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A Technique For Timeliness Measurement In Information Manufacturing System (IMS)

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A TECHNIQUE FOR TIMELINESS MEASUREMENT IN INFORMATION MANUFACTURING SYSTEM (IMS)

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Abstract

Timeliness is one of the major dimensions in the field of data quality. Freshness or obsoleteness of data is determined by timeliness data quality dimension. Generally, timeliness is calculated by currency and volatility. Currency is calculated by age, delivery time and input time. On the other side, volatility of data is the duration of the validity of data. Currency and volatility of IMS depend on the factors like refreshment period, waiting period of data in the system, expiry time of the data and the query response time for query requests. Therefore, development a technique for measuring the timeliness of data in IMS is the purpose of this paper.

Keywords: Timeliness, Age, Delivery Time, Input Time, Currency, Volatility

1. Introduction

The information manufacturing system (IMS) is the information system that manufactures information from raw data [Wang et al., 2001]. The most important component of IMS is the data storage system (DSS). It is integrated with the multiple sources of the system. Therefore, it contains inbound raw data come from multiple sources. Data comes from multiple sources are to be processed for the availability of data in the DSS of IMS. Available data in the DSS are then delivered by the processing of a query request as outbound data for information support.

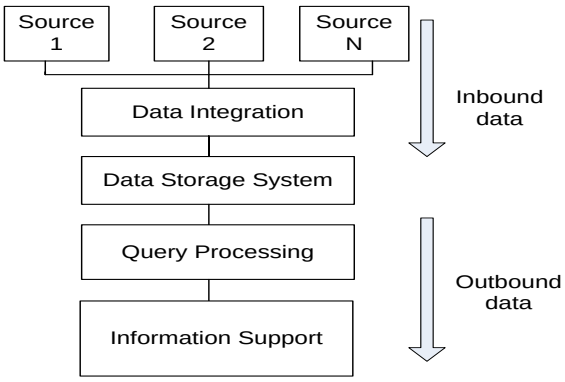

Figure 1. Information Manufacturing System

According to [Santos et al., 2008] [Bouzeghoub et al., 1999] [Mannino et al., 2006], refreshment and query function are to execute in the data storage system of IMS to make the data available and for the information support respectively.

Refreshment Function: It is a complex process comprising the tasks, such as data loading, indexing and propagation of data for synchronizing data in the information manufacturing system (IMS) [Santos et al., 2008], [Bouzeghoub et al., 1999], [Mannino et al., 2006].

Data loading: Storage of manipulating [insert, update] data are to extract from the sources; transformed data if the source data are in the different format. After that, extracted and transformed data are to integrate and to clean for loading data in the data storage system [Santos et al., 2008], [Bouzeghoub et al., 1999], [Mannino et al., 2006].

Indexing: Index is to update for newly loaded manipulated the data or delete data to align the data in the data storage system [Santos et al., 2008]. Indexing determines the effective usability of data collected and aggregated from the sources and increases the performance of the data storage system for information support [Bouzeghoub et al., 1999] [Mannino et al., 2006].

Propagation of Data: Data is to propagate through the refreshment process for synchronizing the data of multiple DSSs of the system.

Query Function: This function of data storage system in IMS is done by the query processing task. The requested query of the user is processed in the data storage system for delivering the information to the user.

In IMS, availability is low, timeliness of data is high. On the contrary, availability is high, timeliness of data is low [Capiello and Helfert, 2008]. Timeliness of data ensure the freshness and obsoleteness of data in IMS [Capeillo et al., 2005]. Therefore, timeliness can make an impact on the accuracy of data in IMS. Further, quality aware query system is now used in the internet system or some other system. For example,
Select the medicine's name, price and the timeliness score of price from relation medicine, for medicine for 'headache', with the timeliness score for amount information greater than 0.60 [Dong et al., 2006].

SELECT Name, Price, TIMELINESS (Price)
FROM Medicine
WHERE Category = 'headache'
WITH QUALITY AS
TIMELINES (Amount) > '0.60'

Furthermore, stock exchange, banking system etc. is to provide continuous information service to the customer. Data of these organizations could be stale for not updating data in time. Therefore, if it is possible to inform the customer about the obsoleteness of data, customer does not get the inaccurate information. Hence, the purpose of this paper is to show a technique for measuring the timeliness of data in IMS.

