Lesser Poland Map

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22 maja 2024

1 Goal of the project

Aim of this project was to create interface for managing two-dimensional spatial types. The goal was to create own data types using CLR UDT (Common Language Runtime User Defined Types).

1.1 Description of functionality

As a part of a project, functionalities listed below were created:

- Creating basic spatial types: point, multiline, polygon,
- Calculating area of any polygon and distance between two points,
- Checking if created point is contained within specified polygons.

2 Created data types

To achieve goal of this project four data types were created using CLR UDT technology:

- Point - object representing X, Y coordinates placed on a plane. Created methods and functions are:
    1. ToString() - to get access to string representation of a point,
    2. Parse(string) - to create Point out of specified string representation. (example of correct input string: "(x,y)"),
    3. ConvertFromCoordinates() - that allows user to map geospatial point to X,Y plane coordinates,
    4. Distance(p1, p2) - allowing to calculate distance between two points p1 and p2 using euclidean distance.

- Multiline - object representing list of continuous lines between points stored within multiline. Methods and functions provided with multiline type:

    1. ToString() - provides access to string representation of a multiline,
    2. Parse(string) - allows to create multiline out of provided string (example of an input string: "[(x1,y1);(x2,y2);...;(xn,yn)]")
    3. Concatenate(l1, l2) - tool to concatenate two multilines if they create continous multiline (beggining of one of them matches the end of the second one).
    4. ConcatenateInPlace(l1, l2) - tool providing the same functionality as Concatenate, but result is saved inside l1 multiline.

- Polygon - object representing closed area. Methods and functions created for polygon data type:

    1. ToString() - to get string representation of a closed multiline that creates polygon,
    2. Parse(string) - creates polygon out of provided string representation of a closed multiline (example of an input: "[(x1,y1);(x2,y2);...;(x1,y1)]"),
    3. IsInside(polygon, point) - checks if provided point is inside polygon, calculating sum of angles between specified point and consecutive points that create polygon.
    4. GetBoundingBox(polygon) - creates a smallest rectangle that includes specified polygon,
    5. Area(polygon) - calculates area of a provided polygon, by decomposing polygon into triangles that all have common point P(0,0), and calculating area of these triangles.
    6. CreatePolyOutOfUnorderedMultilines(id) - creating polygon out of partial, unordered multilines that combined together makes closed polygon, where id is the unique index of a polygon inside database,
    7. ChangePolygonScale(polygon, accuracy) - function allowing to create polygon with accuracy not better than 1 meter.

3 Description of API

To access methods and functions specified above, REST API was designed with Java Spring Boot framework.

- "/operation/area" - endpoint that returns calculated area of polygon provided inside request as a list of points that create closed multiline,

- "/operation/distance" - endpoint that returns distance between two points provided within request,

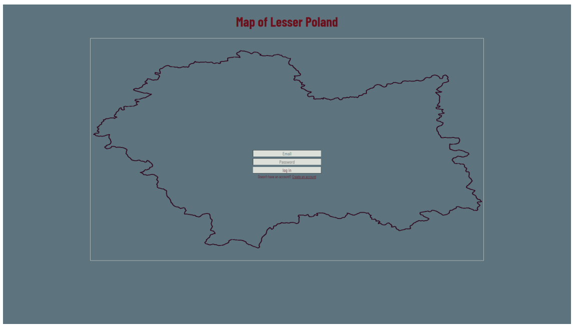
- ”/operation/isinside” - endpoint that returns array of polygons in JSON format. Returned response contains polygons that include specified point provided by request.

