Natively Compiled T-SQL
The Fastest SQL Ever

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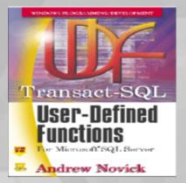

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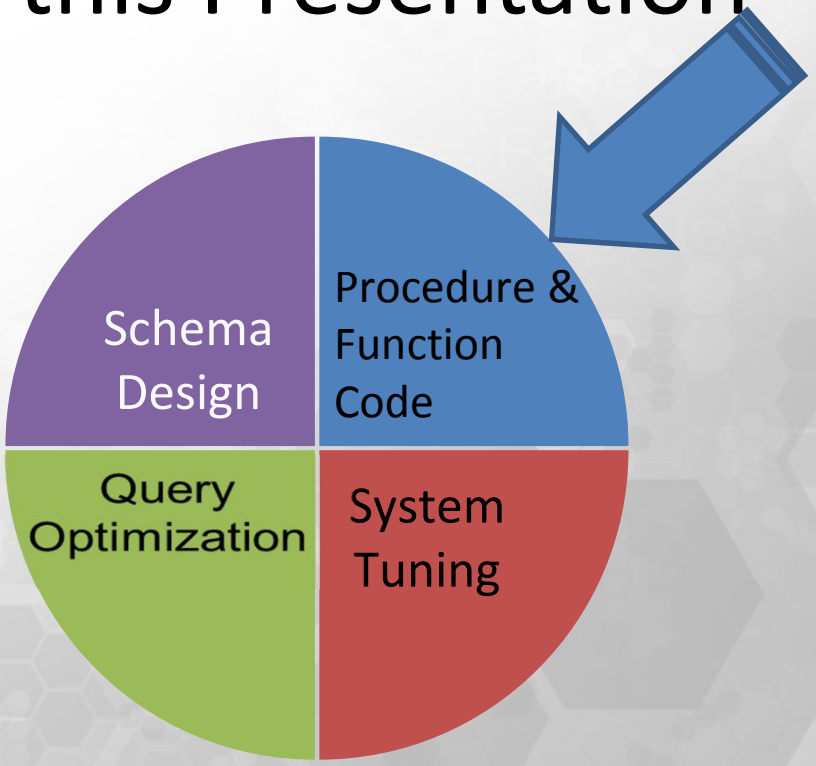
Agenda

- The Hekaton Overview
- In-Memory Tables 2016
- The Natively Compiled Difference

