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A Novel Study of Attribute time stamping models in Temporal Database

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Abstract **--**Time based data is efficiently managed by temporal database models whereas the conventional database models are only capable of storing the present value, temporal database models not only stores historic values but also provide a roadmap to process future valid data. This paper briefly introduces some vital temporal database concepts. After that, various attribute time stamping models are examined in this domain. Finally, a comparative analysis of the various attribute timestamp models is prepared to discuss their strengths and weaknesses of their Implementations and provide useful and optimised results for solving the problems in the field of the temporal database model**.**

Keywords--Temporal database, temporal data models, Attribute time stamping models, transaction time, valid time

I. INTRODUCTION

A temporal database is the extension of arelational database that is capable of storing data relating to time instances. It has temporal data types that stores data of the past, present and future time, for example, maintaining the historical record of fashion trends that gradually changed from 1980's to 2017 or keeping the track of student's preference of stream in choosing a career path that got changed over the period of time. Thus, the collection of time-related data can be stored, managed and analysed by thetemporaldatabase.For example, maintaining the historical record of fashion trends that gradually changed from 1980's to 2017 or keeping the track of student's preference of stream in choosing a career path that got change over the period of time.[3]Thus, thetemporal database stores a collection of time-relateddata. This type of time-based database uses a certain timeframe (such as microseconds or milliseconds or seconds) and then stores only the variations in the measured data. [12]The timestamp is a discretely stored value for each measurement in relational database management system which makes it very inefficient. This time travelling feature of a temporal database makes it possible to record information about fixing errors in the database. It is essential for a true audit photograph of the data which modifies when it records and allows queries related to how to modify the data over time.[13]There is a large application domain that works with temporary data in computer applications for example history of file backups, Financial Applications such as history of stock markets & share prices, Reservation Systemsto know when was a flight booked, Medical Systems forkeeping a track of patient records, archive Management Systems for sporting events, publications and journals, Weather analyzingSystemsforanalyzing weather records for data mining

a) Categorization of Temporal Databases

Based on Time dimension associated with the temporal database, temporal relations were implemented by attaching each tuple with a time interval, a start and end time value indicating when the data is valid. Information on how to form temporal data and relations is given in the background section.

Temporal Aspects includes:

- Valid Time
- Transaction Time

A table that implements one of these is temporal, two is bi-temporal.

1) Valid Time

[1]The time during which a fact is true with respect to the real world,it ismodelled as a range between two timestamps closed at thelowerbound can be open at upper bound.

Valid Time Example [12]

Owner	Property	StartVT	EndVT
Aman	'Some place'	2012-09-28	2016-02-20
Akshay	'Some place'	2014-02-21	∞

2) *Transac*tion Time

[1]The time period during which a fact stored in the database is considered to be true modelled as a range between two timestamps closed at lower bound can be open at upper bound.

Owner	Property	Start VT	EndVT	Start TT	EndTT
Aman	'Some place'	2012-09-28	2016-02-20	2016-09-28	2016-09-09
Akshay	'Some place'	2014-02-21	∞	2016-09-09	∞

However, a BitemporalConceptual data model contains both valid and transaction timestamps.

Based on Time stamping technique supported by temporal databases

1) Attribute time stamping

[2]In the case of attribute time stamping, N1NF relations are used, and time stamps are attached to attribute values. Entire data about an object being modelled can be stored in one tuple of the N1NF relationthe entire history of an object is stored in a tuple. Thus, the data in a tuple which are not affected by any updates are not to be repeated, all the time-specific attributes can be drawn in a relation. Time is linked to the attribute values of a relation and the history of an attribute is included in a set of triplet valued, as shown in table below1.The triplet of the form <[l, u), v> means "l" represents lower time bound, "u" represents upper time bound and "v" represent the value of the attribute, this approach violates 1NF since it does not contain asingle or indivisible value.