Alongside to the endpoints providing access to spatial type methods and functions, within application, additional endpoints were created:

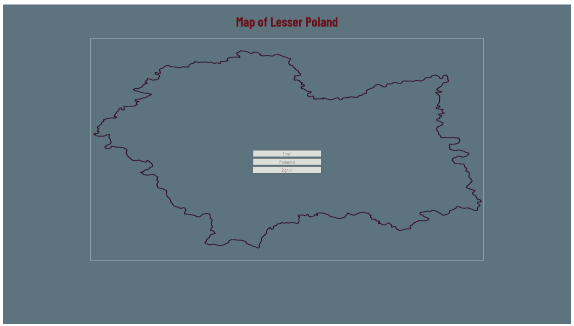
- ”voivodeshipborder/” - endpoint that returns polygon that bounds Lesser Poland voidodeship,
- ”voivodeshipborder/boundingbox” - endpoint returning bounding rectangle of voivodeship for better scaling inside application,
- ”/register” - endpoint allowing user to create account in order to access CLR UDT endpoints,
- ”/login” - endpoint that provides way to authorize user and give access to CLR UDT endpoints
- ”/” - endpoint with basic homepage for logged users

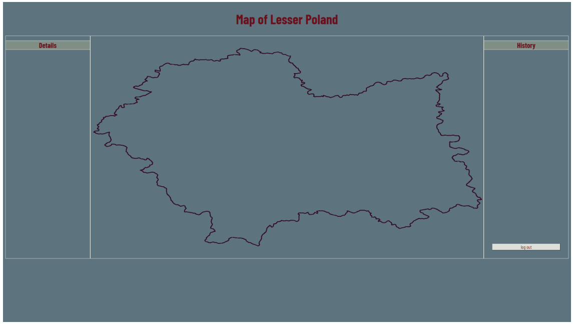
4 Application overview

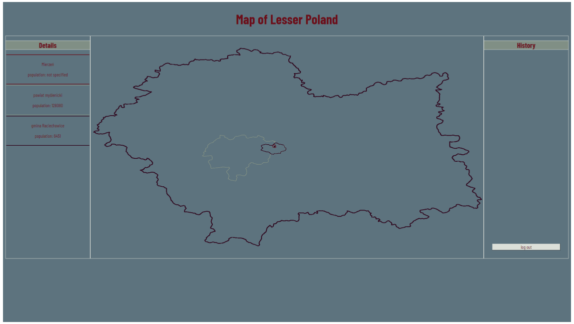
4.1 Views provided by application



Doesn't have an account? Create an account







Mierzeń

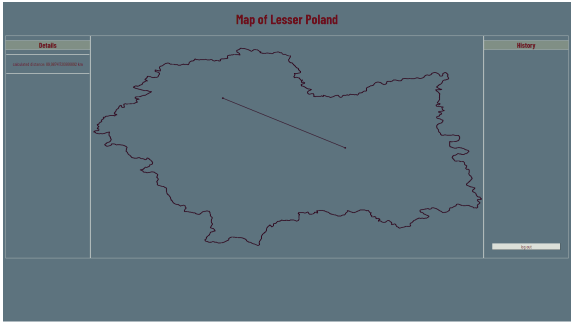
population: not specified

powiat myślenicki

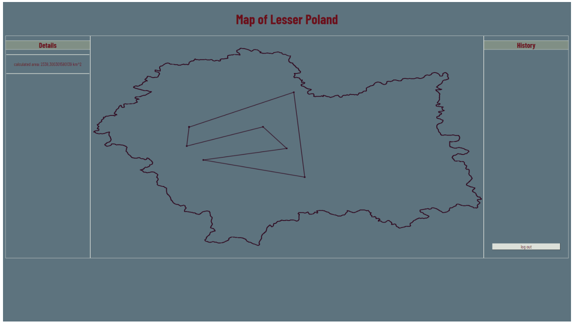
population: 128080

gmina Raciechowice

population: 6451



calculated distance: 89,98741720868892 km



calculated area: 2338,300301580139 km^2

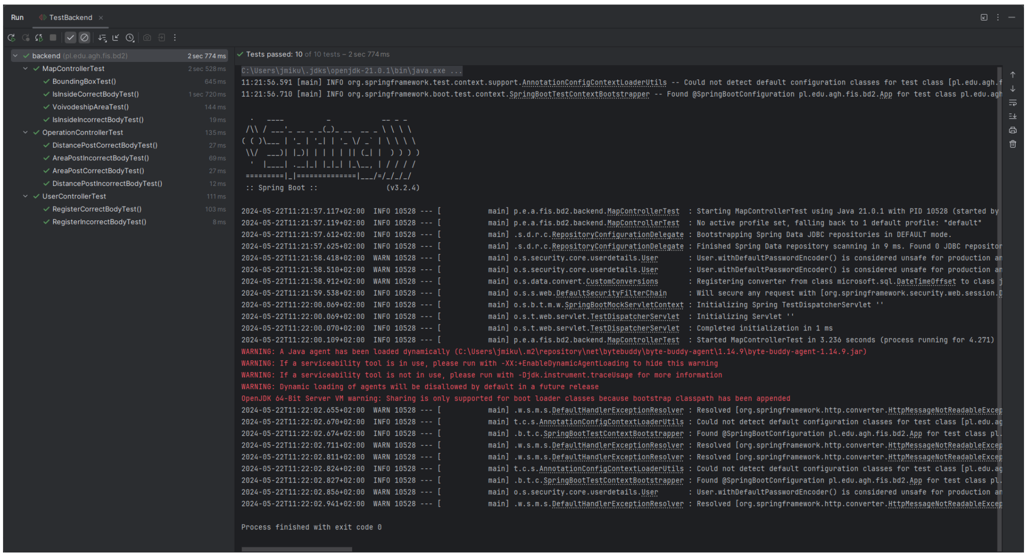
4.2 How to use application

- In order to retrieve administrative areas containing point, click on the map,
- In order to mark polygon to get calculated area hold CRTL while clicking on the map, and to submit polygon, click on first point while holding CRTL,
- In order to calculate distance between two points, hold SHIFT to start marking points, between which to calculate distance.

5 Testing of API

JUNIT 5 framework was use to test correctness of provided API.

Results of created unit tests:



```
backend (pl.edu.agh.fis.bd2)                 2 sec 774 ms
  MapControllerTest                          2 sec 528 ms
    BoundingBoxTest()                        645 ms
    IsInsideCorrectBodyTest()                1 sec 720 ms
    VoivodeshipAreaTest()                    144 ms
    IsInsideIncorrectBodyTest()              19 ms
  OperationControllerTest                    135 ms
    DistancePostCorrectBodyTest()            27 ms
    AreaPostIncorrectBodyTest()              69 ms
    AreaPostCorrectBodyTest()                27 ms
    DistancePostIncorrectBodyTest()          12 ms
  UserControllerTest                         111 ms
    RegisterCorrectBodyTest()                103 ms
    RegisterIncorrectBodyTest()              8 ms
```

