UML Modeling and Validation of Object-Oriented Database for Water Bill Deposit System

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Abstract: The present paper deals with the modeling of object-oriented database for the Water Bill Deposit System (WBDS). A real case study of Water Bill Deposit System is considered in Indian scenario. A well-known UML modeling is used for designing of the class and state diagrams. Different object-oriented test cases have also been generated by the use of Finite State Machine (FSM) for validating the proposed UML model. Snowflake schema is also designed for the object-oriented database to generate master table which reduces the data redundancy. A sample size is also considered which can be implemented upto finite numbers of records.

Keywords: UML, Object-Oriented Database, Snowflake Schema, UML Class, Sequence and State Diagrams, Test Cases

1. Introduction

Due to evolution of object-oriented database, many of the organizations are shifting their relational database towards object-oriented database as it supports huge amount of database in comparison of relational database. The huge amount of database can be stored inside the three dimensional cube and users can performed several queries within a fraction of seconds or search the desired records within few seconds. Many authors have also explored the idea to reduce the query response time by the use of mathematical model. Let us describe some of the important work related to the present work. Smith et al. [1] have described the various advantages of data cube's which can store large database for the similar groups. Data cube supports data analysis and query aggregations also. Lee et al. [2] have described the object-oriented database which supports for the real time application and is growing need for non-traditional applications of database. Urban [3] has postulated the object-oriented database which provides transparency in retrieving data from local sources using the translation process. Saxena and Kumar [4] have stated that many organizations replace their old structured database because object-oriented database query response time gives better results than the relational database. Li [5] has described UML snowflake diagram for XML schemas. Advanced XML schema-based representation of a multidimensional model is used as metadata in prototype system for processing On Line Analytical Processing (OLAP) queries. Efrizoni et al. [6] have described Unified Modeling Language (UML) as a standard object-oriented modeling language having notations that are widely accepted and used by the software development industry. Ramachandran et al. [7] have described Snowflake Schema fact table related to multiple tables and each table is available in normalized form and fact table is the main table. Booch [8] has described that UML is a general purpose modeling language that is used to visualize, construct and document the software. Wei and Wing [9] have proposed that object-oriented database supports the multi-attribute and range of queries by storing and processing work managed to reduce to the network traffic. Linzhang et al. [10] have also described the various test cases which are directly derived from the activity diagram through proposed model. Test case generates all the information on Gray box method.

In the present work, a real case study of WBDS is used for generating the set of records which are similar. For generating the several users' queries, UML is used to create the class model for showing the static behavior of the problem, sequence model to show the dynamic behaviour and state model to generate the test cases for validating the proposed models. Several queries have also been performed to get the desired records within fraction of seconds after drawing the master table in the object-oriented form through snowflake schema.

2. Object-Oriented Database

Datacubes store the data in the form of three dimensional cubes. Datacubes support the division of data into three axis x, y and z and also supports the decision support system. Datacubes support one dimensional, two dimensional and n dimensional data and store large scale of data. Users easily retrieve data in data cube. Datacube's main work is to divide the data in axis form and in the present work, object-oriented database is designed for customers for the sample size of

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100 and sample of data table is shown below in Table 1. In the table three dimensional data like Cust_Id, Cust_Mobile_No and Water_Bill_ Amount are stored in x, y and z directions of datacube and for query purpose OLAP cube software calls the object-oriented database table.

Table 1. Objcet-oriented Database Table

Cust_Id	Cust_Mobile_No	Water_Bill_Amount (In Rs.)
1001	9452184193	400
1002	8004922219	3000
1003	9027374863	1200
1004	9956098198	1100
1005	9795777512	500
1006	9454272113	600
1007	7499047254	2200
1008	9838449043	3000
1009	9839841701	2500
1010	8004922214	1400

An object-oriented database allows referential sharing through the support of object identity and inheritance. Many features are provided in object-oriented database. Object-oriented database supports the multimedia and graphical user interface and works for Object Query Language (OQL).OQL's main advantage is direct stability of the relation between objects. Object-Oriented database's main advantage includes object-oriented properties like association, class, inheritance, binary association.

