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Infrastructure for Spatial Information in the European Community (INSPIRE) Zenith Tropospheric Delay (ZTD) UML model and implementation of the web application based on the ZTD model

Thesis booklet of the Doctoral (PhD) dissertation

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1. The scientific background and introduction of the dissertation

One of the purposes of the satellite measurement is to examine how the atmosphere affects the GNSS signals. This particular case pays attention to the signal delays due to the neutral atmosphere. However, this research started after finishing the European project ”HUSKROUA - Space Emergency System,” (http://meteognss.net/?action=prj_descript) in which Miskolc University participated with Romanian, Slovakian partners under Ukrainian leadership. The project has been expanded to the Western European EIG EUMETNET GNSS Water Vapour Programme (E-GVAP) network (http://egvap.dmi.dk).
The purpose of the E-GVAP project was to collect and control the global navigation satellite system (GNSS) products, which are operational for the Numerical Weather Prediction (NWP) in the whole of Europe.
Furthermore, the main objective of the E-GVAP project was to get GNSS derived Zenith Tropospheric Delay (ZTD) estimates in real-time for metrological purposes. After finishing project E-GVAP, it was suggested to elaborate a ZTD data model according to Infrastructure for Spatial Information in the European Community (INSPIRE) Data Specification.

2. Research objectives of my scientific work

The ZTD estimation has been calculated on the base of specific parameters. For this research, it was used ZTD_estimation.TRP file and GNSS-station.xlsx file. The ZTD_estimation.TRP file is an output of the Bernese software analysis. For the calculation of the ZTD data in the Bernese software, it should be selected input parameters, which are very important to get a correct measurement of the ZTD estimation. The Bernese software was used mainly to process measurements which were collected from the satellites. In this particular case, the measurements were done between satellite and receiver. For the receiver, it was used the metrological station.
The objectives of this thesis work are summarized in the six main theses:

- Elaboration of the ZTD data attributes and comparison of the relevant INSPIRE Data Specification UML model;
- Elaboration of the relevant INSPIRE Data Specification UML model and developing an INSPIRE ZTD UML Data model;
- Creating a web application based on the ZTD data;
- Development of a new web-based technique for the presentation of the ZTD observations on the maps;
- Based on inverse distance weighting it has been developed a method for the interpolation of the attributes (stations) inside the ZTD web application;
- Developing XML files based on the ZTD_estimation.TRP file and their validation;

3. Author’s contribution

During my research work, I have developed and proved six central theses. This dissertation has been based on these theses. In the first two theses, I have been elaborated the ZTD data attributes in the ZTD_estimation.TRP file and based on them, I have compared the relevant INSPIRE Data Specification UML model. Based on the Data Specification, the UML model is made.

In this case, there is an overlap of the two Annexes in INSPIRE, between two application schemas. One is an application schema of the Geophysics (subtheme of the Geology, Annex II) and application schema of the Atmospheric Conditions (Annex III) which is based on the INSPIRE Observation and Measurements.
Furthermore, I suggested an extension of the Atmospheric Conditions application schema with the ZTD model. The details of the package structure have been described in the details in the dissertation.
However, based on the third thesis I have developed a very compact mini GIS system where have also been elaborated these theses: development of a new web-based technique for the presentation of the ZTD observations on the maps, and based on inverse distance weighting, development of a method for interpolation of the attributes (stations) inside the ZTD web application.
In the last thesis, I have developed XML files for the attributes on which is based the model. They are based on the ZTD estimation file, which was the input to the whole research together with the GNSS station coordinates.

4. Experimental research

This experimental research is based on INSPIRE directive data specifications. The input for creating a UML ZTD model was a ZTD_estimation.TRP file. This file has been processed in the Bernese software. It contains input parameters which have been defined by the software, and these parameters are a-priori model gradient model, mapping function, min Elevation and tabular interval from and to.
Furthermore, the output parameters of the software were correction, correction East, correction North, correction Sigma, model, sigma East, sigma North. Based on these parameters, which are held in ZTD_estimation.TRP file, a ZTD UML model, was created, It is based on the INSPIRE Data Specification. For the creation of the ZTD UML model, Enterprise Architect (EA) has been used.
The database has been created using PostgreSQL and PostGIS. In the backend of the web application, an ASP.NET Core framework is used, then data format JSON, web service REST, and HTTP protocol. The frontend was based on the programming language JavaScript, markup language HTML and styling language CSS.
Furthermore, because of the flexibility, Google Maps were used, and vector layers are overlays which are placed on top of the Google Maps raster. Additionally, the implementation of the ZTD web application it is discussed in this research.
Finally, I will explain a higher context of the extension of the Atmospheric conditions model and creation of the ZTD web application. During the research of INSPIRE themes and regulations, I have realized that in the Atmospheric conditions theme, there are a lot of gaps and unfinished work. In AC theme there is no any Style Design Layer (SLD's) which should be created or Web Feature Service or Web Map Service. Even the maps which are presented as a part of this theme just shows the snow land coverage. Just to have on our mind, these maps are available only for several countries. The extension of the AC theme, in this case, ZTD model will be handy for the entire INSPIRE community. The application which is made in this research can also be used by INSPIRE community for the weather forecast and climate changes. There is a lot of advantages of this research work which can be used and modelled by INSPIRE community.

5. Scientific results, theses

Thesis 1.

Elaboration of the ZTD data attributes and comparison of the relevant INSPIRE Data Specification UML model;

In this experimental research, there is an overlap between the two themes. These themes are in the different Annexes of INSPIRE. The theme Geology is in Annex II of the INSPIRE. This theme has three sub-themes: Geology, Hydrology, and Geophysics. This research has been used as a part of the UML model, an application schema of the sub-theme Geophysics.
Furthermore, it will be explained what does the term Geophysical Station mean and also how it is presented in an application schema of the Geophysics sub-theme. By the terms and definitions in INSPIRE (https://inspire.ec.europa.eu/file/1519, 2013, p. 5), the Geophysical Station represents a geophysical measurement, which is referenced in space to a single point location. In Figure 1. UML class diagram of the Geophysics Measurement is presented.