Tests passed: 10 of 10 tests – 2 sec 774 ms

```
C:\Users\jmiku\.jdks\openjdk-21.0.1\bin\java.exe ...
11:21:56.591 [main] INFO org.springframework.test.context.support.AnnotationConfigContextLoaderUtils -- Could not detect default configuration classes for test class [pl.edu.agh.f
11:21:56.710 [main] INFO org.springframework.boot.test.context.SpringBootTestContextBootstrapper -- Found @SpringBootConfiguration pl.edu.agh.fis.bd2.App for test class pl.edu.agh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 :: Spring Boot ::                (v3.2.4)

2024-05-22T11:21:57.117+02:00  INFO 10528 --- [           main] p.e.a.fis.bd2.backend.MapControllerTest  : Starting MapControllerTest using Java 21.0.1 with PID 10528 (started by
2024-05-22T11:21:57.119+02:00  INFO 10528 --- [           main] p.e.a.fis.bd2.backend.MapControllerTest  : No active profile set, falling back to 1 default profile: "default"
2024-05-22T11:21:57.612+02:00  INFO 10528 --- [           main] .s.d.r.c.RepositoryConfigurationDelegate : Bootstrapping Spring Data JDBC repositories in DEFAULT mode.
2024-05-22T11:21:57.625+02:00  INFO 10528 --- [           main] .s.d.r.c.RepositoryConfigurationDelegate : Finished Spring Data repository scanning in 9 ms. Found 0 JDBC repositor
2024-05-22T11:21:58.418+02:00  WARN 10528 --- [           main] o.s.security.core.userdetails.User       : User.withDefaultPasswordEncoder() is considered unsafe for production an
2024-05-22T11:21:58.510+02:00  WARN 10528 --- [           main] o.s.security.core.userdetails.User       : User.withDefaultPasswordEncoder() is considered unsafe for production an
2024-05-22T11:21:58.912+02:00  WARN 10528 --- [           main] o.s.data.convert.CustomConversions       : Registering converter from class microsoft.sql.DateTimeOffset to class j
2024-05-22T11:21:59.538+02:00  INFO 10528 --- [           main] o.s.s.web.DefaultSecurityFilterChain     : Will secure any request with [org.springframework.security.web.session.D
2024-05-22T11:22:00.069+02:00  INFO 10528 --- [           main] o.s.b.t.m.w.SpringBootMockServletContext : Initializing Spring TestDispatcherServlet ''
2024-05-22T11:22:00.069+02:00  INFO 10528 --- [           main] o.s.t.web.servlet.TestDispatcherServlet  : Initializing Servlet ''
2024-05-22T11:22:00.070+02:00  INFO 10528 --- [           main] o.s.t.web.servlet.TestDispatcherServlet  : Completed initialization in 1 ms