2.1 Snowflake Schema

A snowflake schema is a known as the logical arrangement of tables for the multidimensional object-oriented database tables. The snowflake schema is represented by centralized fact table which is connected to multiple dimensions. The snowflake schema is similar to the star schema and dimensions are normalized into multiple related tables. The star schema's dimensions are normalized with each dimension represented by a single table. Snowflake schema reduces the data redundancies. Main advantage of data redundancies in object-oriented database table is easy to maintenance and saves storage space. Snowflake schema diagram is divided into six tables. Bill_Report is a fact table. Mobile and Customer, Water_Bill, Water_Tax_Branch, Time tables are connected to Bill_Reports table. The major advantage of this table is in the normalized form. This diagram shows that all customer record is stored in Customer table which consists of Customer_Id, Customer_Name, Cust_Mobile_No, Cust_Add. Mobile table found the record Cust_Mobile_No, Cust_Bill_Id, Cust_Bill_Amount, Due_Date and Payment_Date. Water_Bill table stores the records of Bill_Id, Water_Bill_Amount and Due_date. Water_Tax_Branch consists of records of Branch_Id, Branch_Name, Branch_Add and Deposit_Scheme. Time table stores Time_id, Day, Month and Year. Snowflake is used in multidimensional table.

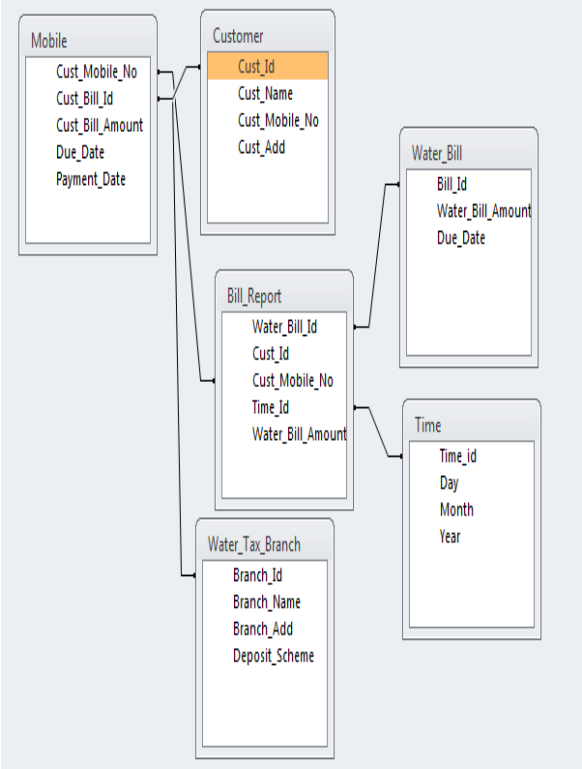

Fig. 1. Snowflake Schema WBDS

3. UML Modeling for WBDS System

3.1 UML Class Diagram

It is a graphical representation of any model and creates an abstract model. Generally, UML is used in software engineering field. In this research paper, UML shows graphical representation of WBDS and divided into three parts. First part shows class name, second part shows attributes name and third part shows operations. UML class diagram is shown in figure 2 which shows the relationship between Customer and Water Tax_Branch. In this diagram, the Customer enquires

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about the bill from Water_Tax_Branch and Customer data is stored in Water_Tax_Branch. In the figure 3, a relationship among Customer, Mobile and Water_Tax_Branch is established. The Customers who have the Mobile numbers are registered for generation of Water Bills from Water_Tax_Branch. The figure 4 shows the relationship among Customer, Mobile, Water_Bill with Water_Tax_Branch. Customer deposits Water_Bill within time duration provided by Water_Tax_office.

