DB2 for i – Temporal Support

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Enhancements timed with TR4:
- Inlined UDTFs
- Trigger (re)deployment
- More IBM i Services
- New DB2 built-in Global Variables
- Enhanced SQL Scalar functions
- Evaluation option for DB2 SMP & DB2 Multisystem

Enhancements timed with TR5 & TR1:
- JSON, TABLE()
- INCLUDE for SQL Routines
- Database features in ACS
- Faster Scalar Functions
- More IBM i Services
- New DB2 for i Services
- And much more…

DB2 for i – Enhancements delivered via DB2 PTF Groups
Major enhancements in DB2 for i deliver significant client value:

- **Temporal Tables – History of rows**
  Data-centric, easily deployed, robust SQL point-in-time capability

- **Online Analytical Processing (OLAP) built-in functions**
  Adding more analytics capabilities directly into DB2 for i

- **Generated Columns for auditing – Row level identity**
  Let DB2 maintain the who, what, & how a row came to be

- **And… all the TR-timed enhancements delivered to IBM i 7.2**
  IBM i Services, VARCHAR_FORMAT, built-in global variables, and many more
What is Temporal?

**Temporal:**

*definition (from dictionary.com)*

- adjective
  - of or relating to time
  - enduring for a time only; temporary; transitory

From a database perspective, ‘temporal’ means managing and maintaining time-related data - **rows in a table**

(the temporary part is up to you 😊)

What is DB2 Temporal support?

To **support** temporal data, database **must** satisfy multiple requirements

- Augment data to provide a time dimension
- Retain/safeguard history of data changes over time
- Provide a way to identify when data changes occur and when data was/is relevant
- Ensure ‘normal’ access uses the latest data and is not ‘confused’ with history

Example of data to be tracked:

- a) Savings account is opened on Monday
- b) Deposit is made mid Tuesday
- c) Withdrawals are made Wednesday and Thursday
- d) Deposits and withdrawals made Friday

Following Monday – banking officials investigate for possible money laundering (joke)
What is DB2 Temporal support cont...

To simplify usage of temporal data, database should provide certain features

- Provide a reasonable way to view the data from a certain point in time
- Simplify the work to apply a point-in-time view for a set of operations e.g. across an application
- Potentially support a way to view data for a specific span of time

Examples:

- What was the account balance Tuesday morning?
- How many deposits and withdrawals occurred between Tuesday 10AM and Thursday 4:30PM?
- Compare the account balance of Monday evening vs. Thursday morning

Auditors love this stuff

More temporal examples

With Temporal Tables, you can answer time-based questions:

- Who was the client rep two years ago?
- Who were the client reps over the last five years?
- Produce an inventory report using a different point in time
Welcome to the Waitless World

DB2 for i & Temporal

IBM i – Common ‘Do It Yourself’ options

Option 1: journals and scraping
- Accessing Data: SELECT
- Modifying Data: INSERT, UPDATE, DELETE
- Changes

Option 2: history table
- Accessing Data: SELECT
- Modifying Data: INSERT, UPDATE, DELETE
- Triggers
- UNION

Tedious
Specialized
Limited
Welcome to the Waitless World

DB2 for i 7.3 temporal support – DB2 for i Manages History!

Accessing Data
- SELECT

Modifying Data
- INSERT
- UPDATE
- DELETE

Accessing Data
- SELECT

Modifying Data
- INSERT
- UPDATE
- DELETE (DBE Only)

Current table

System Managed

History table

DB2 for i and Temporal Tables

With DB2 Temporal Tables, you can ask:

- Who was the client rep two years ago?
  
  SELECT CLIENT_REP FROM ACCOUNTS
  
  FOR SYSTEM_TIME AS OF CURRENT_TIMESTAMP – 2 YEARS

- Who were the client reps over the last five years?
  
  SELECT CLIENT_REP FROM ACCOUNTS
  
  FOR SYSTEM_TIME FROM CURRENT_TIMESTAMP – 5 YEARS
  
  TO CURRENT_TIMESTAMP

- Run the inventory report using a different point in time
  
  SET CURRENT_TEMPORAL_SYSTEM_TIME '2016-12-26 17:00:00';
  
  CALL GENERATE_INVENTORY_REPORT();
How? The foundation

DB2 keeps the history of each row in a temporal table over time

- Q: Is this the same as keeping history of a **business** transaction?

What pieces are needed for tracking data (row) history?