Focus of this Presentation



HEKATON

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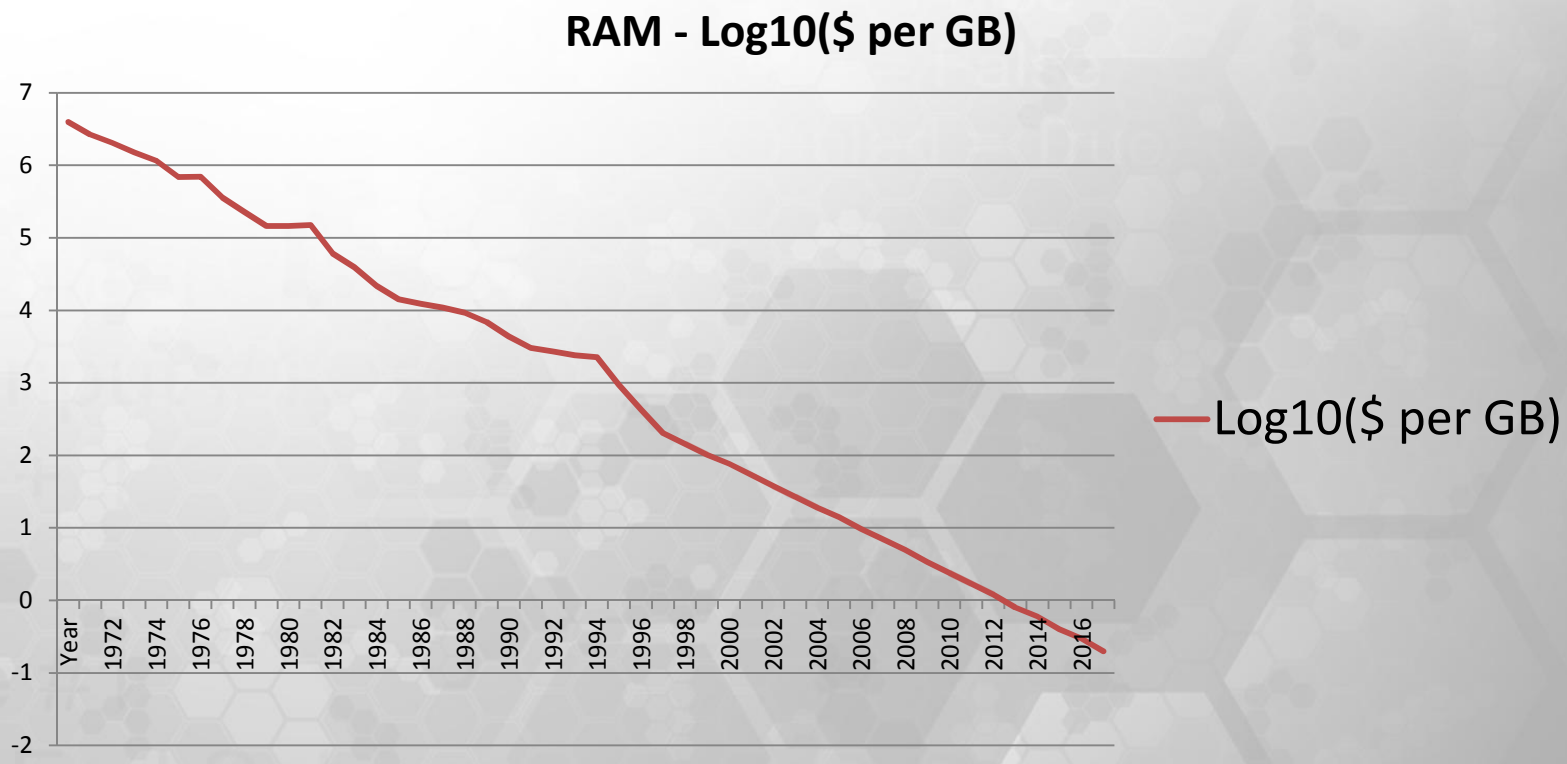
Hekaton

- Aimed to be 100 times faster with
  - In-Memory Data
  - Natively Compiled Code
- Work started 2010
- Initial Release SQL 2014