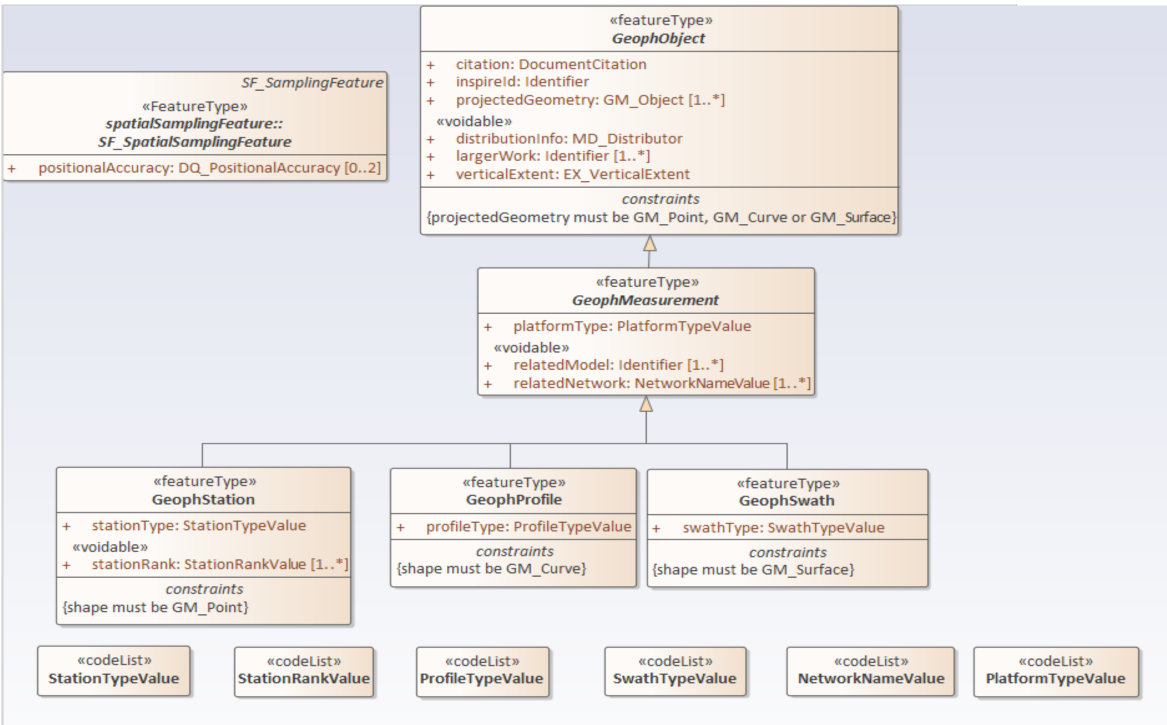

Figure 1. The UML class diagram of the Geophysics Measurement;

Additionally, in this UML class diagram, an essential feature type for this research is GeophStation. GeophStation is defined as the geophysical measurement, which is referenced to a single point location in space. They are used to collect data from an only place, and the collected data are spatially referenced to a single point. The GeophStation can be Gravity station, Magnetic station, and in this case, it is referred to a ground-based GNSS station. The UML application schema of the Atmospheric Conditions is shown in Figure 2.

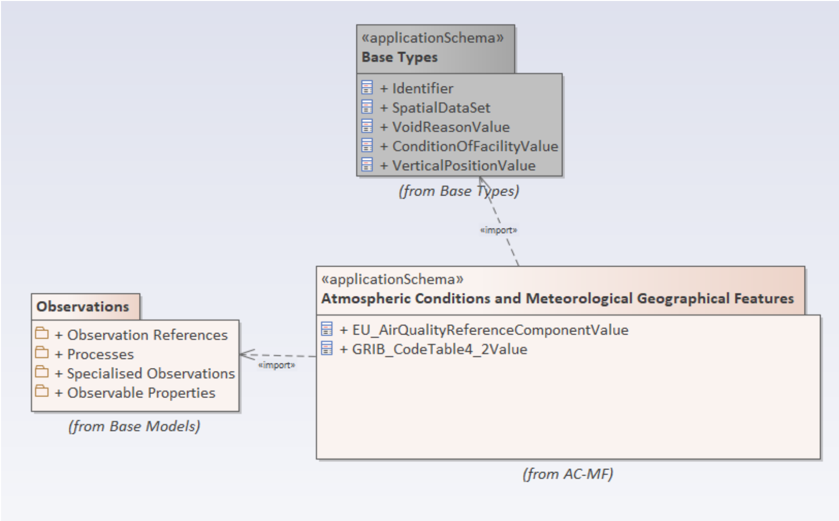

Figure 2. The package structure of the Atmospheric Conditions;

On the other hand, the theme Atmospheric Conditions data specifications are based on the Observation and Measurement conceptual model, which has been defined with ISO 19156:2011 (https://inspire.ec.europa.eu/file/1532, 2013, p. 21). The overview of the conceptual model of the Observations is shown in Figure 3.

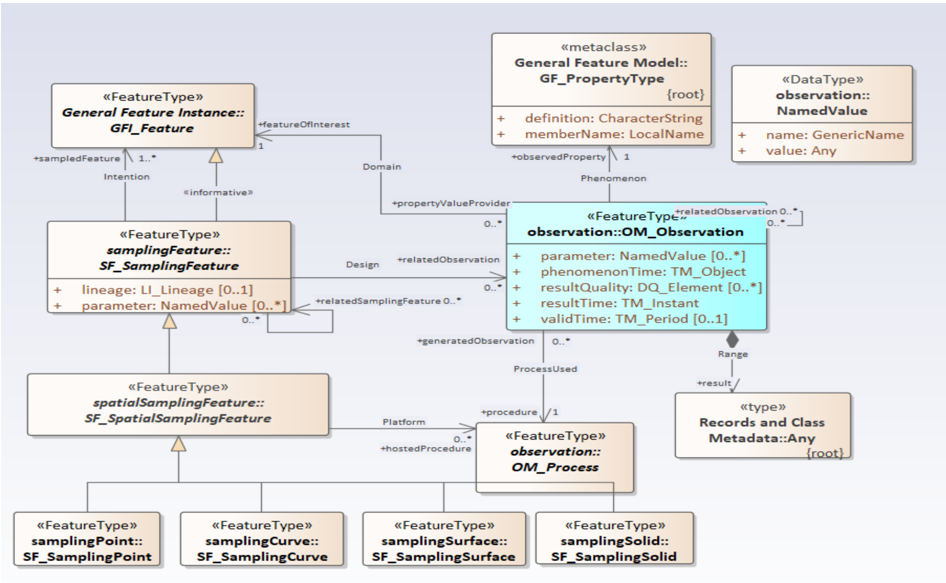

Figure 3. The overview of the Observation concept;