2. Related Research

[Mannino et al., 2006] discussed the necessity and requirements of timeliness in the organizations. [Santos et al., 2008] works on the data quality of time related environment. In the time related environment, data is to deliver as soon as possible to meet the user demand. Data may not deliver as soon as possible for the refreshment process of DSS in IMS. Refreshment process is one of the main data warehouse DSS processes for which quality is an important issue. Factors of timeliness data quality dimensions such as age can be affected for the refreshment process. Therefore, usage and evolution of quality oriented data warehouse DSS are described by [Vassiliadis et

al., 2000]. [Theodoratos and Bouzeghoub, 1999] works on the currency quality factors for data warehouse DSS. Data currency quality goal is expressed by currency constraint associated with every source relation in the definition of every input query. Contribution of the paper of [Sampaio et al., 2005] is addressing data quality issues such as timeliness of data resulting from internet query processing. [Dong et al., 2006] works on the currency bound query request to address the quality of the data of a query result. [Batini and Scannapieco, 2006] describes that trade-off is done for the timeliness in the different environment, such as, web application, administrative application etc. These applications could have redundant data system. Therefore, the presence of trade-offs between availability and timeliness in the data redundant system is analyzed by [Capiello and Helfert, 2008]. The time interval between the realignments and late propagation of data may cause the obsoleteness of data in the redundant system. In data redundant system, timeliness is considered as a critical dimension. Timeliness depends on two factors: the time instant in which data are inserted in the sources or transferred to another system and data volatility. [Ballou et al., 1998], measure the timeliness of data unit for each individual block by developing the timeliness data quality assessment function. In this paper, measurement of timeliness of primitive data units depends on the change frequency of data (long term changing or frequently/ short term changing), volatility of data and the customer's demand of the data for the information product. Volatility of data relies on the change frequency of data and the types of customer/ investors who will use the data. The currency of the overall age of a primitive data unit is good or bad depending on the data unit's volatility. A large value for currency is unimportant if the volatility is infinite. On the other hand, a small value for currency can be deleterious to the quality if the volatility is short. Therefore, timeliness of data unit is measured by the ratio of currency and volatility. [Capiello et al., 2005] measures the time related data quality in both theoretical and experimental aspects. This measurement shows the role of currency dimension for the obsoleteness of data and also shows the timeliness measurement from the currency and volatility value in IMS. Certification of data quality for timeliness is also shown in this paper.

3. Timeliness of Data in IMS

According to [Batini et al., 2006] and [Wang et al., 1993], Timeliness can be defined as currency and volatility dimensions. More specifically, it can be written,

Max (0, 1 – currency/volatility)

Currency of Data in IMS:

According to [Redman, 1996], currency is the degree to which datum is up-to-date. For example, currency indicates how stale is the account balance presented to the user with respect to the real balance at the bank. [Segev and Weiping, 1990] define the currency by capturing the gap between the extraction of data from the sources and its delivery to the users. Therefore, [Batini et al., 2006], generalized following formula for measuring the currency of the data,

Currency = Age + (Delivery Time – Input Time)

Where Age measures how old the data unit is when received, delivery time is the time information product is delivered to the user and input time is the time data unit is obtained. Therefore, the currency dimension of data in the data storage system (DSS) depends on the age, delivery time and input time. In the data storage system (DSS), these parameters can be recognized as below,

General Currency Parameter	DSS Currency Parameter	Notation
Age	Waiting Period + Refreshment Processing Period	W (t) + Rpro(t)
Delivery Time	Query Response Time	Q_T
Input Time	Insertion Time of Data in DSS	I_T

Table 1. Currency Parameter of IMS

Age (A_T): It can be calculated in DSS by adding waiting time of data with the refreshment processing time of data. Waiting time means how long data is waiting in the source before the refreshment processing of data in IMS for the insertion of data in the DSS. Refreshment processing time is calculated by adding the following parameters.

Refreshment Processing Time Parameters	Description	Notation
Loading Period	Time needs for loading data in DSS	L (t)
Indexing Period	Time needs for indexing data in DSS	Ix (t)
Propagation Delay	Time needs for propagating data from one DSS to another DSS.	P (t)

Table 2. Refreshment Processing Period Parameters

Therefore, it can be calculated the refreshment processing time of the data in DSS in the following way,

$$Rpro\ (t) = L\ (t) + Ix\ (t) + P\ (t)$$

Data loading is the mandatory task for making data available in IMS. Indexing and propagation of data does not need for each type of IMS for making data available. Therefore, the refreshment processing period is varied if data do not need to be indexed or data do not need to be propagated in the IMS.