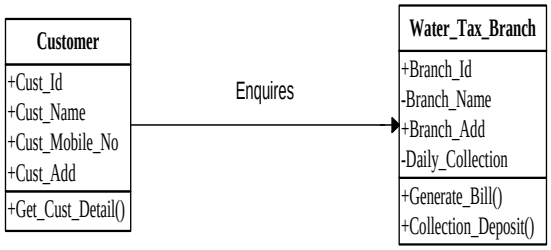

Fig. 2. Representation of Single Association

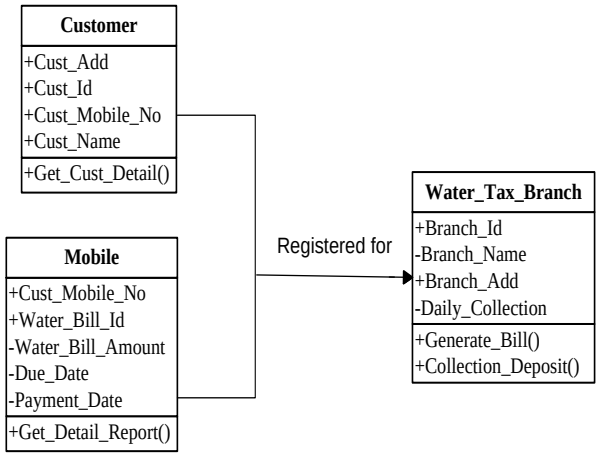

Fig. 3. Representation of Double Association

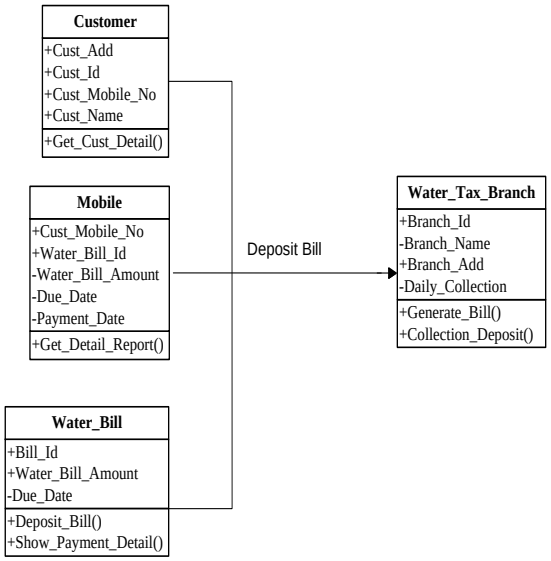

Fig. 4. Representation of Triple Association

Let us describe the UML class diagram for depositing the bills of Water in the Water_Tax_Office. It is represented in the figure 5 and it shows that Water_Tax_Office generates the Water_Bill of the Customer and it displays on the Mobile of the Customer. The major classes are Customer, Mobile, Water_Tax_Office and Water_Bill and these are interacting with each other as shown in the diagram.