Finally, the Observations package from the base model can import application schema for the Specialised Observations and also introduce leaf Point Observations, which are from Specialised Observations. The input for creating the ZTD UML data model was ZTD_estimation.TRP file. This file was the output of the processed data with Bernese software, as it was mentioned in the previous subchapters. In Figure 4. there is a ZTD_estimation.TRP file with its values and input and output parameters.

```
SGO NRT ZTD estimation                                                18-SEP-14 02:30
-----------------------------------------------------------------------------------------------------------------------------
 A PRIORI MODEL:  -15   MAPPING FUNCTION:    4   GRADIENT MODEL:    1   MIN. ELEVATION:    5   TABULAR INTERVAL:  1800 / 43200

 STATION NAME     FLG   YYYY MM DD HH MM SS   YYYY MM DD HH MM SS   MOD_U   CORR_U  SIGMA_U TOTAL_U  CORR_N  SIGMA_N  CORR_E  SIGMA_E

 ANKR 20805M002    A    2014 09 17 14 00 00                        2.0534  0.15193 0.00134 2.20529 -0.00016 0.00012 -0.00088 0.00009
 ANKR 20805M002    A    2014 09 17 14 30 00                        2.0534  0.15725 0.00089 2.21061 -0.00015 0.00011 -0.00081 0.00009
 ANKR 20805M002    A    2014 09 17 15 00 00                        2.0534  0.15505 0.00090 2.20841 -0.00014 0.00010 -0.00073 0.00008
 ANKR 20805M002    A    2014 09 17 15 30 00                        2.0534  0.15912 0.00098 2.21248 -0.00012 0.00009 -0.00066 0.00007
 ANKR 20805M002    A    2014 09 17 16 00 00                        2.0534  0.16490 0.00078 2.21826 -0.00011 0.00009 -0.00058 0.00007
 ANKR 20805M002    A    2014 09 17 16 30 00                        2.0534  0.16662 0.00095 2.21998 -0.00009 0.00008 -0.00051 0.00006
 ANKR 20805M002    A    2014 09 17 17 00 00                        2.0534  0.16420 0.00077 2.21756 -0.00008 0.00007 -0.00043 0.00006
 ANKR 20805M002    A    2014 09 17 17 30 00                        2.0534  0.15839 0.00083 2.21175 -0.00006 0.00007 -0.00036 0.00006
 ANKR 20805M002    A    2014 09 17 18 00 00                        2.0534  0.16271 0.00070 2.21606 -0.00005 0.00006 -0.00028 0.00005
 ANKR 20805M002    A    2014 09 17 18 30 00                        2.0534  0.16071 0.00087 2.21407 -0.00003 0.00006 -0.00021 0.00005
 ANKR 20805M002    A    2014 09 17 19 00 00                        2.0534  0.16700 0.00077 2.22036 -0.00002 0.00006 -0.00013 0.00005
 ANKR 20805M002    A    2014 09 17 19 30 00                        2.0534  0.16450 0.00083 2.21786 -0.00000 0.00006 -0.00006 0.00005
 ANKR 20805M002    A    2014 09 17 20 00 00                        2.0534  0.16999 0.00078 2.22335  0.00001 0.00005  0.00002 0.00006
 ANKR 20805M002    A    2014 09 17 20 30 00                        2.0534  0.16858 0.00102 2.22194  0.00003 0.00006  0.00009 0.00006
 ANKR 20805M002    A    2014 09 17 21 00 00                        2.0534  0.16933 0.00081 2.22269  0.00004 0.00006  0.00017 0.00006
 ANKR 20805M002    A    2014 09 17 21 30 00                        2.0534  0.16750 0.00092 2.22086  0.00006 0.00006  0.00024 0.00007
 ANKR 20805M002    A    2014 09 17 22 00 00                        2.0534  0.16564 0.00078 2.21900  0.00007 0.00007  0.00032 0.00007
 ANKR 20805M002    A    2014 09 17 22 30 00                        2.0534  0.16620 0.00070 2.21955  0.00009 0.00007  0.00039 0.00008
 ANKR 20805M002    A    2014 09 17 23 00 00                        2.0534  0.16814 0.00067 2.22150  0.00010 0.00008  0.00047 0.00008
 ANKR 20805M002    A    2014 09 17 23 30 00                        2.0534  0.17340 0.00094 2.22676  0.00012 0.00009  0.00054 0.00009
 ANKR 20805M002    A    2014 09 18 00 00 00                        2.0534  0.17250 0.00099 2.22585  0.00013 0.00009  0.00062 0.00010
 ANKR 20805M002    A    2014 09 18 00 30 00                        2.0534  0.16531 0.00105 2.21867  0.00059 0.00008  0.00060 0.00008
 ANKR 20805M002    A    2014 09 18 01 00 00                        2.0534  0.16107 0.00089 2.21443  0.00105 0.00011  0.00059 0.00010
 ANKR 20805M002    A    2014 09 18 01 30 00                        2.0534  0.15825 0.00101 2.21161  0.00151 0.00017  0.00058 0.00014
 ANKR 20805M002    A    2014 09 18 02 00 00                        2.0534  0.16495 0.00143 2.21831  0.00197 0.00022  0.00056 0.00019
```

Figure 4. The ZTD_estimation.TRP file;

Additionally, another data has been calculated on the base of the input parameters, and they are structured in the groups of 12.5 hours for the period of 49 stations. The measurements from each station have 11 attributes and according to the ZTD_estimation.TRP file. The INSPIRE ZTD UML model will be elaborated for one group of the processed data. As we have data from the 49 metrological stations, and measurements were done for each station 12.5 hours, so the data for each station will be stored in 49 identical INSPIRE ZTD UML model.

Thesis 2.

Elaboration of the relevant INSPIRE Data Specification UML model and developing an INSPIRE ZTD UML Data model;

The proposition of the extension of the INSPIRE ZTD UML data model was based on the part of the application schema of the Geophysics (this is a subtheme of the Geology) and application schema Atmospheric Conditions which are based on the Observations. In the package structure AC-MF, the application schema ZTD Observations (AC-MF) was imported from the ZTD model. The proposed application schema ZTD Observations (AC-MF) is shown in Figure 5.

