14: Drill Down

- Drill-down is performed by stepping down a concept hierarchy for the dimension time.
- Initially the concept hierarchy was "day < Week < Month< year."
- On drilling down, the time dimension is descended from the level of month to the level of week which add one more dimension as week.
- It helps to breakdown to one more sub-level for more detail information as monthly to weekly.

Slice

The slice operation extract one specific dimension from a given cube and provides a new sub-cube. Let's study the diagram which describe how slice works (Rathod, 2012).

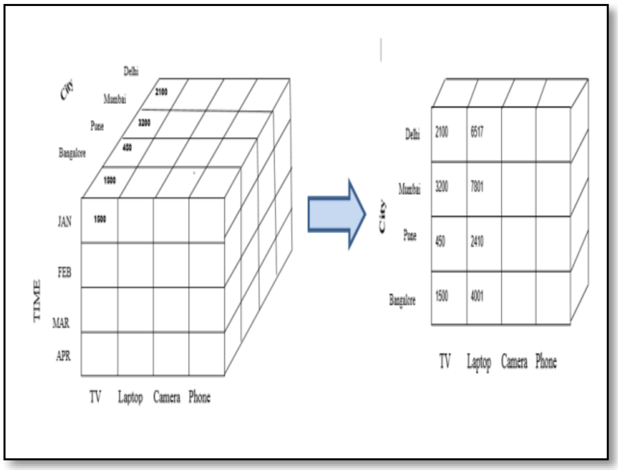


Figure: 1-15: Example on Slice

Here, Slice is performed for the dimension "time" using the criterion time = "Monthly”. It creates a new sub-cube by selecting one or more dimensions here (time = Month = January)

Dice

Dice selects two or more dimensions from a given cube and provides a new sub-cube. Consider the following diagram that shows the dice operation.

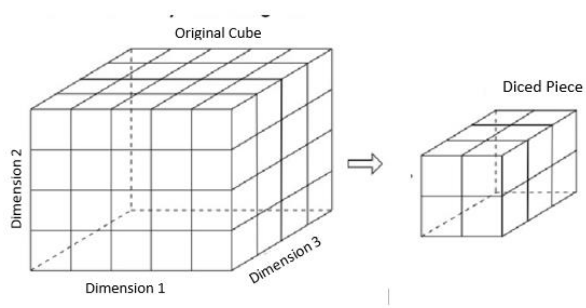


Figure 1-16: (Rathod, 2012)

Pivot

When user wants to view a data cube in different orientation then this method is used.

OLAP VS OLTP

As analysis of data has become very important to the management of modern enterprises. The following rules differentiate OLAP systems from relational databases:

Data	OLTP SYSTEM	OLAP SYSTEM
Where to collect (Source)	Need real-time data (Transaction based).	Need both online and historical data. from the various OLTP Databases
Reason to collect Data (Purpose)	To control and run basic business need.	To help - planning, problem solving, and decision support
What type of data	Transactional Data	OLAP typically use multidimensional data structures which helped organization to analyze numeric values from different angels as location, time, products, and others
Data Inserts or Data Updates	Short/Update initiated by end users	Only Read Purpose Periodic data needed.
Queries on Data	Simple queries which return expected few records	Mostly complex queries involving aggregations. Data manipulation and analysis is too easy for any nontechnical person.
Processing Speed	Typically optimized for fast processing	Architecture of the system allows constantly fast access to the data due to OLAP solutions typically pre-aggregate data. Depends on the amount of data involved, periodic data population complex queries may take many hours.
Space Needed	Required relatively less space if historical data is archived	Larger due to the existence of aggregation structures and history data. It required more indexes in compare to OLTP.
Database Design	Normalized with many tables	Typically, de-normalized with fewer tables. star and snowflake schemas being used in OLAP server.
Backup and Recovery	Backup religiously. operational data is critical to run the business and data loss is likely possible.	Periodically data reloading the OLTP data.

Expectation of BI

Business intelligence, while analyzing data, never focuses on the source from which the data is coming or how the process is happening. The following important characteristics of OLAP tools prove that OLAP has major role in BI.

- **On Time:** Manipulating data in a modern OLAP system is a much faster way of producing required business data in an intelligent way rather than querying data from a relational database.
- **Accuracy:** Multidimensional data along with accuracy, it can drill down depending on the complexity of data for example for marketing data we can store monthly, weekly and daily information, if needed.
- **High volume:** Even though an OLAP system deals in multidimensional data, it is still the same information that is housed

in the transactional systems. Using OLAP, you can perform advanced data manipulation and analysis on just about any data stored in your enterprise.

