Data-driven systems

Programming Microsoft SQL Server

BME AUT
Automatizálási és
Alkalmazott
Informatikai Tanszék

Contents

- Microsoft SQL Server platform
- Server-side programming of databases
- Transact-SQL language
  - Cursors
  - Stored procedures and functions
  - Error handling
  - Triggers

Relational databases

Database definition

- Organized collection of logically related data
- Data: known facts recorded digitally
  - Basic: text, number, date
  - Multimedia: images, sounds, video
  - Structured: XML, JSON
- Organized collection: easy to find
- Related data: required for an application

Relation (table) properties

record / row

ColumnID	ColumnA	ColumnB	ColumnC
Key1	Scalar value		
Key2			
Key3			
Key4			

column / attribute

Integrity requirements

OszlopID	ColumnA	ColumnB	ColumnC
Key1	123		
Key2	456		
Key3	789	Rec999	

XXX	YYY
Rec998	
Rec999	

1. Entity integrity: key ≠ NULL
2. Domain integrity: column data type and domain
3. Referential integrity: foreign key

Microsoft SQL Server platform

Server components

- SQL Server Service
- SQL Server Browser
- SQL Server Agent
- SQL Server Analysis Services
- SQL Server Reporting Services
- SQL Server Integration Services
- SQL Writer

Databases

- Database
  - Data file (.mdf)
    - Can be filegroup
  - Transaction log (.ldf)
  - Can contain multiple schemas
    - Default schema: dbo
    - Logical separation, access control
- Built-in databases
  - Master, Model, Distribution, MSDB, Temp

User schema

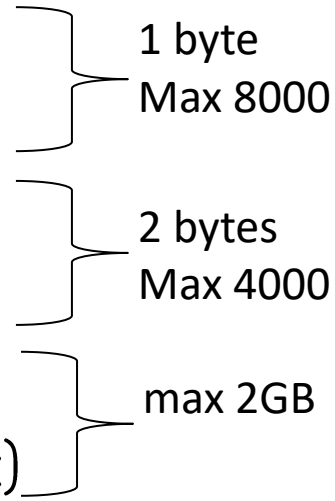
- User schema = objects in the database

- Table
  - Column
  - Computed Column
    - Virtual
    - Stored
- View
  - Indexable → Stored
- Index
- Sequence

- Programmability
  - Procedure
  - Method
  - Trigger
  - Assembly

Data types

- Text
  - Char(n)
  - Varchar(n)
  - Nchar(n)
  - Nvarchar(n)
  - Varchar(max)
  - Nvarchar(max)



- Large objects
  - ~~Image~~
  - ~~TEXT / ntext~~
  - VARBINARY
- Numeric
  - Int
  - Float
  - Numeric(p,s)
- Date
  - Datetime
    - From Jan. 1st 1753 (!)
  - Datetime2
- Other
  - XML
  - Hierarchyid
  - Geographic data

Sidenote

- Where do we store images for a web application?

- Database?
- File system?
- External / cloud service?

- Performance, security, backup/restore, scaling, maintainability, simplicity, …

Generating values for primary key

- Identity keyword
  - create table Status(
    ID int identity(1,1) primary key,
    Name nvarchar(20))
  - Insert into Status values (‘Ready’)
- Query
  - ident_current(‘Status’)
    - Any session, any scope, specific table
  - @@IDENTITY
    - Current session, any scope, any table
  - SCOPE_IDENTITY ()
    - Current session, current scope, any table

Scope vs session

- Scope
  - Structural unit
  - Procedure, trigger, function, batch
  - They are in the same scope if, for example, they are in one procedure
- Session
  - Logical database connection
  - Either from a terminal window or programmatically
  - A logical flow of message exchanges
  - Typically a 1:1 physical connection
    - MARS – one physical connection, multiple sessions

Creating a new record and query the key

```
create table VAT
(
    ID int identity primary key,
    Percentage int
)

insert into VAT(Percentage)
values (27)

select @@identity
```