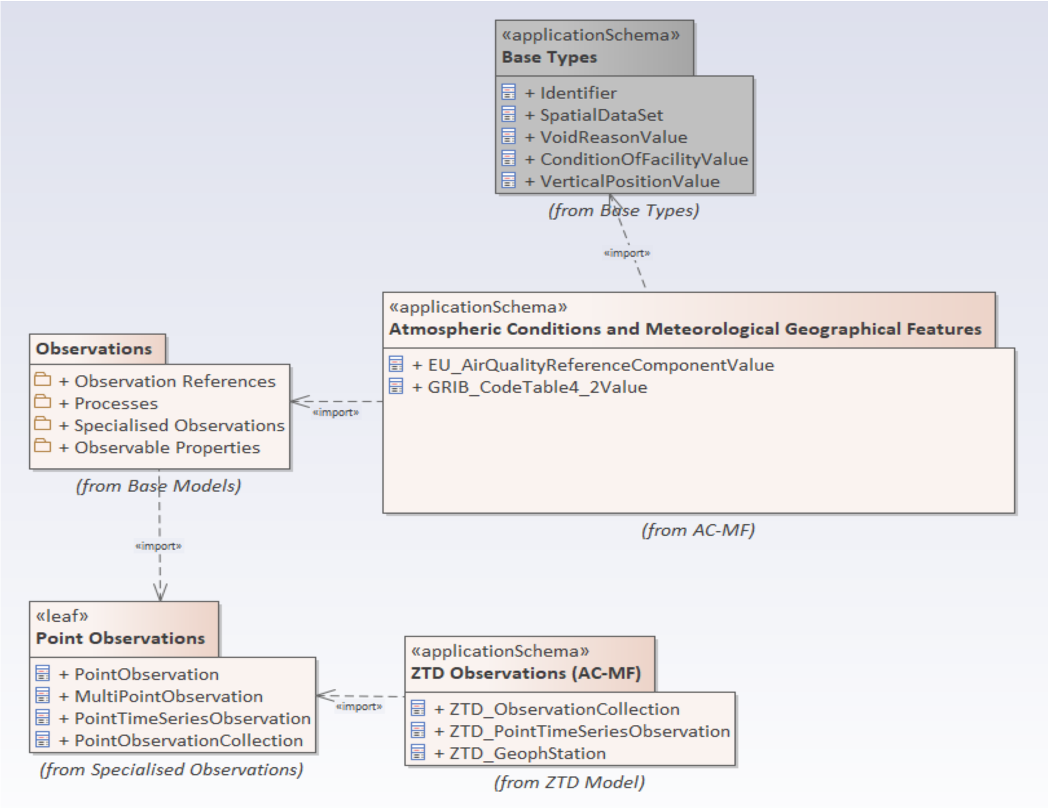

Figure 5. The package structure of the application schema ZTD Observations (AC-MF);

The Observation package is imported from the base model, and the leaf Point Observations belong to the Specialised Observations as it was previously mentioned. Still, PointTimeSeriesObservation will be used, because it is an observation that represents a time-series measurement of a property at the fixed location in the space and time.
Furthermore, three classes for the ZTD Observations (AC-MF) are made as to the proposition of extension of the model, and they are extensions of the exciting classes. Each class that has been made will be described. The first performed class for the creation of the model is ZTD_GeophStation. It is shown in Figure 6.

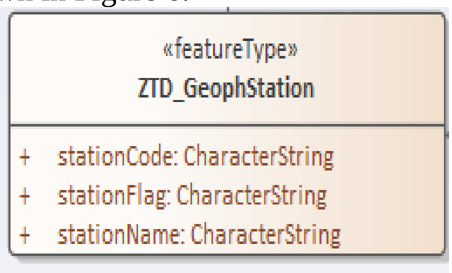

Figure 6. The first created class ZTD_GeophStation;

The first class, ZTD_GeophStation, was made based on the GeophStation from the application schema of the Geophysics, under the package GeophMeasurement.
The second extended class is ZTD_PointTimeSeriesObservation, defined as the single station generated ZTD measurement samples, which are taken each second, averaged per period of 30 minutes. Figure 6.8. shows the extended class ZTD_PointTimeSeriesObservation.

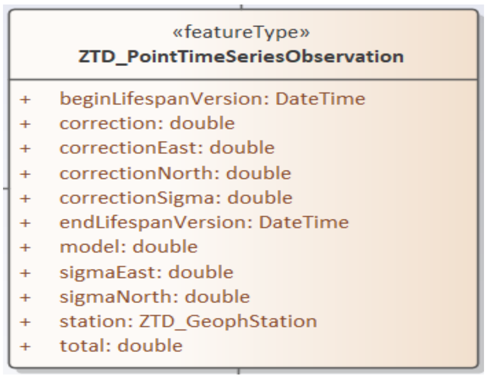

Figure 7. The second created class ZTD_PointTimeSeriesObservation;

The extended third class is ZTD_ObservationCollection. This class is defined as a ZTD measurement collection based on specified process parameters. So, the third class is shown in Figure 8.

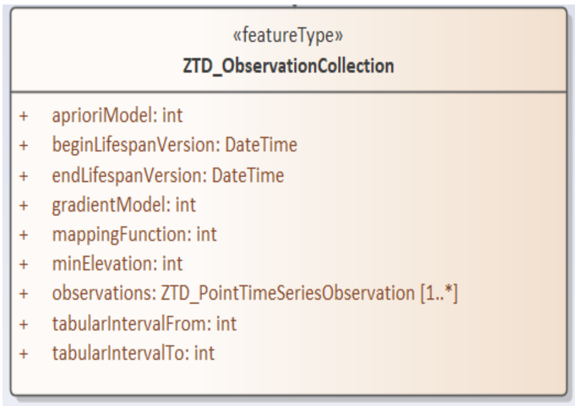

Figure 8. The third created class ZTD_ObservationCollection;

Furthermore, this class provides the input parameters of the Bernese software, on which calculations are based.