- A repository for the rows’ history – **history table**
- An identifier to track a row as it changes over time – **transaction id**
- When was a row’s historic value valid? – **row begin and row end** timestamps

Configuring a Temporal Table

```sql
ALTER TABLE employee
ADD COLUMN instance_begin
TIMESTAMP(12) NOT NULL
GENERATED ALWAYS AS ROW BEGIN
ADD COLUMN instance_end
TIMESTAMP(12) NOT NULL
GENERATED ALWAYS AS ROW END
ADD COLUMN transaction_id
TIMESTAMP(12)
GENERATED ALWAYS AS TRANSACTION START ID ADD PERIOD
SYSTEM_TIME (instance_begin, instance_end)
```

- Establish birth/death of a row

```sql
CREATE TABLE employee_history LIKE employee
```

- Create history table

```sql
ALTER TABLE employee ADD VERSIONING USE HISTORY TABLE employee_history
```

- Enable Temporal tracking
Configuring a Temporal Table

```
ALTER TABLE employee
ADD COLUMN instance_begin
    TIMESTAMP(12) NOT NULL IMPLICITLY HIDDEN
    GENERATED ALWAYS AS ROW BEGIN
ADD COLUMN instance_end
    TIMESTAMP(12) NOT NULL IMPLICITLY HIDDEN
    GENERATED ALWAYS AS ROW END
ADD COLUMN transaction_id
    TIMESTAMP(12) IMPLICITLY HIDDEN
    GENERATED ALWAYS AS TRANSACTION START ID ADD PERIOD
    SYSTEM_TIME (instance_begin, instance_end)

CREATE TABLE employee_history LIKE employee

ALTER TABLE employee
ADD VERSIONING USE HISTORY TABLE employee_history

Create history table
Establish birth/death of a row
Enable Temporal tracking
```

Temporal FAQs

- Can there be more than one temporal table on my system?
  - Absolutely. Temporal is per table, so many tables can be made temporal (except history tables of course)

- Can a DDS file (not just DDL/SQL) be made temporal?
  - Yes, though the three timestamp fields must exist in the file, which requires ALTER TABLE to add

- Is journaling required? -- Yes

- Can I mix different FOR SYSTEM_TIME settings in different parts of a select e.g. two sides of a UNION can be at different SYSTEM_TIMEs? -- Yes

- Are constraints supported?
  - Yes on the main table, but constraints are not allowed on the history table
Temporal FAQs...

- Can I attach an existing table as the history table?
  - Yes, but columns and attributes must exactly match. Simplest is to use CREATE TABLE LIKE

- Can the history table have a superset of columns of the main table? -- No

- Can columns in the history table be in a different order than the corresponding columns in the main table? -- No

- Can column attributes be different (but compatible) between main table and history table?
  - No, attributes must exactly match

- Can I ALTER TABLE a temporal (main) table to add a column?
  - Yes. The database automatically adds the same column to the history table

- Can I ALTER TABLE of a temporal (main) table to drop a column?
  - No. History could be lost so database prevents it

SQL access is by far preferred for **time-based access** since ease of access is built into the language

- When SQL statements reference the current table, DB2 for i automatically accesses the history table as needed

- New clauses on the SELECT statement
  - FOR SYSTEM_TIME AS OF <value>
  - FOR SYSTEM_TIME FROM <value> TO <value>
  - FOR SYSTEM_TIME BETWEEN <value> AND <value>

- New special register
  - CURRENT TEMPORAL SYSTEM_TIME

Note:
- Native access is manual work. Current and history tables are considered different accesses
- Database **does** still manage (and enforce) history tracking, even for native driven data changes
Temporal in motion

**Inserting rows does not impact the history table**

- ROW BEGIN (RB) Column – timestamp when the row was born
- ROW END (RE) Column – set to “end of time”

**Temporal in motion**

**Updating rows causes rows to be added to the history table**

- ROW BEGIN (RB) Column – timestamp when the row was born
- ROW END (RE) Column – the death of the row results in the RE of the historical row matching the RB of the active row
Temporal in motion

Deleting rows removes them from the temporal table and adds them to history table

- ROW END (RE) Column – set to the death time of the row

Optional autogenerated columns

DATA CHANGE OPERATION
- one character value recording the last data change:
  - I = Insert
  - U = Update
  - D = Delete

Note: the Delete record will be included if the temporal table was configured with the ON DELETE ADD EXTRA ROW clause.