VV: Valid Time, TT: Transaction time

Here we are considering a temporal database of teachers in a college for example consider an example of EMP#E2 in table 1,Jagriti Verma in between the time <[T12,T27]TT,[T15,T27]VT, JagritiVerma(value)> lives at Pashchimvihar<[T12,T27)TT,[T15,T27)VT, Pashchimvihar (value)>.when Jagriti got married , her surname and residential address got changed (<[T28,T40]TT,[T28,T40]VT, Jagriti jolly (value)> lives at Adarshnagar<[T28,T40)TT,[T28,T40)VT, Adarshnagar (value)>)Later she had a divorce so her surname and residential address in valid time [T41,T45] got changed again and restored with the values <[T41,T45],[T41,T45],Jagritiverma> and residential address <[T41,T45],[T41,T45], Pashchimvihar>Now in valid time [T53,Now] Jagriti get re married, changing her surname <[T53,Now],[T55,Now],Jagritiyadav> and address <[T53,NOW],[T55,NOW],Noida>} , this value get stored in the bitemporal table with a transaction time [T55,Now].All those values are stored in single tuple and all time varying attribute like address and name is modelled in one relation.

Table 1: A Nested Temporal Relation

EMP	NAME	ADDRESS	BIRTH DATE	DEPARTMENT
E1	<[T1,Now],[T1,Now],Aman Jolly>	<[T1,NOW],[T1,NOW],Adarshnagar>	31/08/1994	Computer science
E2	<[T12,T27],[T15,T27],JagritiVerma> <[T28,T40],[T28,T40],JagritiJolly > <[T41,T45],[T41,T45],JagritiVerma> <[T53,Now],[T55,Now],JagritiYadav >	{<[T12,T27],[T15,T27],Pashchimvihar > <[T28,T40],[T28,T40],Adarshnagar> <[T41,T45],[T41,T45],Pashchimvihar> <[T53,NOW],[T55,NOW],Noida>}	4/10/1994	ComputerScience
E3	<[T15,Now],[T15,Now],DishaAggrawal>	{<[T15,T56],[T18,T56],Pashchimvihar ><[T57,NOW],[T57,NOW],Noida>}	28/08/1994	Electronics

2) Tuple time stamping

There are two models in the Tuple time-stamping approach and use all the benefits of traditional relational databases. [2] The Tuple Timestamp Single Relations (TTSR), which keeps its all-time-related features with non-temporal features with different properties, is therefore presented as two additional time attributes called "from" and "To" fields, when the approach is not efficient since if a relation has many attributes, a whole new tuple version is created whenever any one of the attributes is updated.

If the attributes are updated asynchronously, then each new version can have only one attribute difference, thus repeating the value of the other attributes which are same requires a huge space to accommodate and another is called Tuple Timestamp Multiple the relations (TTSR) where time is as decomposed into time varying attribute and distributed over several relations and non-temporal attributes are gathered into separate relation. Also, a separate relation is required for each time dependent attribute as well. A relation schema is augmented with two (four) time attributes to designate the time reference of its tuples. However, each time varying attribute should be in a separate relation, which results in many small relations. Here we are using Tuple Timestamp Multiple Relation (TTMR) because [1] TTMR is cost effective and surpass Tuple Timestamp Single Relation (TTSR) in terms of themagnitude of performance with regards to execution time and used space memory.

Table 2: Non-Time Varying Attributes

EMP	BIRTH DATE	DEPARTMENT
E1	31/08/1994	Computer science
E2	4/10/1994	Computer science
E3	28/08/1994	Electronics

Table 3 Employee Name Table

EMP	NAME	TT_LB	TT_UB	VT_LB	TT_UB
E1	Aman Jolly	T1	Now	T1	Now
E2	JagritiVerma	T12	T27	T15	T27
E2	JagritiJolly	T28	40	T28	40
E2	JagritiVerma	T41	T45	T41	T45
E2	Jagriti Yadav	T53	Now	T55	Now
E3	DishaAggarwal	T15	Now	T15	Now

Table 4 Employee Address Table

EMP	ADDRESS	TT_LB	TT_UB	VT_LB	TT_UB
E1	Adarsh Nagar	T1	Now	T1	Now
E2	PashchimVihar	T12	T27	T15	T27
E2	Adarsh Nagar	T28	T40	T28	T40
E2	PashchimVihar	T41	T45	T41	T45

E2	Noida	T53	Now	T55	Now
E3	PashchimVihar	T15	T56	T18	T56
E3	Noida	T57	Now	T57	Now