2024-05-22T11:22:00.109+02:00  INFO 10528 --- [           main] p.e.a.fis.bd2.backend.MapControllerTest  : Started MapControllerTest in 3.236 seconds (process running for 4.271)
WARNING: A Java agent has been loaded dynamically (C:\Users\jmiku\.m2\repository\net\bytebuddy\byte-buddy-agent\1.14.9\byte-buddy-agent-1.14.9.jar)
WARNING: If a serviceability tool is in use, please run with -XX:+EnableDynamicAgentLoading to hide this warning
WARNING: If a serviceability tool is not in use, please run with -Djdk.instrument.traceUsage for more information
WARNING: Dynamic loading of agents will be disallowed by default in a future release
OpenJDK 64-Bit Server VM warning: Sharing is only supported for boot loader classes because bootstrap classpath has been appended
2024-05-22T11:22:02.655+02:00  WARN 10528 --- [           main] .w.s.m.s.DefaultHandlerExceptionResolver : Resolved [org.springframework.http.converter.HttpMessageNotReadableExcep
2024-05-22T11:22:02.670+02:00  INFO 10528 --- [           main] t.c.s.AnnotationConfigContextLoaderUtils : Could not detect default configuration classes for test class [pl.edu.ag
2024-05-22T11:22:02.674+02:00  INFO 10528 --- [           main] .b.t.c.SpringBootTestContextBootstrapper : Found @SpringBootConfiguration pl.edu.agh.fis.bd2.App for test class pl.
2024-05-22T11:22:02.711+02:00  WARN 10528 --- [           main] .w.s.m.s.DefaultHandlerExceptionResolver : Resolved [org.springframework.http.converter.HttpMessageNotReadableExcep
2024-05-22T11:22:02.811+02:00  WARN 10528 --- [           main] .w.s.m.s.DefaultHandlerExceptionResolver : Resolved [org.springframework.http.converter.HttpMessageNotReadableExcep
2024-05-22T11:22:02.824+02:00  INFO 10528 --- [           main] t.c.s.AnnotationConfigContextLoaderUtils : Could not detect default configuration classes for test class [pl.edu.ag
2024-05-22T11:22:02.827+02:00  INFO 10528 --- [           main] .b.t.c.SpringBootTestContextBootstrapper : Found @SpringBootConfiguration pl.edu.agh.fis.bd2.App for test class pl.
2024-05-22T11:22:02.856+02:00  WARN 10528 --- [           main] o.s.security.core.userdetails.User       : User.withDefaultPasswordEncoder() is considered unsafe for production an
2024-05-22T11:22:02.941+02:00  WARN 10528 --- [           main] .w.s.m.s.DefaultHandlerExceptionResolver : Resolved [org.springframework.http.converter.HttpMessageNotReadableExcep

Process finished with exit code 0
```
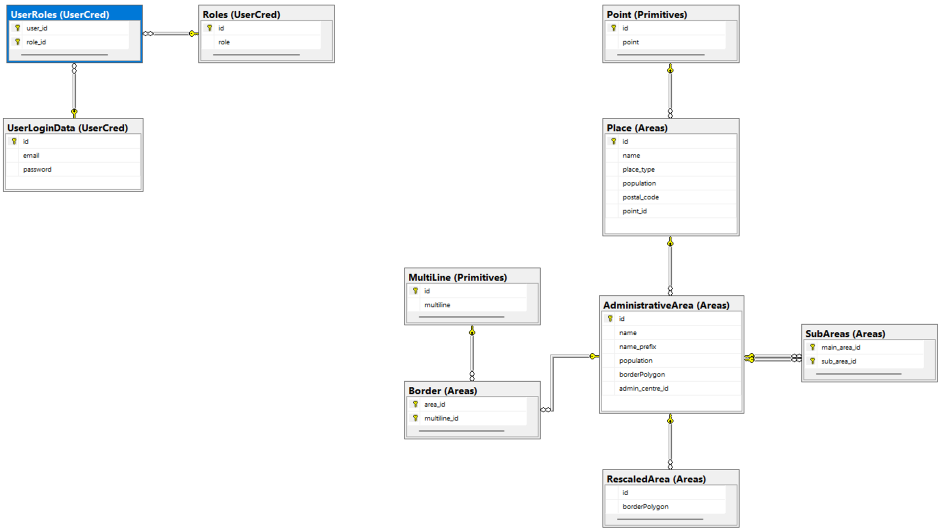
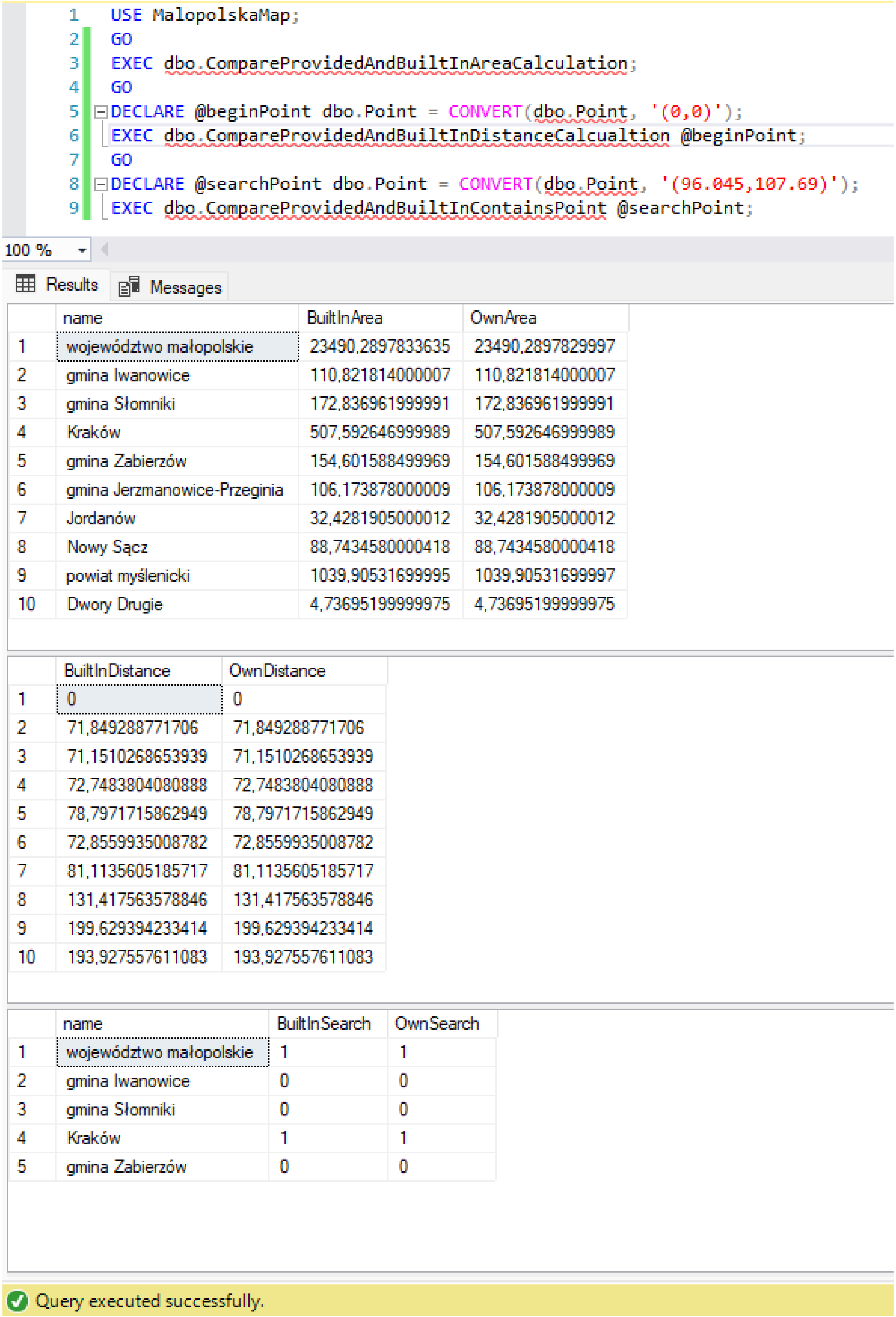