@@IDENTITY vs SCOPE_IDENTITY

- For example, a trigger runs on table T1, which creates a new row on T2 when a row is inserted
- After inserting a new row into T1:
  - @@IDENTITY: Returns the ID of a row inserted in table T2
  - SCOPE_IDENTITY: returns the ID of the new row added to T1

Transaction boundary

- Specific to a connection
- Starting a transaction (depends on configuration)
  - Auto commit: All statements are independent transactions
    - This is the default mode
  - Explicit transactions: Begin tran, for multiple statements
    - Can be nested
    - @@TRANCOUNT variable
  - Implicit transactions: Automatically starts a transaction after the end of the previous one
    - If there is no current transaction, certain statements automatically begin one
- DML and DDL statements can be part of transactions too
  - Few exceptions: Create Database, Backup, Restore

Supported isolation levels

- Isolation levels in the SQL standard
  - Read uncommitted
  - Read committed ← Reading: uses shared locks
Writing: no one can read it
  - Repeatable read
  - Serializable
- Not in the standard
  - Snapshot
    - Snapshot when the transaction starts
    - Row-level versioning

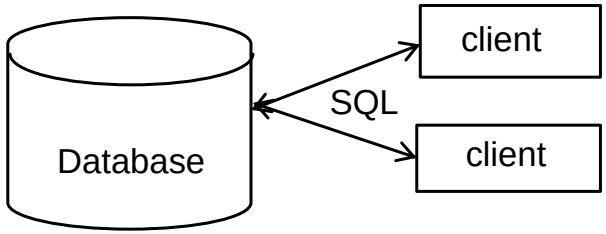
Access control

- System-level
- Database-level
- Schema-level
- Object-level
  - Specific to an object
  - Can be column specific in case of tables and views
- Allow and deny permissions
- No row-level access control.
  - Some level of support since MSSL2014

Database server-side programming

Role of the database

- Data model: tables
- Data manipulation: SQL language



- Tasks, that are outside the scope of the relational model
  - Business Layer
  - Data Layer → **Server-side programming**

Server-side programming: motivation

- Example: Registering for an exam in Neptun
  - Exams table: ID, Course, Date, Limit
  - ExamRegistration table: ExamId, StudentId
- Pseudo-code:

```
func registerForExam(examid, studentId) {
   registered_cnt = count examregistration ID==examid
   if registered_cnt < exam.limit
       insert examregistration examid, studentid
   else error
}
```

Server-side programming: motivation

- Example: Registering for an exam in Neptun
- With T-SQL using a stored procedure

```
create procedure examregistration
@examid int, @studentid int
as
begin
   declare @registered_cnt int =
             select count(*) from examregistration where ID=@examid
   declare @examlimit int
   select @examlimit = limit from exam where ID=@examid
   if @registerd_cnt < @examlimit
       insert into examregistration values(@examid, @studentid)
   else
       throw 51005, 'exam limit reached'
end
```

Server-side programming: motivation

- Example: Registering for an exam in Neptun
- With T-SQL using a stored procedure

```
create procedure examregistration
@examid int, @studentid int
as
begin
    declare @registered_cnt int =
                select count(*) from examregistration where ID=@examid
    declare @examlimit int
    select @examlimit = limit from exam where ID=@examid
    if @registerd_cnt < @examlimit
        insert into examregistration values(@examid, @studentid)
    else
        throw 51005, 'exam limit reached'
end
```

Stored procedure ~ method

Parameters

Local variable

Procedural code

Branching (control flow)

Errors

Advantages of server-side programming - 1

- Database is responsible for consistency
  - Role of the database changes
    - Data source + Services
- Security
  - Data modification through public "interface"
    - E.g., this is the stored procedure
  - Closed execution environment
    - Data does not need to get outside of the database

Advantages of server-side programming - 2

- Increase performance
  - Reduce network traffic
  - Database caching
- Productivity
  - The code is called by multiple components
  - Easier maintenance -> need to fix in the DB

Disadvantages of server-side programming

- Not standardized
  - Platform specific languages
  - Platform specific solutions
- Interpreted
- Increases the load of the server
- Not possible or hard to scale