Input Time (I_T): Data has to be inserted in DSS for making data available in IMS. Data insertion will be completed if refreshment processing of data in the DSS is done. Therefore, end of refreshment processing time point of a data is the input time of data.

Delivery Time (Q_T): It is defined in DSS by query response time. This query response time of DSS means, what time query request of a user query is responded in DSS.

Volatility of Data in IMS:

As the definition of volatility, it is known that the length of time data remains valid is volatility [Batini et al., 2006]. Therefore, volatility of data depends on the expiry time of each individual data of DSS. Expiry time of data varies for the change frequency of data. Therefore, following formula can be written for the calculation of volatility period of a data in the DSS of IMS,

$$Volatility = Expiry\ Time - Input\ Time$$

Expiry time indicates the limit of the validity of data or the currency binding time of data. It can be represented as E_T. Input time is discussed in above.

4. Timeliness of Data Measurement in IMS

Data comes from multiple sources are stored in the IMS. The set of data that are stored in IMS can be shown as,

Set of Storage Data (d_i) in IMS = {d_1, d_2, d_3… d_n}

Currency of Data Calculation in IMS:

Currency of data could be changed for the continuous or periodic refreshment process in IMS. Therefore, currency of data can be calculated in IMS by the following formula,

$$\textbf{Currency Calculation of Data in IMS} = A_T(d_i) + \int_{I_T}^{Q_T} d_i \, dt$$

Age of the data could be varied for the continuous and periodic refreshment process. Therefore, the formula of the age calculation for continuous and periodic refreshments are given below,

Age calculation for the continuous refreshment process,

$$A_T = Rpro\ (t)$$

$$= L(t) + Ix(t) + P(t)$$

Age calculation for the periodic refreshment process,

$$A_T = W\ (t) + RPro(t))$$

$$= W(t) + (\ L(t) + Ix(t) + P(t)\ )$$

These data could be delivered in different moment of time. Therefore, the set of delivery time or query response time can be shown as,

Set of Query Response Time of Data in IMS (Q_T (d_i)) = { Q_T, (Q_T + 1), (Q_T + 2)… (Q_T + n) }

The input time depends on the end of refreshment processing time point of a data. Therefore, input time of each data of IMS will not be exact. Hence, the set of input time of stored data in IMS can be shown as,

Set of Input Time of Data in IMS (I_T (d_i)) = { I_T , (I_T + 1), (I_T + 2)… (I_T + n) }

Volatility of Data Calculation in IMS:

Expiry time and input time are important for calculating the volatility of the data. Therefore, we can calculate the volatility of each datum of the IMS by considering the following formula,

Volatility of Data Calculation in IMS = $\int_{I_T}^{E_T} d_i \, dt$

DSS of IMS can contain uniform or non-uniform change frequency of data. Therefore, expiry time of each DSS data may not be exact. Hence, the set of the expiry time of all data of DSS can be shown in the following way,

Set of Expiry Time of Data in IMS $E_T(d_i) = \{E_T, E_T + 1, E_T + 2 \ldots\ldots\ldots\ldots E_T + n\}$

Set of input time of data of the IMS are shown in the currency calculation of data in IMS section. These sets of input time can be used for calculating the volatility of data in IMS.

Timeliness of Data Calculation in IMS:

Now, the following timeliness formula can be formed by using the currency and volatility formula shown in above. Timeliness of each data in IMS can be calculated by using the following formula.

Timeliness of Data in IMS = $1 - \frac{\mathbf{A_T(d_i)} + \int_{I_T}^{Q_T} d_i dt}{\int_{I_T}^{E_T} d_i dt}$

5. Timeliness of Data Measurement in Simulated IMS

A timeliness measurement tool has been used for measuring the timeliness of data in simulated IMS. A large volume of data is extracted from the sources with the refreshment process and stored data in the data storage system. SQL server database software is used for creating the data storage system. Both periodic and continuous refreshment process is used for measuring the age of data in simulated IMS. For the continuous refreshment mechanism, only the refreshment processing period is counted for calculating the age. On the other side, time distance between two consecutive refreshment periods is counted as the waiting time for the periodic refreshment mechanism. Therefore, this time distance is added to the refreshment processing period for calculating the age of the data. Starting of the refreshment processing period is indicated by the starting time in the tool. Further, validity of data depends on the change frequency of data, therefore, an expiry time is added to each data row of the sources for measuring the volatility of the data. Henceforth, timeliness is calculated in simulated IMS by responding the query request.