RAM prices over the last 40 Years



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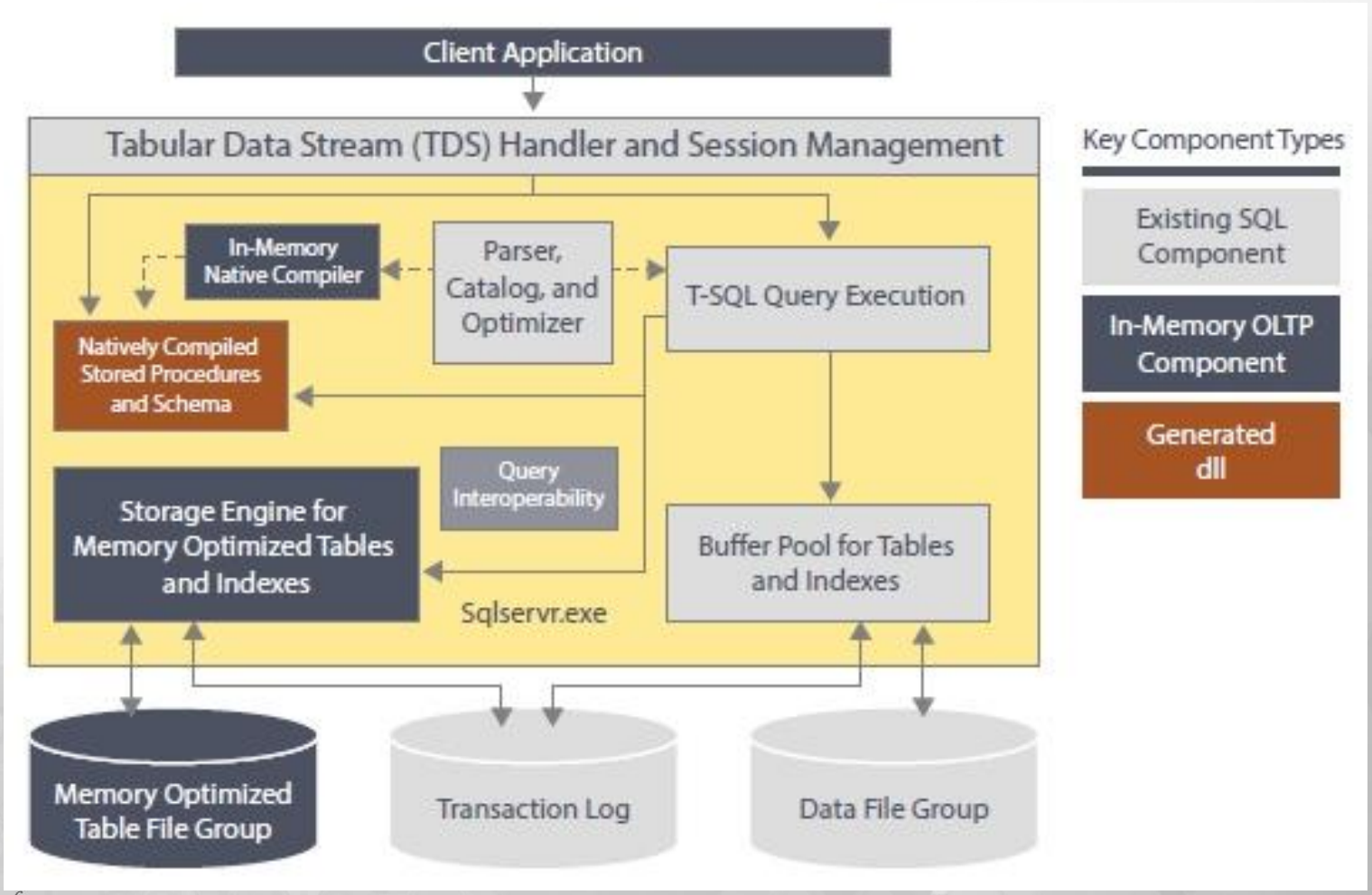

Client Application
Tabular Data Stream (TDS) Handler and Session Management
In-Memory Native Compiler
Parser, Catalog, and Optimizer
T-SQL Query Execution
Natively Compiled Stored Procedures and Schema
Query Interoperability
Storage Engine for Memory Optimized Tables and Indexes
Buffer Pool for Tables and Indexes
Sqlservr.exe
Memory Optimized Table File Group
Transaction Log
Data File Group
Key Component Types
Existing SQL Component
In-Memory OLTP Component
Generated dll

This is an Enterprise Edition feature

	SQL Server 2016 Enterprise	SQL Server 2016 Standard	SQL Server 2016 Express	SQL Server 2016 Developer
Advanced OLTP: In-memory OLTP, operational analytics	●			●

Also in Developer and Azure V12 Premium

In-Memory Tables – CREATE TABLE 2016

```
CREATE TABLE Product_inmem(
    ProdID int IDENTITY(1,1) NOT NULL,
    Name nvarchar(50) COLLATE SQL_Latin1_General_CP1_CI_AS NOT NULL,
    Color nvarchar(15) COLLATE SQL_Latin1_General_CP1_CI_AS NULL,
    ModifiedDate datetime2(7) NOT NULL
            CONSTRAINT DF_Product_ModifiedDate DEFAULT (sysdatetime()),
    Notes nvarchar(max) NULL,
    CONSTRAINT IMPK_Product_ProdID PRIMARY KEY NONCLUSTERED HASH
                        (ProdID) WITH ( BUCKET_COUNT = 1048576),

    INDEX IX_Name NONCLUSTERED (Name ASC),

)WITH ( MEMORY_OPTIMIZED = ON , DURABILITY = SCHEMA_AND_DATA )
```

In-Memory Tables – What's the Difference 1

- **A**tomaticity — Yes! Transactions are all or nothing
- **C**onsistency — Yes! The database is always consistent
- **I**solation — Yes! Concurrent transactions isolated
- **D**urability — Yes! But Durability is OPTIONAL!
- Tables are in Memory – No reading the disk!
- Indexes – Up to 8 – In memory only
- Data Files - Checkpoint Files – Append only