[10] The example which was mentioned above for Table 1(Attribute time-stamping) same have been used in tuple time stamping here the table has been bifurcated into many relations. Becausethe1NF form is used in tuple time stamping. Separate tuples are needed to store any change in the object which increases the tuple size. Here in Table 3 E2 of EMP attribute is replicated four times just to show the change in name. In Table 4 also E3 of EMP attributes replicated four times just to show the change in address. Same thing happened when E3 address got changed, the tuple of table 4 with EMP attribute E3 multiplied 2 times just to show the change in address whereasnon-time varying attributes like birth date and department are grouped into separate Table 2.This methodology increases the relations between the tables. In attribute time stamping a single relationship is used whereas in tuple time stamping relationship withintable increases as the time varying attributes increases.

[9]A brief comparison shows that less space is used in attribute time-stamping as compared to tuple time-stamping due to data redundancy whereas attribute time stamping requires a bit more time than tuple time-stamping because nested Bitemporal Relational database creates a separate table. Attributetimestamping supports both homogeneous and as well as temporally heterogeneous data whereas tuple timestamping supports only homogeneous data. In attribute time stamping 1NF rule is violated as non-temporal attributes are allowed in a single relation with temporal attributes which allows nesting and avoids redundancy unlike tuple time-stamping.

II. Literature Review

In this section, we have presented a literature review of Temporal Databases in various domains.

CananErenAtay[2] have presented how attribute and tuple time stamped bitemporal databases can be implemented in an object-relational database and tested to see which one performs better in terms of time and space. The Author has done a comparative analysis using Oracle 9i's AUTOTRACE utility and found that an attribute time-stamping approach might require relatively a bit more time because the nested bitemporal relational database creates a separate table for each time-relatedattributes, however, attribute time stamping requires less space and supports temporally heterogeneous as well as homogeneous data.

Michal Kvet, Karol Matiaško [4] have shown that how brain tumour can be monitored and processed by data obtained from magnetic resonance imaging management techniques and storing the MRI results in temporal database models. He chose two models one is column level temporal system and other is epsilon column level temporal system and found that Object level temporal system does not fulfil the performance requirement because of the duplicities. The improved way for modelling is column level, which manages not the whole objects, but only attributes. The performance of column level can also be improvised by the definition of the minimal valid change of the marker value – Epsilon (_).

MatteoGolfarelli and Stefano Rizzi [5] discussed the issues related to temporal data warehousing and the open research issues with temporal data implementation on commercial tools. They concluded that there is still very marginal support to changes in theschema by commercial tools. They compared two commercial tools, one is SQL Compare and the other is Oracle Change Management Pack. SQL Compare compares and synchronises SQL Server database schema, and can be used when changes made to the schema of a local database need to be pushed to a central database on a remote server. Oracle Change Management Pack is aimed to report and track the evolving state of meta-data, thus allowing to compare database schema, and to generate and execute scripts to carry out the changes. In both cases, formulating a single query spanning multiple databases with different schema is not possible so there is a need to deliver effective solutions by both researchers and vendors

Ricardo Campos, Gae¨ L Dias, Al´Ipio M. Jorge, Adam Jatowt[6] overviewed the important advances in Temporal information retrieval as they explained crucial concepts related to the notion of time, calendar systems, handling temporal expressions in texts, and the different types of sources of temporal information on the web. They also surveyed existing research that deals with the temporal aspects of both search queries and documents and the diverse ways of generating temporally enhanced search results.

Michal Kvet, Karol Matiasko, and Marek Kvet[7]proposed aColumn level temporal system. It is an efficient approach to process data with different granularity and keeps the duplicity to minimal. Minimising the duplicities is one of the important factors which improve processing speed to get acurrent snapshot and all data during thelife cycle of the object in the proposed system.

Michal Kvet, Karol Matiasko and Marek Kvet[8] extended the concept of Column Level Temporal System(CLTS) and proposed two models- Extended Column Level Temporal System and Epsilon Column Level Temporal System. Extended Column Level Temporal System keeps the principal of CLTS intact but changes the history management and management of temporal table. It uses two additional attributes in thetemporal table - Data type, Operation and also introduces Restore operation which provides validity restoration after transaction failure or data distribution failure. Data Manipulation Operations such as Insert, Update are manipulated using triggers and procedures.