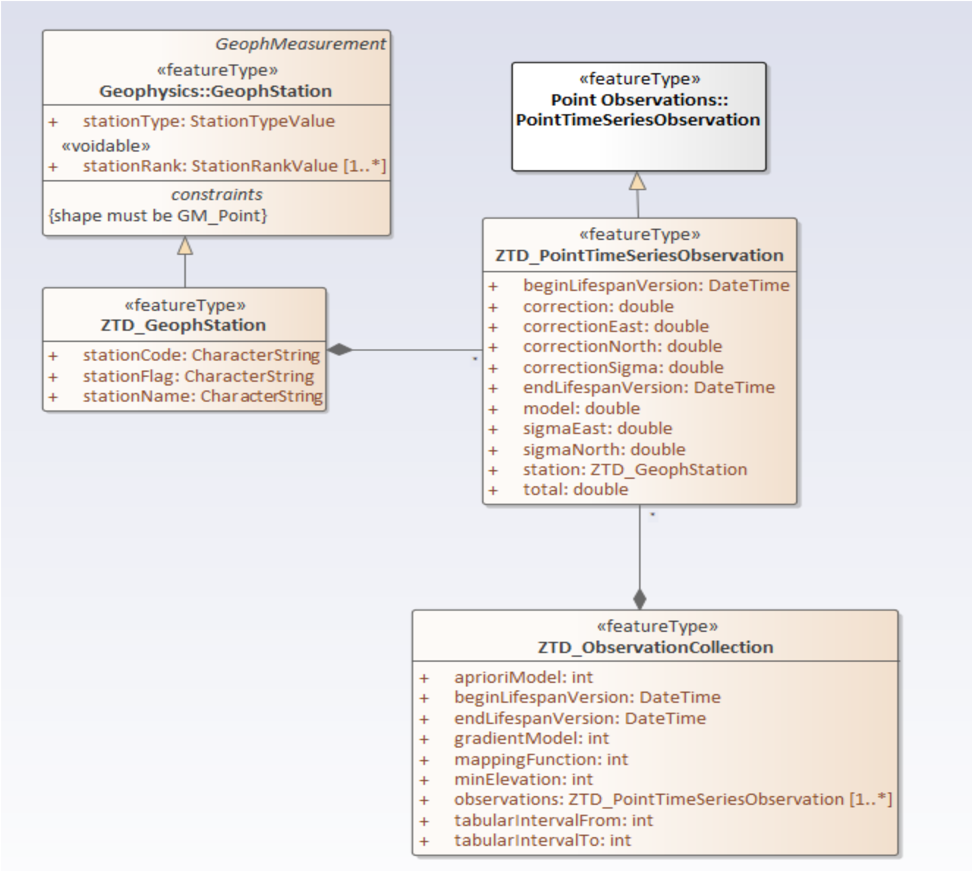

Figure 9. The proposed extension of the Atmospheric Conditions (AC-MF) INSPIRE ZTD UML data model;

The extension of the proposed model is based on these relationships between them, and they are generalization and aggregation. The relation between classes ZTD_GeophStation and Geophysics:: GeophStation is a generalization which means that ZTD_GeophStation is a single station which has a series of measurement with the specific type of geometry which is the 2D point. The station beside their characteristics has code, flag and name properties, too.
However, the relation between the ZTD_GeophStation and ZTD_PointTimeSeriesObservation is aggregation, which means that one station comprises several measurements. Each measurement which has been done on this station has its station from which one was done. So, that is confirmed with this type of relation.
Additionally, ZTD_PointTimeSeriesObservation class inherits the Observation and Measurement class in this case PointObservations::PointTimeSeriesObservations. The relationship between them is a generalization, which means that the measurements have a specific time series.
In the end, the relation between classes ZTD_PointTimeSeriesObservation and ZTD_ObservationColection is aggregation, and that means that objects of the ZTD_PointTimeSeriesObservation class can access to the objects of another class in this case ZTD_ObservationCollection.
In this relation, the dependent object is ZTD_PointTimeSeriesObservation because the ZTD_ObservationCollection contains parameters (input parameters of the Bernese software) on which basis are calculated all attributes of the ZTD_PointTimeSeriesObservation.

Thesis 3.

Creating a web application based on the ZTD data;

The web application is executed in the web browser. It collects data from the server-side or backend and shows it on the web page. Modularly it is decoupled to:

- HTML (HyperText Markup Language) – web page structure
- CSS (Cascade Style Sheet) – web page styling
- JS (JavaScript) – web page functionality

ZTD represents a single page web application, and it has three files in the frontend part: index.html, main.css, and main.js. HTML page structure is hierarchically organized, containing structural elements which can include other components. A model with the hierarchical organization of web pages is called DOM (Document Object Model). Functionalities or user's operations are handled by JavaScript code in the main.js file. It also initializes the Google Maps component and calls backend for data.
Google Map satellite imagery or raster is automatically loaded from Google Map service. The map is initialized by using google.maps.Map Java Script class or prototype. After that, dates and figures, drop-down selection components are populated with data that came from the server-side.
Apart from Google Maps raster base, there are three additional layers:

- Stations – shows stations names and respective geolocations
- Circles – shows a location-based circle-size diagram for selected figure and time
- Heatmap – shows green-red gradient heatmap over the map for selected figure and time

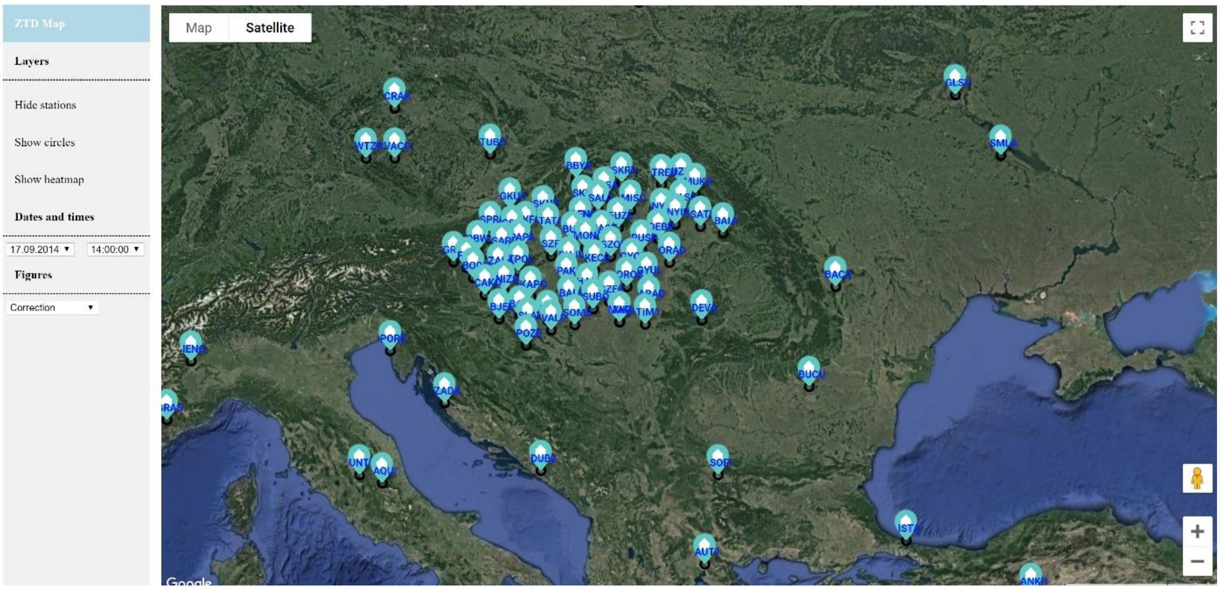

Figure 10. Stations layer;

The station's layer represents a simple marker map of stations along with their names. Station data is read from the *ztd_geoph_station* table on the server-side and rendered on the frontend. For the representation of markers, google.maps.Marker Java Script class or prototype is used. It receives parameters for coordinates, name, marker icon, and text style.