In-Memory Tables – What's the Difference 2

- No Locks
- No Latches
- No Spinlocks

- Achieved using a newer CPU Instruction

  interlocked-compare and exchange

In-Mem Tables – Limitations - 2014

- No LOB – Varchar(MAX), NVARCHAR(MAX)
  - Text, ntext, image, varbinary(max)
- No computed columns
- No CHECK, Unique or Foreign Key constraints
- No Triggers
- No Replication
- Only Bin2 character cols in in indexes

In-Mem Tables – Limitations - 2016

- No LOB – ~~Varchar(MAX), NVARCHAR(MAX)~~
  - Text, ntext, image, ~~varbinary(max)~~
- No computed columns
- ~~No CHECK, Unique or Foreign Key constraints~~
- ~~No Triggers~~ Only AFTER
- No Replication
- ~~Only Bin2 character cols in in indexes~~

In-Memory Tables – 2016 Changes

- ALTER
- Row sizes > 8060 Bytes
- BLOB types VARCHAR(MAX), etc.
- Constraints: Foreign Key and CHECK
- Triggers – Natively Compiled Only
- Auto-Update Statistics
- Indexes on Non-BIN Character Columns

In-Memory Tables – What's Not Available

- XML types
- CLR types
- Legacy LOB (Text, Ntext, Image)

In-Memory Tables 2016 – Scalability

- 2 TB of In-Memory tables per database
- 1.2 Million Transactions/Sec
- 900 MB per Second Written

In-Memory Table Usability

- Interop
  - Use In-Memory tables with standard T-SQL
- Natively Compiled T-SQL
  - Can only use In-Memory Tables

In-Memory Tables - Durability

- SCHEMA_AND_DATA (PK required)
- SCHEMA_ONLY (Index required)

- DELAYED DURABILITY

In-Memory – Concurrency Control

- Optimistic Locking
- Multi-version Concurrency Control – MVCC

- Isolation Levels
  - SNAPSHOT
  - REPEATABLE READ
  - SERIALIZABLE

First In Memory Use Case

- Replace #temp tables
  - Faster than #temp tables
- Replace @temp tables
  - Scales (rows) better than @temp tables

In-Memory Table Types

```
CREATE TYPE dbo.EAV_tt_inmem  AS TABLE (
    [entity_id] int NOT NULL,
    attribute_id smallint NOT NULL ,
    [value] VARCHAR(256) NOT NULL,
    INDEX IX_entity_attribute
            NONCLUSTERED ([entity_id], attribute_id)
  ) WITH (MEMORY_OPTIMIZED = ON)


DECLARE @eav_temp dbo.EAV_tt_inmem;
```

Second In-Memory Use-Case

- Replace #temp tables with in-memory tables
- Difference is the scope
- Add session_id column
- Use Row Level Security to limit access

In-Memory – Temp Table Replacement 1

```
CREATE TABLE EAV_temp_inmem  (
    [entity_id] int NOT NULL,
    attribute_id smallint NOT NULL ,
    value VARCHAR(256) NOT NULL,
    session_id smallint NOT NULL DEFAULT (@@SPID),
    INDEX IL_session_id (session_id),
    INDEX IX_entity_attribute
       NONCLUSTERED (session_id, [entity_id], attribute_id),
    CONSTRAINT CHK_temp1_session_id
              CHECK ( session_id = @@SPID )
    ) WITH (MEMORY_OPTIMIZED = ON, DURABILITY=SCHEMA_ONLY);
```

In-Memory – Temp Table Replacement 2

```
CREATE FUNCTION dbo.fn_SessionFilter(@session_id smallint)
    RETURNS TABLE
     WITH SCHEMABINDING, NATIVE_COMPILATION
   AS
        RETURN SELECT 1 as fn_SessionFilter
                    WHERE @session_id=@@spid;
```

```
CREATE SECURITY POLICY dbo.temp1Filter
     ADD FILTER PREDICATE dbo.fn_SessionFilter(session_id)
     ON dbo.EAV_temp_inmem
     WITH (STATE = ON);
```