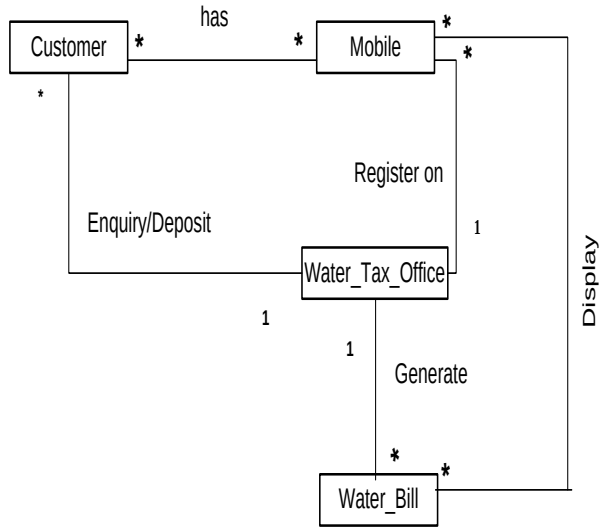

Fig. 5. UML Class Diagram for WBDS

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3.2 UML State Diagram

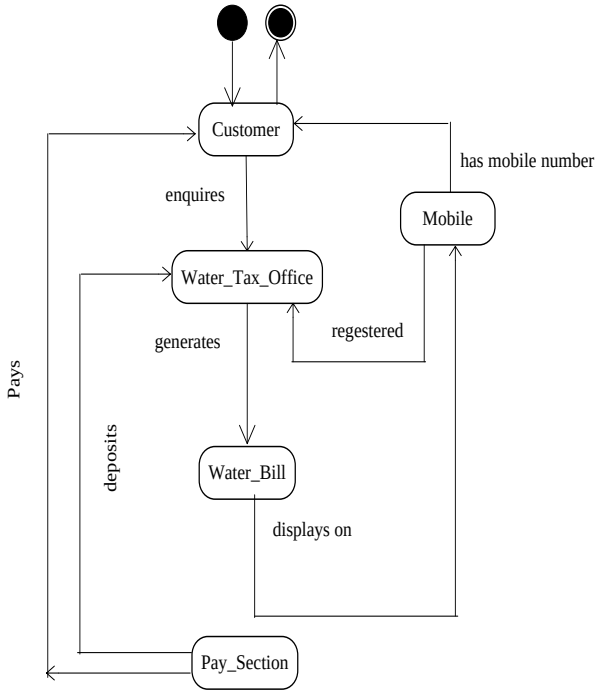

Fig. 6. UML State Diagram WBDC

UML state diagram shows the arrangement of the events and similar kinds of the events are grouped together and form a state and it shows the step by step sequence of process and it is a dynamic diagram. Let us design and describe the UML state diagram for the WBDS system. The classes are arranged and represented in the form of states. State diagram depends on events and state. Next state depends on current state. The diagram shows that Customer enquiries on Water_Tax_Office. Water_Tax_Branch register Customer Mobile. Water_Tax_Branch generates the Water_Bill and Water_Bill display in Customer Mobile. Then Customer deposits the Water_Bill in Water_Tax_Branch.

3.3 Finite State Machine

All the states as q_0, q_1, q_2, q_3 and q_4 are represented for Customer, Mobile, Water_Tax_Office, Water_Bill and Pay_Section, respectively. The different eight events are shown below in the table 2.

Table 2. Representation of Events

Events	Representation
a	enquires
b	generates
c	registered
d	displays on
e	has mobile number
f	deposits
g	pays

After defining the various states and events, a UML state diagram represented in the figure 6 which is converted into the state transition diagram and shown below in the figure 7 and corresponding transition table is defined in table 3**:**

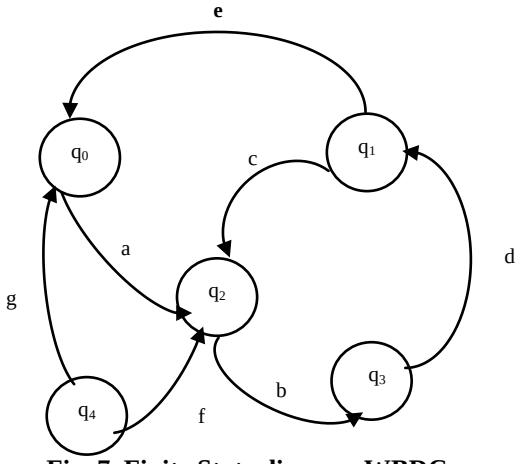

Fig. 7. Finite State diagram WBDC

Table 3. A Transition Table

δ/∑	a	b	c	d	e	f	g
q_0	q_2	Ø	Ø	Ø	Ø	Ø	Ø
q_1	Ø	Ø	q_2	Ø	q_0	Ø	Ø
q_2	Ø	q_3	Ø	Ø	Ø	Ø	Ø
q_3	Ø	Ø	Ø	q_1	Ø	Ø	Ø
q_4	Ø	Ø	Ø	Ø	Ø	q_2	q0

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3.4 Generation of Test Cases

Test case is defined to validate the output of the segment of code, macro, subroutine, etc. It is the backbone of the coding and one can also use it for unit, integration, system and acceptance testing. From the table 3, regular grammar is generated and thereafter, one can generate valid test cases. The grammar is defined below:

$q_1 \rightarrow eq_0$
$q_1 \rightarrow cq_2$
$q_0 \rightarrow aq_2$
$q_2 \rightarrow bq_3$
$q_3 \rightarrow dq_1$
$q_4 \rightarrow gq_0$
$q_4 \rightarrow fq_2$

Valid Test Case: Water Bill of Customer Displays on Mobile

From the above, the grammar is given below:

$q_0 \rightarrow aq_2$
$q_2 \rightarrow bq_3$
$q_3 \rightarrow dq_1$
$q_1 \rightarrow eq_0$

By replacing the non-terminals, one can get the following string:

$q_0 \rightarrow abde$

The above string shows that the Water_Tax_Office generates Water_Bill which is displayed on the mobile of the customer. It is very much clear from the figure 6 also.

4. Concluding Remarks

From the above, it is concluded that UML modeling is a powerful tool for representation of the problem in static or dynamic way. In the above WBDS, water bill is generated by the water tax office and these are modeled by means of class and state diagrams. A snowflake schema is also demonstrated for the object-oriented database. The state diagram is validated through finite state machine. The validation method for generating the regular grammar can also be implemented for the other real case studies.

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