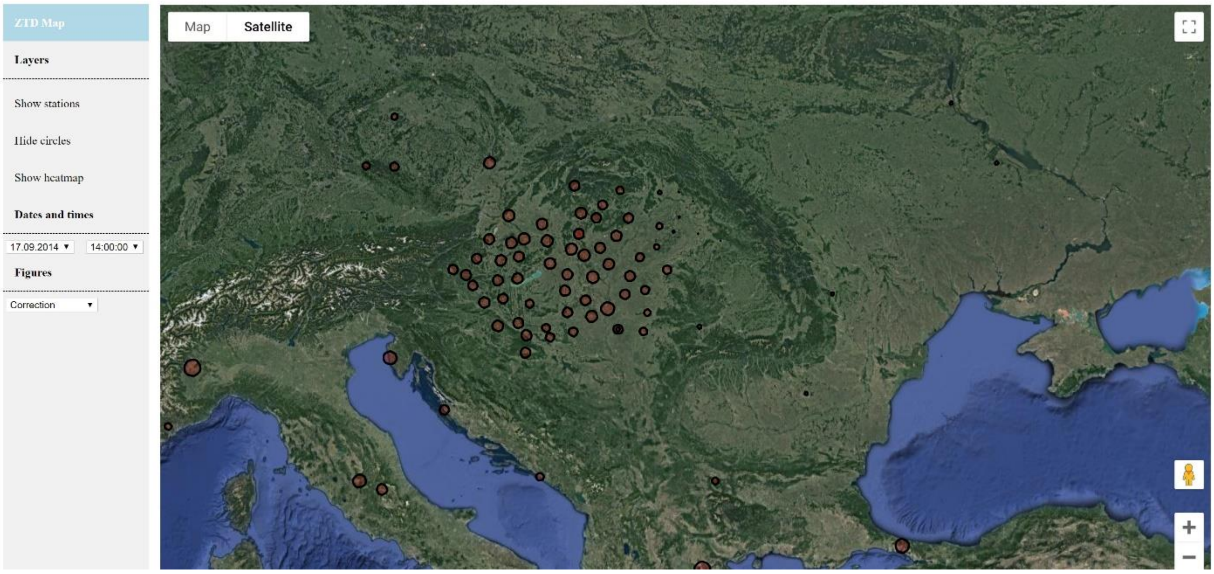

Figure 11. Circle-size layer;

The circle-size layer shows circles whose respective radius is calculated based on selected figures and time. For every circle, google.maps.Circle Java Script class or prototype is utilized. It receives the following parameters: centre location, radius and colour.

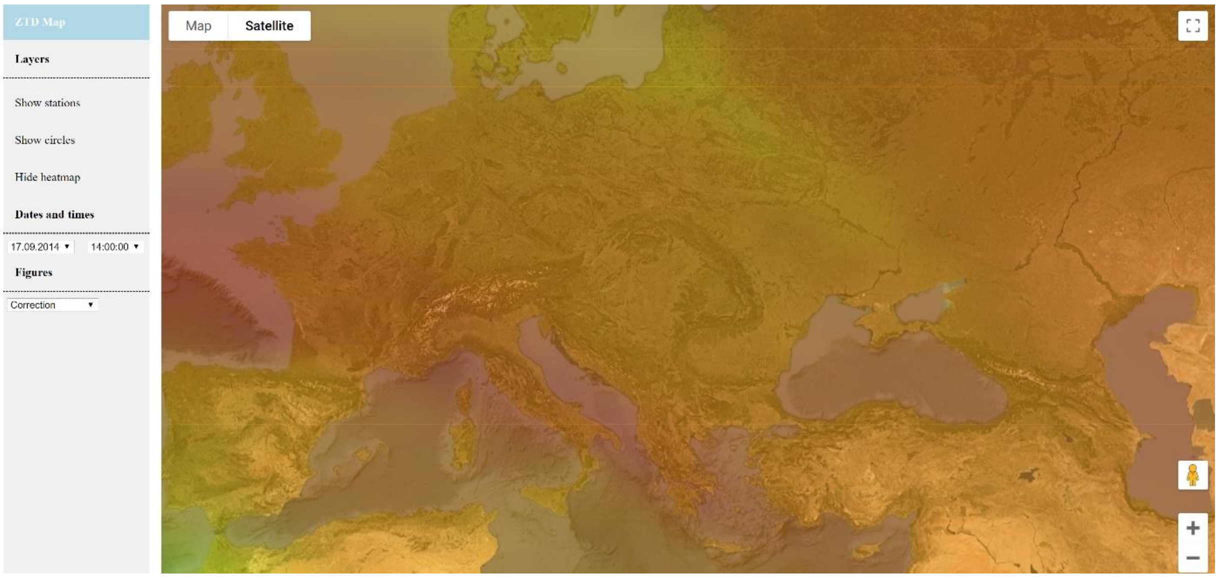

Figure 12. Heatmap layer;

The heatmap layer is different from Circle-size and Station layers because it is based on raster data, not vector data. Heatmap represents an RGB bitmap put over Google Maps satellite imagery raster with a setting of transparency or opacity. It uses google.maps.GroundOverlay class which receives an image URL (Uniform Resource Locator) and image bounds where the image should be "glued." Image bounds represent the whole map visible on the screen. URL of the image is a heatmap, which points to HeatmapController on the server-side which generates the image with Service package help.

Thesis 4.