NATIVELY COMPILED T-SQL

Natively Compiled Code

- Stored Procedures
- Scalar Functions
- After Triggers

- T-SQL with Limits
  - In-Memory Data only
  - Reduced T-SQL Syntax

Why is it faster

- T-SQL -> C C-> machine code

- Query Plans are compiled in
  - sp_recompile to get new query plans

CREATE PROCEDURE

```
CREATE PROC dbo.myProc (@myStr VARCHAR(64) NOT NULL)
                        WITH NATIVE_COMPILATION, SCHEMABINDING
AS BEGIN ATOMIC WITH (TRANSACTION ISOLATION LEVEL=SNAPSHOT
                      language = N'English')

        -- BODY GOES HERE
END
```

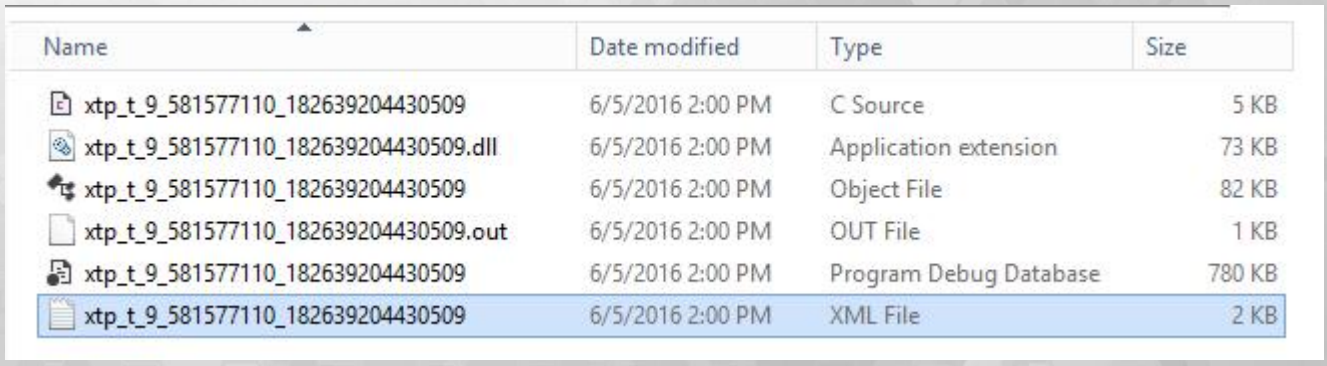
- WITH NATIVE_COMPILATION
- SCHEMABINDING
- BEGIN ATOMIC

```
CREATE PROC dbo.myProc (@myStr VARCHAR(64) NOT NULL)
            WITH NATIVE_COMPILATION, SCHEMABINDING
AS BEGIN ATOMIC WITH (TRANSACTION ISOLATION LEVEL=SNAPSHOT,
                                  language = N'English')

DECLARE @eav_temp dbo.EAV_tt_inmem;

insert dbo.EAV_temp_inmem (entity_id, attribute_id, value)
  OUTPUT inserted.entity_id,inserted.attribute_id,inserted.[value]
   into @eav_temp ([entity_id], attribute_id, [value])
   values (1,2,'abcd')

SELECT [entity_id], attribute_id, [value] FROM @eav_temp

END
```

TAKE A LOOK AT THE C CODE

Files that get produced

- Stored in the XTP directory
  - …\MSSQL13.instance\Data\XTP\db_id()
- 6 Files per object



Name	Date modified	Type	Size
xtp_t_9_581577110_182639204430509	6/5/2016 2:00 PM	C Source	5 KB
xtp_t_9_581577110_182639204430509.dll	6/5/2016 2:00 PM	Application extension	73 KB
xtp_t_9_581577110_182639204430509	6/5/2016 2:00 PM	Object File	82 KB
xtp_t_9_581577110_182639204430509.out	6/5/2016 2:00 PM	OUT File	1 KB
xtp_t_9_581577110_182639204430509	6/5/2016 2:00 PM	Program Debug Database	780 KB
xtp_t_9_581577110_182639204430509	6/5/2016 2:00 PM	XML File	2 KB

BENCHMARK

Chapter 7 Bankruptcy

Wide World Importers – The new sample

- Located on GitHub

- .bak files or construct from scripts
- WideWorldOLTP
- WideWorldDW
- InMemDB (From script only)