Transact-SQL language

T-SQL language

- Transact-SQL / T-SQL
- Language of Microsoft SQL Server
- Instructions according to the SQL language
  - + variables
  - + statement blocks
  - + cycles
  - + structured error handling
  - + new language constructs

T-SQL language

- SQL language review
- MSSQL specific syntax
- Server-side programming

> See details in the lecture notes

T-SQL nyelv

```
DECLARE @c int = 0
SELECT @c = COUNT(*) FROM Product
WHILE @c < 1000
BEGIN
    INSERT INTO Product VALUES ('Alma')
    SET @c = @c + 1
END
```

T-SQL nyelv

```
DECLARE @cid int = 123

DECLARE @name nvarchar(max)
SELECT @name=Name FROM Customer WHERE ID=@cid

IF @name IS NOT NULL
BEGIN
    PRINT 'Email cim frissitese'
    UPDATE Customer SET Email='...' WHERE ID=@cid
END
ELSE
BEGIN
    PRINT 'Nincs ilyen vevo'
END
```

T-SQL functions

- Isnull(kif1,kif2)
- CASE *input_expression*
  WHEN *when_expression* THEN
  result_expression [...*n*] [ELSE
  else_result_expression]
  END
- CAST (*expression* AS *data_type*
  [(*length*)])
- CONVERT (*data_type* [(*length*)
  ] , *expression* [, *style*])
  - style → conversion, formatting
- Try_cast / Try_convert

- Date
  - Getdate()
  - DateAdd(datepart , number, date)
  - Month(date)
  - Year(date)
  - …
- String
  - Replace
  - Trim
  - Ltrim
  - Rtrim
  - Len
  - Format
  - …

Some examples

```
-- Részstring csere
SELECT REPLACE('Happy Birthday!', 'day', 'month')
-- Happy Birthmonth!
```

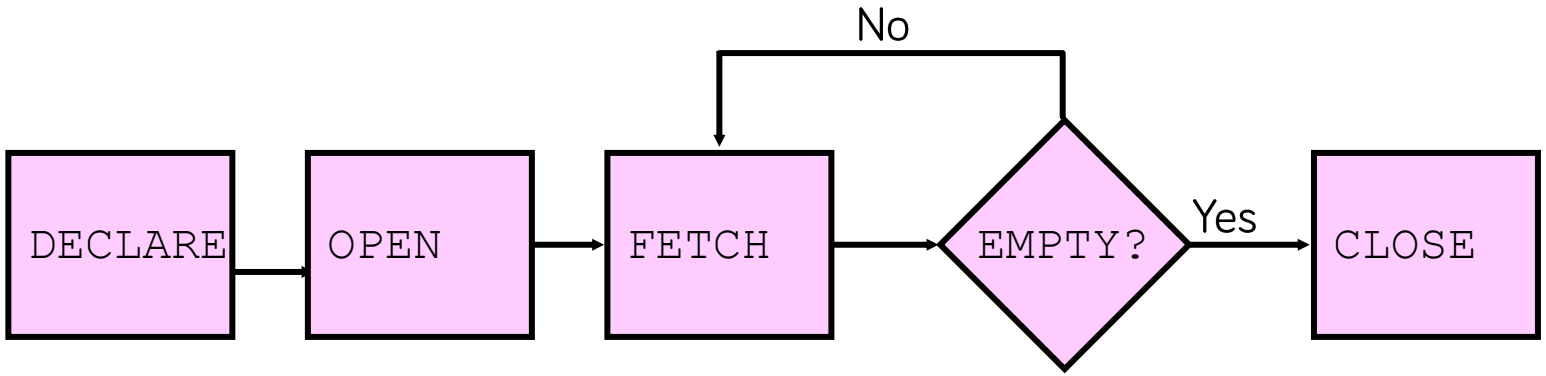
```
-- Dátumok közötti különbség adott mértékegységben (itt: nap) mérve
SELECT DATEDIFF(day, '2021-09-28 12:10:09', '2021-11-04 13:45:09')
-- 37
```

```
SELECT CONVERT(int, '12')
-- 12
```

```
DECLARE @a int
DECLARE @b int = 5
SELECT ISNULL(@a, @b)
-- 5
```