SESSION_USER
- (var)char containing the user profile currently in use which identifies who is making the data change to the database

Ex:
ALTER TABLE fact_table
ADD COLUMN audit_type_change CHAR (1) GENERATED ALWAYS AS (DATA CHANGE OPERATION)
ADD COLUMN audit_user VARCHAR(128) GENERATED ALWAYS AS (SESSION_USER)
Data Change Operation and Row-level Auditing detail

History table stores previous versions of a system-period temporal table’s rows

- ROW BEGIN (RB) Column – timestamp when the rows were born
- ROW END (RE) Column – set to “end of time”
- Data Change Operation (CHG) – ‘I’ for INSERT
- Session User (USR) – identity of inserter

<table>
<thead>
<tr>
<th>Temporal TABLE</th>
<th>RB</th>
<th>RE</th>
<th>TS</th>
<th>CHG</th>
<th>USR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>I</td>
<td>Tom</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>I</td>
<td>Tom</td>
</tr>
</tbody>
</table>

Data Change Operation and Row-level Auditing detail

History table stores previous versions of a system-period temporal table’s rows

- ROW BEGIN (RB) Column – Birth
- ROW END (RE) Column – Death
- Data Change Operation (CHG) – ‘U’ for UPDATE
- Session User (USR) – identity of updater

<table>
<thead>
<tr>
<th>Temporal TABLE</th>
<th>RB</th>
<th>RE</th>
<th>TS</th>
<th>CHG</th>
<th>USR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>U</td>
<td></td>
<td>I</td>
<td></td>
<td>Nick</td>
</tr>
<tr>
<td></td>
<td>I</td>
<td></td>
<td></td>
<td>I</td>
<td>Tom</td>
</tr>
</tbody>
</table>
ON DELETE ADD EXTRA ROW – in motion

History table stores previous versions of a system-period temporal table’s rows

- ROW BEGIN (RB) Column – Birth
- ROW END (RE) Column – Death
- Data Change Operation (CHG) – ‘D’ for DELETE
- Session User (USR) – identity of deleter

<table>
<thead>
<tr>
<th>Temporal TABLES</th>
<th>RB</th>
<th>RE</th>
<th>TS</th>
<th>CHG</th>
<th>USR</th>
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</thead>
<tbody>
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<td>Tom</td>
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<td></td>
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<td></td>
<td>Nick</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td>Tom</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Jim</td>
</tr>
</tbody>
</table>

Temporal – more example queries

- Compare balances between different points in time for account 88880001

```sql
SELECT T1.BALANCE AS BALANCE_2013,
      T2.BALANCE AS BALANCE_2014
FROM account
  FOR SYSTEM_TIME AS OF '2013-12-31' T1,
  account
  FOR SYSTEM_TIME AS OF '2014-12-31' T2
WHERE T1.ACCT_ID = '88880001' AND T2.ACCT_ID = '88880001';
```

<table>
<thead>
<tr>
<th>BALANCE_2013</th>
<th>BALANCE_2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>50000.00</td>
<td>60000.00</td>
</tr>
</tbody>
</table>
Temporal – more example queries

- Query all versions of rows for account ‘88880001’

```sql
SELECT ACCT_ID,
       BALANCE,
       BALANCE - LAG(BALANCE,1,0) OVER(ORDER BY TRANSACTION_TIME) AS CHANGES,
       TRANSACTION_TIME,
       ROW_DEATH
FROM account FOR SYSTEM_TIME
BETWEEN '0001-01-01' AND '9999-12-30'
WHERE ACCT_ID = '88880001'
ORDER BY TRANSACTION_TIME ASC;
```

LAG is one of many new OLAP specifications added in IBM i 7.3

Temporal – more example queries

- Query all versions of rows for account ‘88880001’

```sql
SELECT ACCT_ID,
       BALANCE,
       BALANCE - LAG(BALANCE,1,0) OVER(ORDER BY TRANSACTION_TIME) AS CHANGES,
       TRANSACTION_TIME,
       ROW_DEATH
FROM account FOR SYSTEM_TIME
BETWEEN '0001-01-01' AND '9999-12-30'
WHERE ACCT_ID = '88880001'
ORDER BY TRANSACTION_TIME ASC;
```

System Time Sensitivity is controlled at the program level:

- `SYSTEM_TIME_SENSITIVE` column within catalog QSYS2.SYSPROGRAMSTAT
  - `NULL` or `'NO'` – Program is not time sensitive
  - `'YES'` – Program is time sensitive
- Programs built prior to IBM i 7.3 are by default, not time sensitive
  - `CURRENT TEMPORAL SYSTEM_TIME` is ignored
- Programs (re)built on IBM i 7.3 are by default, time sensitive
  - `CURRENT TEMPORAL SYSTEM_TIME` is applied when queries reference temporal tables

Build time controls:

- Routines (SQL/External) → `SET OPTION SYSTIME = 'YES' or 'NO`
- `CRTSQLxxx` → `OPTION('SYSTIME' or 'NOSYSTIME')`
- `RUNSQLSTM` → `SYSTIME('YES' or 'NO')`
Considerations with temporal tables

Aggregation (GROUP BY)

- Be very careful aggregating across time ranges: FOR SYSTEM_TIME BETWEEN or FOR SYSTEM_TIME FROM. A ‘row’ could be counted several times!