Bechmark 1 - VehicleLocation

- Azure VM – 2 Core , 14 GB RAM
- Insert 500,000 Rows
- Single Threaded

	insert into disk-based table (in ms)
1	159725

	insert into memory-optimized table (in ms)
1	131741

	insert into memory-optimized table using native compilation (in ms)
1	1859

Benchmark Magic

- Use Binary Collations
- Fixed # of detail lines instead of table
- Compare to bad code
- No error handling

STORED PROCEDURE STRUCTURE

```
CREATE { PROC | PROCEDURE } [schema_name.] procedure_name
    [ { @parameter data_type } [ NULL | NOT NULL ] [ = default ]
                    [ OUT | OUTPUT ] [READONLY] ]
     [ ,... n ]
  WITH NATIVE_COMPILATION, SCHEMABINDING
     [ , EXECUTE AS clause ]
AS
{
  BEGIN ATOMIC WITH (set_option [ ,... n ] )

     sql_statement [;] [ ... n ]
[ END ]
}   [;]
```

NOT NULL Parameters and Variables

- Parameters can be NOT NULL

```
CREATE PROC myProc (@myStr VARCHAR(64) NOT NULL)
```

- Variables can be NOT NULL

```
DECLARE @myStr VARCHAR(64) NOT NULL = 'Navigabimus Nunc‘
```

- Assignment of NULL does NOT fail

```
SET @myStr = NULL; -- Compiles but Fails at runtime
```

BEGIN ATOMIC - SET OPTIONS

```
LANGUAGE =  [ N ] 'language'

TRANSACTION ISOLATION LEVEL =
                  { SNAPSHOT | REPEATABLE READ | SERIALIZABLE }

[ DATEFIRST = number ]
[ DATEFORMAT = format ]
[ DELAYED_DURABILITY = { OFF | ON } ]
```

BEGIN ATOMIC Required Settings

- TRANSACTION ISOLATION LEVEL
  - SNAPSHOT
  - REPEATABLEREAD
  - SERIALIZABLE
- LANGUAGE
  - All languages in sys.syslanguages

BEGIN ATOMIC Optional Settings

- DATEFORMAT = number
- DATEFIRST = format
- DELAYED_DURABILITY = OFF | ON

BEGIN ATOMIC standard settings (1 of 2)

SET OPTION	System Default for ATOMIC Blocks
ANSI_NULLS	ON
ANSI_PADDING	ON
ANSI_WARNING	ON
ARITHABORT	ON
ARITHIGNORE	OFF
CONCAT_NULL_YIELDS_NULL	ON
IDENTITY_INSERT	OFF
NOCOUNT	ON

BEGIN ATOMIC standard settings (2 of 2)

SET OPTION	System Default for ATOMIC Blocks
NUMERIC_ROUNDABORT	OFF
QUOTED_IDENTIFIER	ON
ROWCOUNT	0
TEXTSIZE	0
XACT_ABORT	OFF
CONCAT_NULL_YIELDS_NULL	ON

Natively Compiled T-SQL – Added to 2016

- LEFT and RIGHT OUTER JOIN
- SELECT DISTINCT
- OR and NOT operators
- Subqueries in all clauses of a SELECT statement
- Nested stored procedure calls
- UNION and UNION ALL
- All built-in math functions
- Some security functions, including @@spid
- Scalar user-defined functions
- EXECUTE AS CALLER

Error Handling

- TRY CATCH and THROW
- No RAISERROR – use THROW
- Try and have just one TRY CATCH

Natively Compiled T-SQL – Still Missing in 2016

- CASE expressions
- MERGE
- TOP with ORDER BY Limited to 8192 rows
- TOP WITH TIES or PERCENT
- INSERT VALUES with multiple rows
- Most hints
  - LOOP JOIN is supported

Forbidden in Natively Compiled Procedures

- Cross Container Access – Disk Based Tables
- Dynamic SQL NO EXEC (‘’) or sp_executeSQL
- Cross database transactions
- Distributed Transactions