How the cursor works

- „Foreach iterator”
- Process record sets
- Enumerate a record set
  - Open
  - Process the record
  - Fetch next record



Cursor: declaration

```
DECLARE cur_name CURSOR
[ FORWARD_ONLY | SCROLL ]
[ STATIC | KEYSET | DYNAMIC | FAST_FORWARD ]
[ READ_ONLY | SCROLL_LOCKS | OPTIMISTIC ]
FOR query_string
[ FOR UPDATE [ OF column_name [ ,...n ] ] ]
```

Cursor: opening and navigating

- OPEN

  OPEN cur_name

- FETCH

  FETCH
  [[**NEXT** | **PRIOR** | **FIRST** | **LAST**
  | **ABSOLUTE** { n | @nvar }
  | **RELATIVE** { n | @nvar }
  ]
  FROM
  ]
  cursor_name [**INTO** @variable_name [,...n]]

- @@FETCH_STATUS
  - Returns the status of the last FETCH
    - 0 – FETCH succeeded
    - -1 – FETCH was unsuccessful
    - -2 – row cannot be found

Cursor: closing and releasing

- CLOSE
  - Release the record set
  - Release locks
  - Data structure is kept, can be opened later

  CLOSE cur_name
- DEALLOCATE
  - Decrements the reference counter of the cursor
  - If all references are removed, the structure is disposed

  DEALLOCATE cur_name

Cursor sample

```
DECLARE products_cur CURSOR SCROLL SCROLL_LOCKS
FOR
  SELECT Id, Name FROM Product WHERE Stock < 3 -
FOR UPDATE OF Price -- Szeretnénk frissíteni is
```

```
-- Tipikus megnyitás, fetch, ciklus
OPEN products_cur
FETCH NEXT FROM products_cur INTO @ProductID, @ProductName
WHILE @@FETCH_STATUS = 0
BEGIN
```

```
  -- Következő rekord lekérdezése, majd ugrás a WHILE ciklushoz
  FETCH NEXT FROM products_cur INTO @ProductID, @ProductName
END
```

```
-- Kurzor használatának befejezése
CLOSE products_cur
DEALLOCATE products_cur
```

Stored procedures and functions

Stored procedure

- Motivation: write commonly used logic
- Object-oriented solution: function/method

- Stored procedure: a code stored in the database that we can call from T-SQL code
  - Procedure: typically does not have return value (but can have)
- Stored function: has return value, but can only read the database (cannot write)

Stored procedure types

- Internal
  - T-SQL language
  - Interpreted
  - Closed environment
- External: .NET Assembly
  - Tasks that fall out of the scope of the database

Stored procedures

- Creation
  - CREATE PROCEDURE

CREATE OR ALTER PROC [EDURE] *proc_name*
[{ @*param data_type*}
] [,...*n*]

AS *sql_statements* [...*n*]

- Modify
  - ALTER PROCEDURE
    - The whole new procedure body is specified.
- Delete
  - DROP PROCEDURE

Stored procedure sample

```
create or alter procedure InsertNewVAT -- tárolt eljárás létrehozása, neve
    @Percentage int                    -- tárolt eljárás paraméterei
as
  begin
  -- innen kezdődik a kód, amit az eljárás meghívásakor végrehajt a rendszer
  begin tran                           -- nem megismételhető olvasás elkerülése
  set transaction isolation level repeatable read

  declare @Count int

  select @Count = count(*)
  from VAT
  where Percentage = @Percentage

  if @Count = 0
      insert into VAT values (@Percentage)
  else
      print 'error';

commit
end
```

```
exec InsertNewVAT 27
```

Stored function types

- Scalar-valued
  - Calculates a single scalar result
- Table-valued
  - Returns with a result set
  - Can be used as a table in queries
  - Can collect records using a complex logic (abstraction)
- Aggregate
  - Custom aggregation functions
  - .NET Assembly