III. Attribute time stamping models

The temporal model aims at managing static information as well as time varying information in a singular approach. There are lots of existing conventional database models like relational, entity relationship models. However, there is a robust need for temporal data models as a result of using the conventional databases, managing the time-varying data is left at the developer end or other ad hoc methods that must be re-implemented or reworked upon whenever a new application or software is developed. Therefore usage of conventional database models results in an inefficient approach to manage the temporal data and so there is the

requirement of a standard framework for all applications provided by temporal information models. A huge quantity of work has been done to store and access the temporal data. All the work that has been done revolves around two approaches. Initial approach has been to change the underlying conventional database model by introducing special attribute, temporal types etc. to map the temporal feature of data. Many information models are projected using this approach. Out of those conventional models, using therelational model to increase and propose temporal model is that the most popular choice because it continues to be widely employed in commercial applications. As mentioned, to represent the temporal data using this approach needs representation of temporal aspect within the kind of attributes in relations, in addition to the static data attributes. Next would be the brief introduction relating to completely different Attribute data models and comparative analysis among them.

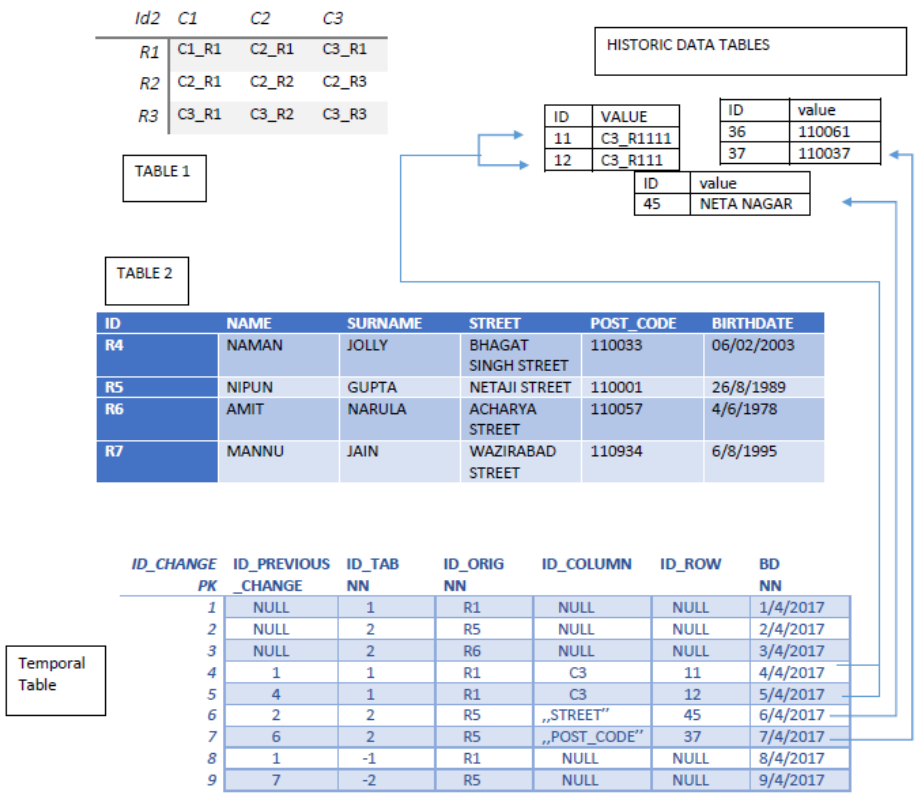
A. Column level temporal system

[7]The column level temporal system is coined by Michal Kvet, Karol Matiasko and Marek Kvet in 2004.Because of the duplicate values in uni-temporal and bitemporal systems, thedifference between the processing in currently valid data and historical data is important. Thus, it's an economical approach to process information with totally different granularity and keeps the duplicity to lowest. Minimising the duplicities is one of the necessary factors that improve processing speed to get acurrent snapshot and all information throughout thelife cycle of the object within the projected system. They have planned to manage the attributes and not the complete object for the modification. Every temporal attribute is maintained in aseparate table with history being managed by thetemporal table. The static attributes are kept in one table with no duplicity. The values are tracked by theid of thetable, thecolumn being updated and table id, row id, and column id wherever the modified value is inserted. Performance experiments are carried out on Oracle 11g database with a total number of hundred thousand records in themain structure. Though providing spectacular results on performance, thesystem isn't able to get future valid values before executing the job, an automatically scheduled functionality to be executed after the scheduled time.