5.1 ER Diagram of created Lesser Poland Map database



5.2 Comparison between MSSQL built-in spatial types and methods with own created using CLR UDT



```sql
USE MalopolskaMap;
GO
EXEC dbo.CompareProvidedAndBuiltInAreaCalculation;
GO
DECLARE @beginPoint dbo.Point = CONVERT(dbo.Point, '(0,0)');
EXEC dbo.CompareProvidedAndBuiltInDistanceCalcualtion @beginPoint;
GO
DECLARE @searchPoint dbo.Point = CONVERT(dbo.Point, '(96.045,107.69)');
EXEC dbo.CompareProvidedAndBuiltInContainsPoint @searchPoint;
```

	name	BuiltInArea	OwnArea
1	województwo małopolskie	23490,2897833635	23490,2897829997
2	gmina Iwanowice	110,821814000007	110,821814000007
3	gmina Słomniki	172,836961999991	172,836961999991
4	Kraków	507,592646999989	507,592646999989
5	gmina Zabierzów	154,601588499969	154,601588499969
6	gmina Jerzmanowice-Przeginia	106,173878000009	106,173878000009
7	Jordanów	32,4281905000012	32,4281905000012
8	Nowy Sącz	88,7434580000418	88,7434580000418
9	powiat myślenicki	1039,90531699995	1039,90531699997
10	Dwory Drugie	4,73695199999975	4,73695199999975

	BuiltInDistance	OwnDistance
1	0	0
2	71,849288771706	71,849288771706
3	71,1510268653939	71,1510268653939
4	72,7483804080888	72,7483804080888
5	78,7971715862949	78,7971715862949
6	72,8559935008782	72,8559935008782
7	81,1135605185717	81,1135605185717
8	131,417563578846	131,417563578846
9	199,629394233414	199,629394233414
10	193,927557611083	193,927557611083

	name	BuiltInSearch	OwnSearch
1	województwo małopolskie	1	1
2	gmina Iwanowice	0	0
3	gmina Słomniki	0	0
4	Kraków	1	1
5	gmina Zabierzów	0	0

✓ Query executed successfully.

6 Summary

Created spatial Common Language Runtime User Defined Types and Functions provide same level of precision as built-in MSSQL Server spatial types.

However calculations are correct, area and distance results don't match real data. This problem might be caused by incorrect matching between geospatial coordinates and (X,Y) plane coordinates.

Created app accurately calculates distance between points as well as area of marked polygon created by user when compared to the built-in MSSQL Server spatial types. In addition to this application provides real-time searching of administrative areas which contains specified point with precision of 1km.

7 Literature

List below contains sources, from where I drew knowledge to create this application:

- https://learn.microsoft.com/en-us/sql/sql-server
- https://spring.io/projects/spring-boot