Function sample

```
CREATE OR ALTER FUNCTION LargestVATPercentage()
RETURNS int
BEGIN
RETURN (SELECT MAX(Percentage) FROM VAT)
END
```

```
select dbo.LargestVATPercentage()
-- A dbo előtag a séma azonosítása, amivel azt jelöljük, hogy ez nem egy beépített
-- Enélkül a függvényt nem találja meg a rendszer

-- avagy például
DECLARE @maxvat int = dbo.LargestVATPercentage()
select @maxvat
```

Error handling

Error handling

- **@@Error** function
  - Can be queried after each statement
  - If there are no errors, value is 0
  - sys.messages table contains the error codes

- Structured error handling

```
BEGIN TRY
    Statements
END TRY
BEGIN CATCH
    Statements
END CATCH
```

```
USE AdventureWorks2012;
GO
UPDATE HumanResources.EmployeePayHistory
    SET PayFrequency = 4
    WHERE BusinessEntityID = 1;
IF @@ERROR = 547
    BEGIN
    PRINT N'A check constraint violation occurred.';
    END
GO
```

Raising errors - Throw

- Since SQL Server 2012
  - Earlier: RaisError – don't use it!
- THROW error_number, message, state
- Peculiarities
  - Error is not string-based
    - FORMATMESSAGE
  - Can be thrown again
    - Throw in the catch block
  - error_number > 50000

Error handling sample

```
create or alter procedure InsertNewVAT
    @Percentage int
as
begin

  begin tran
  set transaction isolation level repeatable read

  declare @Count int

  select @Count = count(*)
  from VAT
  where Percentage = @Percentage

  if @Count = 0
      insert into VAT values (@Percentage)
  else
      throw 51000, 'error', 1;

  commit
end
```

Triggers

Trigger: motivation

- Make sure that any deletion is logged (audit logging)
  - Solution 1: delete from DB then log in the business logic
    - Problem: can be forgotten, can be circumvented
  - Solution 2: "subscribe" to the deletion event in the database

    → Trigger
- The order should have a cumulative total value
  - Can be calculated from the order items, but let us save this as a separate value (denormalization)
  - If any item of the order changes, the value must be updated

Create DML triggers

CREATE TRIGGER *trigger_name*

ON { *Table* | *View* }

FOR { [DELETE] [,] [INSERT]

[,] [UPDATE] }

AS

sql_statement [...*n*]

Triggers

- Event handler procedures
- Maintenance of derived values
  - Denormalization
- Logging
- Collect statistics
- For managing special referential integrity

Events

- **DML events**
  - Insert, update, delete
  - For tables
- **DDL trigger**
  - Create, alter, drop, …
  - For schema
- System events
  - Logon, logoff, SysError, …
- Instead of triggers
  - Special DML triggers
  - Updating views

Trigger types

- DML triggers
  - Executed after statements
  - Works on a table
  - Executed after data modification
    - Executed within the same transaction
- Instead of trigger
  - Executed instead of the original statement
  - Updating views
  - Valid for tables too, works as a trigger before data modification
    - Can reference the table itself within the trigger, causes no recursion

Accessing modified records

- Through log tables
  - Structure is the same as the table that is being used
  - Table is accessible only within the trigger
  - Specific to a session

	Insert	Delete	Update
Inserted	New records	Empty	New values of the records
Deleted	Empty	Deleted records	Previous values of the records

Trigger sample

- The AuditLog table has one field: Description
- Insert the text formatted with the name of the deleted product from the special "**deleted**" table

```
-- Napló tábla létrehozása
create table AuditLog([Description] [nvarchar](max) NULL)
go

-- Naplózó trigger
create or alter trigger ProductDeleteLog
  on Product
  for delete
as
insert into AuditLog(Description)
select 'Product deleted: ' + convert(nvarchar, d.Name) from deleted d
```

Worth to know: batch

Batch

```
USE AdventureWorks2012;
GO

DECLARE @MyMsg VARCHAR(50)
SELECT @MyMsg = 'Hello, World.'
GO

PRINT @MyMsg
```

- Collection of statements sent to the server at once
  - > *Not part of the T-SQL language*