[7]In the column attribute level, the entire state is formed by the grouping the properties and states of the attributes. The most advantage is that the chance of data processing in time with different granularity - sensory data.

The temporal table consists of the next mentioned attributes [8] see also figure. 1:

- ID change: it's a primary key of temporal table
- ID previous change – projects the last change of an object identified by ID. This attribute can also have aNULL value that means, so the data has been inserted for the first time in past and are still actual and the data have not been updated yet.
- ID_tab – projects the table whose record has been managed by DML statement.
- ID_orig - carries the information about the identifier of the row that has been changed.
- ID_column, ID_row – hold the referential information to the old value of anattribute (if the DML statement was UPDATE). Only update statement of temporal column sets not null value.
- BD – the beginning date of the new state validity of an object.



Id2	C1	C2	C3
R1	C1_R1	C2_R1	C3_R1
R2	C2_R1	C2_R2	C2_R3
R3	C3_R1	C3_R2	C3_R3

ID	VALUE
11	C3_R1111
12	C3_R111

ID	value
36	110061
37	110037

ID	value
45	NETA NAGAR

ID	NAME	SURNAME	STREET	POST_CODE	BIRTHDATE
R4	NAMAN	JOLLY	BHAGAT SINGH STREET	110033	06/02/2003
R5	NIPUN	GUPTA	NETAJI STREET	110001	26/8/1989
R6	AMIT	NARULA	ACHARYA STREET	110057	4/6/1978
R7	MANNU	JAIN	WAZIRABAD STREET	110934	6/8/1995

ID_CHANGE PK	ID_PREVIOUS _CHANGE	ID_TAB NN	ID_ORIG NN	ID_COLUMN	ID_ROW	BD NN
1	NULL	1	R1	NULL	NULL	1/4/2017
2	NULL	2	R5	NULL	NULL	2/4/2017
3	NULL	2	R6	NULL	NULL	3/4/2017
4	1	1	R1	C3	11	4/4/2017
5	4	1	R1	C3	12	5/4/2017
6	2	2	R5	„STREET"	45	6/4/2017
7	6	2	R5	„POST_CODE"	37	7/4/2017
8	1	-1	R1	NULL	NULL	8/4/2017
9	7	-2	R5	NULL	NULL	9/4/2017

Figure 1. Column Level Temporal System Flowchart

B. *Extended Column level temporal system*

The extended column level temporal system relies on object attribute (one sensor) [8] because the main part of the granularity and can be considered because of the improvement of the column level characteristics within the term of performance and model management simplicity. The differences are based on the explicit definition of the type of the operation and opportunities to manage also transaction access. The principles of column level approach are delineated in. Moreover, new improved system definition permits existing applications to be connected to the current system without any Amendment of the program code. Only database characteristics are enlarged.

The core of the system is that the table, that manages any modification on temporal attributes. The temporal attribute represents the state (characteristics) that ought to be monitored over the time – sensing element. If the value is modified, data regarding the update is kept within the developed temporal table and historical value is inserted into to the table containing historical values. Conversely, conventional attribute represents data, that don't modify their values over the time or the system needs solelyan actual state of those elements – e.g. descriptive knowledge. The application is directly connected to the main tables with current valid values. It implies that presently used applications are used without any modification. Historical values are kept within the special section, every temporal data type has one table outlined by the identifier (primary key) got using the sequence and trigger and also the values themselves. Thus, the principle and system are comparable to the column level temporal system, however historical values management and the temporal table is different.