Ex:  
SELECT COUNT(*) FROM ORDER_HEADER  
FOR SYSTEM_TIME BETWEEN '0001-01-01' AND '9999-12-30';

Does NOT count the total number of orders since the beginning!

Joins (joining tables)

- From a business perspective, do all tables need to be temporal?  
  - Is a subset of tables enabled as temporal enough?
- Could the join column(s) change when a row is updated?  
  - If so, think through update situations to ensure answers are consistent

Warning!
Enhanced data-centric auditing – with autogenerated columns

- Autogenerated columns are a very powerful building block for data-centric programming in that they direct the database to automatically generate column values
  - Database manages them. Row values cannot be altered, even by a developer

- Prior to IBM i 7.3, DB2 for i supported:
  - IDENTITY columns (which are very good for surrogate primary keys)
  - ROW CHANGE TIMESTAMP (which records the time whenever a row is changed)

- The SQL syntax GENERATED ALWAYS prevents anyone from modifying those column values, including a knowledgeable hacker

- IBM i 7.3 includes support for additional options:
  - DATA CHANGE OPERATION (I/U/D)
  - Special register
  - Built-in Global Variable

Autogenerated columns – DATA CHANGE OPERATION

- DATA CHANGE OPERATION is a one character value recording the last data change:
  - I = Insert
  - U = Update
  - D = Delete

- These work well with temporal tables in that history table will provide a timeline of what changes were made and when
  - The Delete record will be included if the temporal table was configured with the ON DELETE ADD EXTRA ROW clause

```
ALTER TABLE fact_table
  ADD COLUMN audit_type_change CHAR (1)
  GENERATED ALWAYS AS (DATA CHANGE OPERATION)
```
Special Registers and Global Variables (Review)

DB2 provides different ways to communicate across an application flow. Two are of particular interest:

1. **Special Registers**
   - Predefined special values that can be referenced in SQL
     - Examples: CURRENT USER, CURRENT TIMESTAMP, CURRENT DATE...
   - Most registers are maintained by the database. However, some registers can be SET by the application
     - Examples: CLIENT_ACCTNG, CLIENT_USERID...

2. **Global Variables**
   - Variables that can be created and used across SQL statements
     - Example:
       ```sql
       CREATE VARIABLE QGPL.MYVAR INT DEFAULT 123
       ...
       SELECT * FROM MYTAB WHERE MYCOL = QGPL.MYVAR
       ```
   - Database defines and manages some built-in global variables
     - Examples: QSYS2.JOB_NAME, SYSIBM.CLIENT_IPADDR

**Review!**

### Autogenerated columns – special registers

- Special registers can be used to record information about the user making the change and/or the application environment
- Client registers can be set by the application to provide additional application information
- CURRENT SERVER contains the currently connected server
- SESSION_USER and USER contain the user profile currently in use which identifies who is making a change to the database

```sql
ALTER TABLE fact_table
ADD COLUMN audit_app_client_userid VARCHAR(255)
GENERATED ALWAYS AS (CURRENT CLIENT_USERID)
ADD COLUMN audit_user VARCHAR(128)
GENERATED ALWAYS AS (SESSION_USER)
```
Autogenerated columns – built-in global variables

- Built-in global variables are managed by the system and provide additional environmental information
- You can use these to monitor things like which job or which IP address is being used to make a change to the database

```sql
ALTER TABLE fact_table
ADD COLUMN audit_job_name VARCHAR(28) GENERATED ALWAYS AS (QSYS2.JOB_NAME)
ADD COLUMN audit_client_IP VARCHAR(128) GENERATED ALWAYS AS (SYSIBM.CLIENT_IPADDR)
```

More Information
DB2 for IBM i Resources

• DB2 for IBM i homepage:  www.ibm.com/systems/power/software/i/db2

• DB2 for IBM i wiki:  ibm.biz/Bd4fFb

DB2 for IBM i Lab Services

• Facilitated workshops covering current state, requirements, future state, possible solutions, implementation best practices, and formulation of a strategic roadmap:
  • RCAC
  • Temporal Tables

• Customized consulting workshops
  • Advanced SQL and Datacentric Programming
  • SQL Performance Best Practices, Monitoring and Tuning

• Consulting on any DB2 for i topic

For more information, contact mcain@us.ibm.com
DB2 for i – SQL Programming Resources

Essential resource for SQL & DB2 for i database application development
Refreshed in 2016

www.redbooks.ibm.com/abstracts/sg248326.html

Thank You!

www.ibm.com/developerworks/ibmi/techupdates/db2
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