Timeliness Measurement Tool

Application IMS About

INPUT TIME	STARTING TIME	DELIVERY TIME	EXPIRY TIME	AGE in MS	CURRENCY in MS	VOLATILITY in MS	TIMELINESS
12-08-13 03:23:29:640	2012-08-13 03:23:29:627	2012-08-13 03:27:11:560	2012-08-13 03:31:40:000	13	221933	490373	0.55
12-08-13 03:23:29:640	2012-08-13 03:23:29:627	2012-08-13 03:27:11:560	2012-08-13 03:31:40:000	13	221933	490373	0.55
12-08-13 03:23:29:640	2012-08-13 03:23:29:627	2012-08-13 03:27:11:560	2012-08-13 03:31:40:000	13	221933	490373	0.55
12-08-13 03:23:29:640	2012-08-13 03:23:29:627	2012-08-13 03:27:11:560	2012-08-13 03:31:40:000	13	221933	490373	0.55
12-08-13 03:23:29:653	2012-08-13 03:23:29:627	2012-08-13 03:27:11:560	2012-08-13 03:31:40:000	26	221946	490373	0.55
12-08-13 03:23:29:653	2012-08-13 03:23:29:627	2012-08-13 03:27:11:560	2012-08-13 03:31:40:000	26	221946	490373	0.55
12-08-13 03:23:29:653	2012-08-13 03:23:29:627	2012-08-13 03:27:11:560	2012-08-13 03:31:40:000	26	221946	490373	0.55
12-08-13 03:23:29:670	2012-08-13 03:23:29:627	2012-08-13 03:27:11:560	2012-08-13 03:31:40:000	43	221963	490373	0.55
12-08-13 03:23:29:670	2012-08-13 03:23:29:627	2012-08-13 03:27:11:560	2012-08-13 03:31:40:000	43	221963	490373	0.55
12-08-13 03:23:29:670	2012-08-13 03:23:29:627	2012-08-13 03:27:11:560	2012-08-13 03:31:40:000	43	221963	490373	0.55
12-08-13 03:23:29:670	2012-08-13 03:23:29:627	2012-08-13 03:27:11:560	2012-08-13 03:31:40:877	43	221963	491250	0.55
12-08-13 03:23:29:687	2012-08-13 03:23:29:627	2012-08-13 03:27:11:560	2012-08-13 03:31:40:000	60	221980	490373	0.55
12-08-13 03:23:29:687	2012-08-13 03:23:29:627	2012-08-13 03:27:11:560	2012-08-13 03:31:40:000	60	221980	490373	0.55
12-08-13 03:23:29:687	2012-08-13 03:23:29:627	2012-08-13 03:27:11:560	2012-08-13 03:31:40:000	60	221980	490373	0.55
12-08-13 03:23:29:687	2012-08-13 03:23:29:627	2012-08-13 03:27:11:560	2012-08-13 03:31:40:000	60	221980	490373	0.55
12-08-13 03:23:29:700	2012-08-13 03:23:29:627	2012-08-13 03:27:11:560	2012-08-13 03:31:40:000	73	221993	490373	0.55
12-08-13 03:23:29:700	2012-08-13 03:23:29:627	2012-08-13 03:27:11:560	2012-08-13 03:31:40:000	73	221993	490373	0.55
12-08-13 03:23:29:700	2012-08-13 03:23:29:627	2012-08-13 03:27:11:560	2012-08-13 03:31:40:000	73	221993	490373	0.55
12-08-13 03:23:29:700	2012-08-13 03:23:29:627	2012-08-13 03:27:11:560	2012-08-13 03:31:40:000	73	221993	490373	0.55
12-08-13 03:23:29:700	2012-08-13 03:23:29:627	2012-08-13 03:27:11:560	2012-08-13 03:31:40:000	73	221993	490373	0.55
12-08-13 03:23:29:717	2012-08-13 03:23:29:627	2012-08-13 03:27:11:560	2012-08-13 03:31:40:000	90	222010	490373	0.55
12-08-13 03:23:29:717	2012-08-13 03:23:29:627	2012-08-13 03:27:11:560	2012-08-13 03:31:40:000	90	222010	490373	0.55