Development of a new web-based technique for the presentation of the ZTD observations on the maps;

The ZTD application contains five packages, each containing the classes responsible for the package's general purpose. Controllers incorporate or use Services, Models, DAL, and an external third-party package called Microsoft.AspNetCore for inherited functionalities. The models' package class diagram is shown in Figure 13.

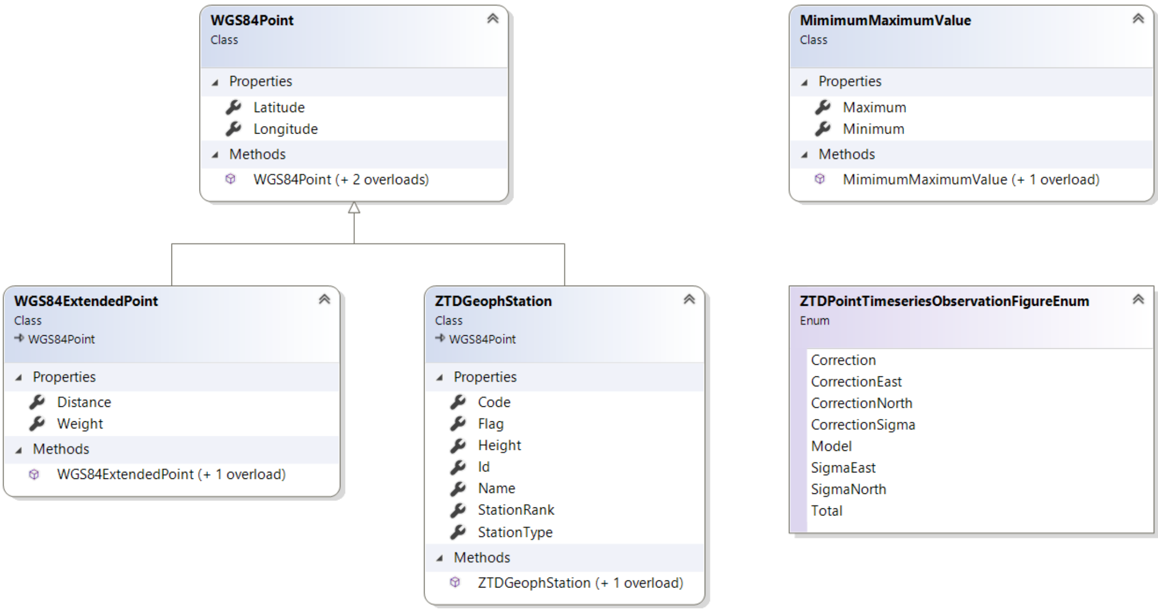

Figure 13. Models package class diagram;

Models package or namespace represents POCO classes (Plain Old Common language runtime Objects). Those classes are data transfer objects between Controllers, Services, and DAL. WGS84Point is classic longitude, latitude attributed point class which is inherited by WGS84ExtendedPoint (having extra distance and weight) and ZTDGeophStation.

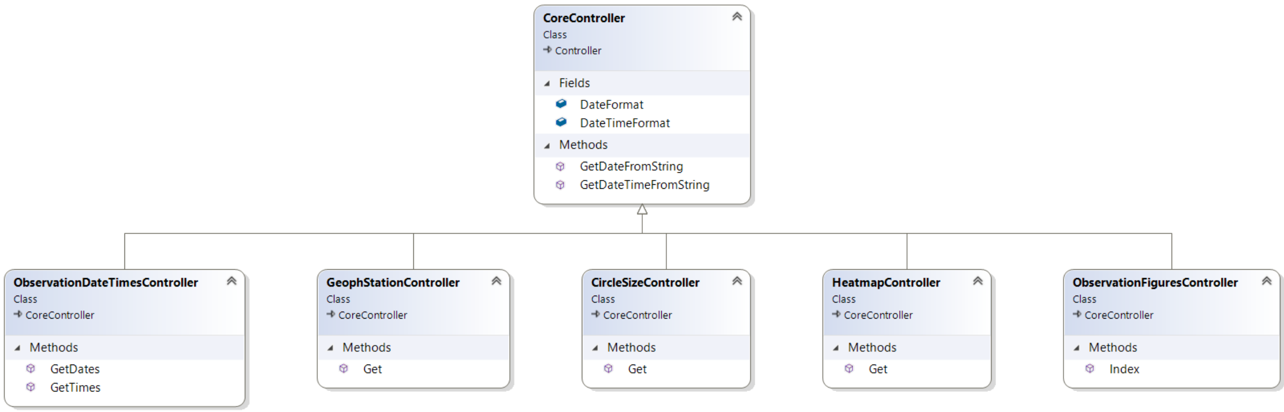

Figure 14. Controllers' package class diagram;

All exposed Controllers inherit CoreController which provides Date and DateTime formats used in the application, to avoid duplication. The controllers' package class diagram is represented in Figure 14. ObservationDateTimesController provides the exposure of dates and

times which are attached to specific observations. The GeophStationController returns a list of geophysical stations along with attributes. Then the CircleSizeController is used for the particular layer in the application, showing a circle size diagram on the map. The HeatmapController is responsible for the heatmap layer on the map.
Furthermore, ObservationFiguresController returns a list of figures available in ZTDPointTimeseriesObservationFigureEnum. The DAL package diagram is represented in Figure 15.

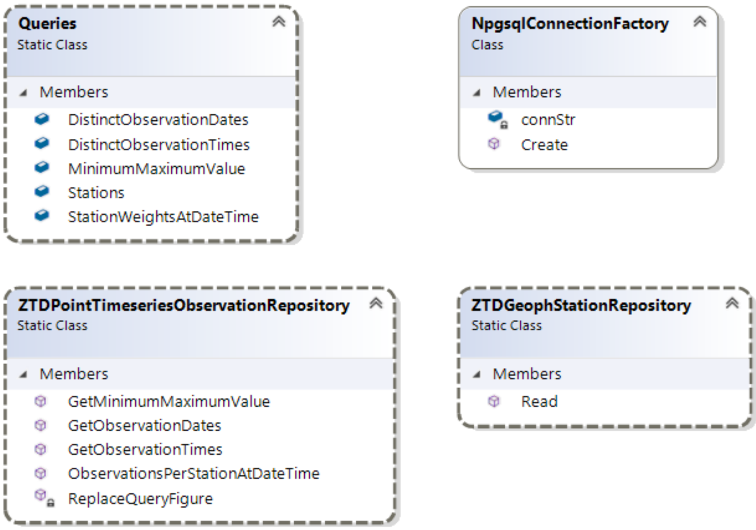

Figure 15. DAL package class diagram;

DAL represents an interface towards a data store or database. In this case, it is PostgreSQL with PostGIS plugin for GIS functionalities.
For every call, they create a new NpgsqlConnection instance over NpgsqlConnectionFactory and then create a NpgsqlCommand instance by setting which particular SQL query is going to be executed. In the end, NpgsqlDataReader is being emphasized through to extract data used for specific object creation.