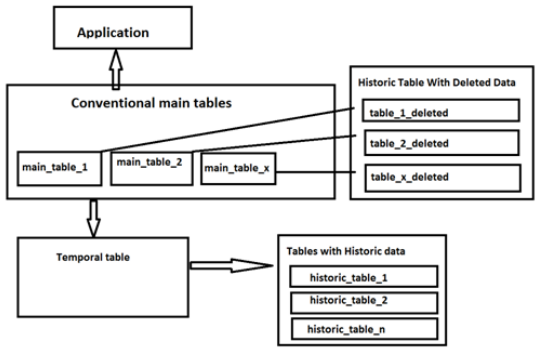


Figure 2. Extended Column Level Temporal System Architecture

C. *Epsilon Column level temporal system*

Epsilon Column Level Temporal System is an additional improvement of Extended CL TS[4]. It records only important knowledge that is defined as data wherever the difference between the new and previous value is larger than or equal to epsilon value (constant). This additional improves the performance of assorted operations like Insert and select due to areduction in thevariety of records. These models offer transaction access by using four transaction parameters. These four parameters outline the rules and conditions within which transaction is applied. These models are enforced for performance experiments using Oracle Ilg database with ten thousand magnetic resonance imaging records where every record contains ten magnetic resonance imaging results.

Widening of the temporal system definition provides epsilon (_) principle that is predicated on dependability and important change. Every sensing element has defined quality –Measurement precision. Therefore, it's not necessary to store all modified values, only those, that indeed represent important modification. The relevant data modification is characterised by the minus of the actual and new value got from the sensing element, that ought to be on top of outlined parameter (_) - threshold.

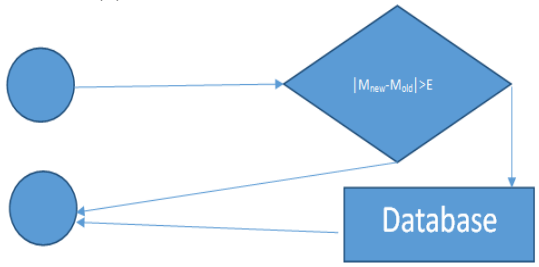


Figure 3. Process In Epsilon Column Level Temporal System

IV. Comparative Analysis of various data Models

Name of Model	Column Level Temporal System	Extended Column Level Temporal System	Epsilon Column Level Temporal System
Data Management Techniques	1.Temporal table for handling historic data 2. Each attribute of main base table has a distinct table 3.Transaction handling	1. same as Column Level, same conventional main tables-no change in thecurrent application 2.Added two extra attributes in temporal table Data type Operation Also Introduced Restore operation which provides validity restoration after transaction	1.Extended temporal table 2.Captures only significant changes-change greater than epsilon value 3. Conventional main tables-no change in current application 4. Transaction management by Transaction Access Rules

		failure or data distribution failure 3.Transaction handling by Transaction Access Rules 4.DML operations management using triggers, procedures	
Advantages	1.Data processing in time with different granularity 2.Better processing time in comparison to standard Uni-Temporal System/Bi-temporal System	1.Data processing in time with different granularity 2.Improved performance and model management simplicity as compared to Column Level Temporal System	1.Data processing in time with different granularity 2.Improved performance compared to Column Level Temporal System And Extended Column Level Temporal System due to reduction in number of records
Disadvantages	Not possible to get data valid in future before the executing of JOB	Record all the changes resulting in large number of records	Not defined
Shortcoming observed in implementation	Not Defined	Necessary to know the ratio of changed attributes to total number of attributes For Update operation	Necessary to know the ratio of changed attributes to total number of attributes For Update operation
Valid time aspect	Available	Available	Available
Transaction time aspect	un available	un available	un available
I NF relation Normal Form of Relation	Logically Not available but practically implemented in model	Logically Not available but practically implemented in model	Logically Not available but practically implemented in model
Database tool used	Oracle 11g	Oracle 11g	Oracle 11g

V. CONCLUSION AND FUTURE SCOPE

The goal of this survey is to define the concept of thetemporal database in a nutshell and compare some vital Attribute time-stamping temporal models, we have assessed few attribute time-stamping models in Temporal Database in this paper. There is no doubt that the Column Level Temporal System/Extended Column Level Temporal System of attribute time stamping model is useful whereonly the attribute is changed but not the entire object, unlike Object level temporal system where data redundancy is the key issue. Also Epsilon Column LevelTemporal System would be considered as an excellent choice where only the significant data in the historic tables are recorded, Epsilon Column Level system have a capability to save the cost of data and processing time as it selectively choose data to be inserted in the tables instead of recording each and every change which significantly reduces the size of the structure

We believe that our effort will be helpful for the researchers in designing new data models and rectifying the shortcomings of the present system.

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