Figure 2. Timeliness Measurement in IMS for Continuous Refreshment Process

Timeliness Measurement Tool

Application IMS About

INPUT TIME	STARTING TIME	DELIVERY TIME	EXPIRY TIME	AGE in MS	CURRENCY in MS	VOLATILITY in MS	TIMELINESS
2-08-13 03:43:25:...	2012-08-13 03:43:25:...	2012-08-13 03:47:07:...	2012-08-13 03:51:36:...	120013	341573	490373	0.30
2-08-13 03:43:25:...	2012-08-13 03:43:25:...	2012-08-13 03:47:07:...	2012-08-13 03:51:36:...	120013	341573	490373	0.30
2-08-13 03:43:25:...	2012-08-13 03:43:25:...	2012-08-13 03:47:07:...	2012-08-13 03:51:36:...	120013	341573	490373	0.30
2-08-13 03:43:25:...	2012-08-13 03:43:25:...	2012-08-13 03:47:07:...	2012-08-13 03:51:36:...	120013	341573	490373	0.30
2-08-13 03:43:25:...	2012-08-13 03:43:25:...	2012-08-13 03:47:07:...	2012-08-13 03:51:36:...	120026	341619	490373	0.30
2-08-13 03:43:25:...	2012-08-13 03:43:25:...	2012-08-13 03:47:07:...	2012-08-13 03:51:36:...	120026	341619	490373	0.30
2-08-13 03:43:25:...	2012-08-13 03:43:25:...	2012-08-13 03:47:07:...	2012-08-13 03:51:36:...	120026	341619	490373	0.30
2-08-13 03:43:25:...	2012-08-13 03:43:25:...	2012-08-13 03:47:07:...	2012-08-13 03:51:36:...	120043	341650	490373	0.30
2-08-13 03:43:25:...	2012-08-13 03:43:25:...	2012-08-13 03:47:07:...	2012-08-13 03:51:36:...	120043	341650	490373	0.30
2-08-13 03:43:25:...	2012-08-13 03:43:25:...	2012-08-13 03:47:07:...	2012-08-13 03:51:36:...	120043	341650	490373	0.30
2-08-13 03:43:25:...	2012-08-13 03:43:25:...	2012-08-13 03:47:07:...	2012-08-13 03:51:36:...	120043	341650	490373	0.30
2-08-13 03:43:25:...	2012-08-13 03:43:25:...	2012-08-13 03:47:07:...	2012-08-13 03:51:36:...	120043	341650	490373	0.30
2-08-13 03:43:25:...	2012-08-13 03:43:25:...	2012-08-13 03:47:07:...	2012-08-13 03:51:36:...	120060	341679	490373	0.30
2-08-13 03:43:25:...	2012-08-13 03:43:25:...	2012-08-13 03:47:07:...	2012-08-13 03:51:36:...	120060	341679	490373	0.30
2-08-13 03:43:25:...	2012-08-13 03:43:25:...	2012-08-13 03:47:07:...	2012-08-13 03:51:36:...	120060	341679	490373	0.30
2-08-13 03:43:25:...	2012-08-13 03:43:25:...	2012-08-13 03:47:07:...	2012-08-13 03:51:36:...	120060	341679	490373	0.30
2-08-13 03:43:25:...	2012-08-13 03:43:25:...	2012-08-13 03:47:07:...	2012-08-13 03:51:36:...	120060	341679	490373	0.30
2-08-13 03:43:25:...	2012-08-13 03:43:25:...	2012-08-13 03:47:07:...	2012-08-13 03:51:36:...	120073	341705	490373	0.30
2-08-13 03:43:25:...	2012-08-13 03:43:25:...	2012-08-13 03:47:07:...	2012-08-13 03:51:36:...	120073	341705	490373	0.30
2-08-13 03:43:25:...	2012-08-13 03:43:25:...	2012-08-13 03:47:07:...	2012-08-13 03:51:36:...	120073	341705	490373	0.30

Figure 3. Timeliness Measurement in IMS for Periodic Refreshment Process

Measurement of timeliness in IMS is done by the timeliness function given in section 3. Figure 2 shows the timeliness calculation for the execution of continuous refreshment process in IMS. Therefore, waiting period is not considered for the

currency calculation. On the other hand, figure 3 is the timeliness calculation for periodic refreshment process in IMS. As, periodic refreshment is done in IMS, waiting period is added to the other factors of the currency parameter of timeliness. Waiting periods of data in the source are 2 minutes or 120000 milliseconds as periodic refreshment is done after each consecutive 2 minutes.

6. Conclusion

This paper proposes a technique for measuring the timelines in IMS. Timeliness is the indicator of freshness or obsoleteness of data in IMS. It could be varied for the heterogeneity of IMS. This can also affect on other data quality dimensions such as completeness, accuracy etc. in IMS. Therefore, our future research will show the influence on data quality for timeliness in heterogeneous IMS.

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