Parameter Passing - Best Practices

- Pass by position
- Pass exact data type
- Hekaton_slow_parameter_passing EE

```
CREATE EVENT SESSION [Natively Compiled Stored Procedures] ON SERVER
 ADD EVENT sqlserver.natively_compiled_proc_slow_parameter_passing,
 ADD EVENT sqlserver.natively_compiled_proc_execution_started
 ADD TARGET package0.event_file(SET filename=N'Natively Compiled Stored
Procedures'),
 ADD TARGET package0.ring_buffer(SET max_memory=(102400))
WITH ( MAX_MEMORY=4096
KB,EVENT_RETENTION_MODE=ALLOW_SINGLE_EVENT_LOSS,
  MAX_DISPATCH_LATENCY=30 SECONDS,MAX_EVENT_SIZE=0 KB,
  MEMORY_PARTITION_MODE=NONE,TRACK_CAUSALITY=OFF,STARTUP_STATE=OFF)
GO
--Start Event Session
ALTER EVENT SESSION [Natively Compiled Stored Procedures]  ON SERVER STATE =
START
```

FUNCTIONS

Types

- Scalar
- No others

Exponentially Weighted Moving Average

$$EMA_{Today} = (Value_{Today} * \left(\frac{Smoothing}{1 + Days}\right)) + EMA_{Yesterday} * (1 - \left(\frac{Smoothing}{1+Days}\right))$$

Traditional Scalar T-SQL UDF

```
CREATE FUNCTION [dbo].[exp_moving_avg_scalar] (

    @ema_yesterday FLOAT
  , @value_today FLOAT
  , @days INT
  , @smoothing FLOAT = 2.0

) RETURNS FLOAT
AS BEGIN
RETURN CASE WHEN @ema_yesterday IS NULL
            THEN @value_today
            ELSE (@value_today * (@smoothing/(1.0+@days)))
                  + (@ema_yesterday
                        * (1.0 - (@smoothing/(1.0+@days))))
            END
END
```

Natively Compiled Scalar Function

```
CREATE FUNCTION [dbo].[exp_moving_avg_scalar_nc] (
    @ema_yesterday FLOAT
  , @value_today FLOAT
  , @days INT
  , @smoothing FLOAT = 2.0
) RETURNS FLOAT
WITH NATIVE_COMPILATION, SCHEMABINDING, CALLED ON NULL INPUT
AS BEGIN ATOMIC WITH(TRANSACTION ISOLATION LEVEL=SNAPSHOT,language=N'English')

IF @ema_yesterday IS NULL RETURN @value_today

RETURN (@value_today * (@smoothing/(1.0+@days)))
                     + (@ema_yesterday
                          * (1.0 - (@smoothing/(1.0+@days))))

END
```

Options Unique to Scalar Functions

- RETURNS NULL ON NULL INPUT
- CALLED ON NULL INPUT

Interpreted Inline T-SQL UDF

```
CREATE FUNCTION [dbo].[exp_moving_avg_inline] (

    @ema_yesterday FLOAT
  , @value_today FLOAT
  , @days INT
  , @smoothing FLOAT = 2.0
) RETURNS TABLE
AS RETURN
SELECT CASE WHEN @ema_yesterday IS NULL
            THEN @value_today
            ELSE (@value_today * (@smoothing/(1.0+@days)))
                  + (@ema_yesterday
                        * (1.0 - (@smoothing/(1.0+@days))))
            END
       as ema_today
```

FUNCTIONS DEMO

ADVISOR

References

- SQL Server Blog
  https://blogs.msdn.microsoft.com/sqlserverstorageengine/

- Kalen Delaney
  SQL Server In-Memory OLTP Internals for SQL Server 2014
  Microsoft June 2016

- Dmitri Korotkevitch
  Expert SQL Server In-Memory OLTP Revolutionizing OLTP Performance in SQL Server , APress, New York, 2015 (SQL 2014 book)

New England Microsoft Developers

- First Thursday of the Month 6:30 to 8:30
- New Location:

  MSFT 5 Wayside Rd, Burlington, MA

  http://www.meetup.com/NE-MSFT-Devs/

October 6th , November 3rd , December 1st

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Thank you for coming!

Database option

- MEMORY_OPTIMIZED_ELEVATE_TO_SNAPSHOT
- When Txn is READ Committed or read Uncommitted

CROSS CONTAINER TRANSACTIONS

- Access in-memory tables in a TRAN
- Execute a native proc when a TRAN is open

Natively Compiled SP - Dynamic SQL

- No EXEC (‘’)
- No sp_executesql

- Can be created by Dynamic SQL

Parameter Passing

- Try and match data types
- Use positional parameters instead of @named parms
- Extended events will show where