- **Actionable:** This is where OLAP system is especially good at aiding in analysis, allowing precise trends to be plotted and activities to be monitored. That means analysts can recommend immediate action to be taken.

Conclusion

OLAP provided interactive analysis by different dimensions and different levels of details (Howson, 2008). The value of an OLAP tool is derived from the ability to quickly analyze the data from multiple point of views. OLAP tools are designed to pre-calculate the aggregations and store them directly in the OLAP databases with multidimensional facility. Building a successful business intelligence environment requires integrating a variety of OLAP servers and front-end tools (Pudi and Krishna, 2009). OLAP operation helps data analysis very effective and easier to use (Pudi and Krishna, 2009). The data source for our analysis does need to be OLTP. It can be from various sources like Excel file, a text file, a web service, or CSV file etc. It helps users to analyze database information from multiple database at same time with cross-dimensional calculation. We must emphasize that we are not saying that OLTP doesn't support analysis; all we are saying is that OLTP databases are not designed for complex analysis. What we need is a non-relational and non-live database where such analysis can be freely run on data to support business intelligence. We should think OLAP server is not a competitor to a relational data warehouse rather it is an extension. Recently, OLAP Software Company focused on improved performance with increased functionality in the core analytic area to manage current high growth of transactional data in most of the organization (Mundy, 2002). OLAP helps the organization for responding quickly to the market demands while making effective decisions. Market responsiveness, in turn, often yields improved revenue and profitability (Saagari et al., 2013).

References

Agarwal, A. (2014). [Online] www.developer.com. Available at: http://www.developer.com/db/the-role-of-analytics-in-business-intelligence.html [Accessed 15 Oct. 2015].

Errattahi, R., Fakir, M. and Salmam, F. (2014). Explanation in OLAP Data Cubes. Journal of Information Technology Research, 7(4), pp.63-78.

Gorbach, I., Berger, A. and Melomed, E. (2009). Chapter 1: Introduction to OLAP and Its Role in Business Intelligence. [Online] Network World. Available at: http://www.networkworld.com/article/2261831/lan-wan/chapter-1--introduction-to-olap-and-its-role-in-business-intelligence.html [Accessed 22 Oct. 2015].

Gupta, G. (2012). *Introduction to Data mining with case studies*. 2nd Ed. New Delhi: PHI Learning Private Ltd.

Han, J. and Kamber, M. (2000). Data Mining: Concepts and Techniques. 2nd ed. San Francisco: Morgan Kaufmann Publishers.

Howson, C. (2008). Successful Business intelligence. New Delhi: Tata McGraw-Hill Edition, pp.40-41.

Kenan, S. (2015). Data warehousing: from OLAP to OLTP.

Kim, J.H. and Yong, H.S., 2002. Web Log Data Sparsity Analysis and Performance Evaluation for OLAP.

Mundy, J. (2002). Relating to OLAP. [Online] www.kimballgroup.com. Available at: http://www.kimballgroup.com/2002/10/relating-to-olap/ [Accessed 4 Nov. 2015].

Pudi, V. and Krishna, R. (2009). Data mining. Oxford: Oxford University Press.

Pujari, A. (2013). *Data mining techniques*. 3rd ed. Hyderabad: Universities Press (India) Pvt. Ltd.

Rathod, Z. (2012). *OLAP & DATA WAREHOUSE*. [Online] Slideshare.net. Available at: http://www.slideshare.net/jalparathod/olap-data-warehouse?related=2 [Accessed 19 Dec. 2015].

Saagari, S., Anusha, P., Priyanka, C. and Sailaja, V. (2013). Data Warehousing, Data Mining, OLAP and OLTP Technologies Are Essential Elements to Support Decision-Making Process in Industries. *International Journal of Innovative Technology and Exploring Engineering*, 2(6), p.93.

Saranya, V. (2013). *OLAP*. [Online] Slideshare.net. Available at: http://www.slideshare.net/ersaranya/olap-27655941?related=3 [Accessed 18 Dec. 2015].

Slideshare.net, (2013). *OLAP*. [Online] Available at: http://www.slideshare.net/ersaranya/olap-27655941?related=3 [Accessed 9 Jan. 2016].

Support.office.com, (2016). Overview of Online Analytical Processing (OLAP) - Excel. [Online] Available at: https://support.office.com/en-my/article/Overview-of-Online-Analytical-Processing-OLAP-15d2cdde-f70b-4277-b009-ed732b75fdd6 [Accessed 1 Jan. 2016].