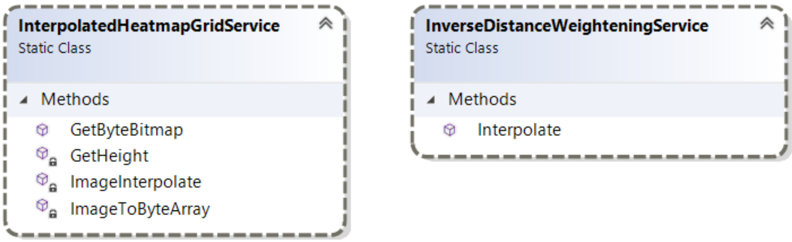

Figure 16. Services package class diagram;

Services package or namespace contains two classes: InterpolatedHeatmapGridService and InverseDistanceWeighteningService

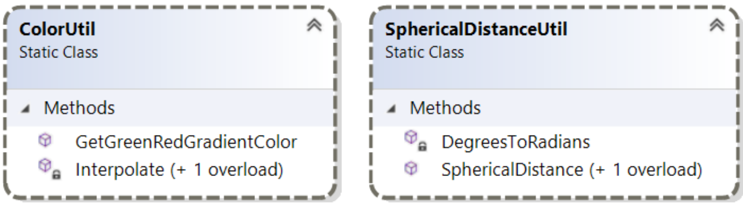

Figure 17. Util package class diagram;

There are two classes in the Util package: ColorUtil and SphericalDistanceUtil. ColorUtil calculates the green-red gradient from percentage. It sets RGB (red, green, blue) values from a single percentage value by setting offsets going from red over yellow to green.

Thesis 5.

Based on inverse distance weighting it has been developed a method for the interpolation of the attributes (stations) inside the ZTD web application;

Services package or namespace contains two classes: InterpolatedHeatmapGridService and InverseDistanceWeighteningService. InverseDistanceWeighteningService implements IDW (Inverse Distance Weighting) interpolation by using the list of station locations and their corresponding figures or weights at a provided time. The algorithm takes k-nearest neighbours to calculate the weight at an arbitrary point, as it can be seen in the picture. The philosophy of IDW interpolation is that the influence of a particular point's weight is inversely proportional to the distance. Distances are calculated by using the SphericalDistanceUtil class, as it has been shown in Figure 18.

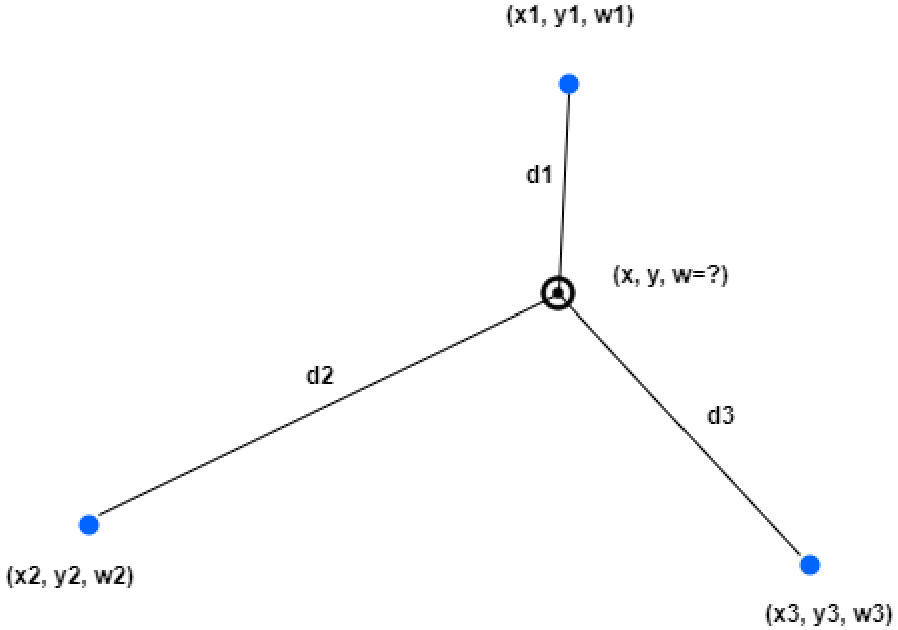

Figure 18. Inverse distance weighting calculation example for 3 points;

The formula for the calculation of the arbitrary weight for *n* points and their respective weights and distances is:

$$W_p = \frac{\sum_{i=1}^{n} \frac{w_i}{d_i^p}}{\sum_{i=1}^{n} \frac{1}{d_i^p}} \tag{7.1}$$

The *p* parameter influences the formula so that it makes near points more critical if it is higher. For the ZTD application, *p* equals 1. Since the majority of figures are similar for different observations, interpolation is done based on two nearest points.

InterpolatedHeatmapGridService returns a bitmap of the heatmap by calculating the green-red gradient for every pixel based on the south-west and north-east boundaries. It goes through pixels and determines the same coordinate projection of pixels on the underlying raster. Then it interpolates the nearest stations and gets the figure which is recalculated to the percentage of the difference of minimum and maximum value of the constitution.

Thesis 6.

Developing XML files based on the ZTD_estimation.TRP file and their validation;

During this experimental research, four XML files were created from the consolidated UML model. The first XML file ZTD_ProcessParameters.xml file describes the input parameters of the Bernese software. The second XML file is ZTD_Record.xml which contains all the output parameters of the ZTD_estimation. TRP file and they are: model, correction, correctionSigma, total, correctionNorth, sigmaNorth, correctionEast and sigmaEast. The third XML is ZTD_Station_ANKR.1. This XML is generated from the ZTD_estimation.TRP file and it should be one XML for each station. This .xml is strongly connected with ZTD_Observations_ANKR-20805M002.1.xml because each station references the one ZTD_Observations_ANKR-20805M002.1.xml file. The last .xml file which has been created is ZTD_ANKR-2005M002-20805M002.1. The ZTD_ANKR-2005M002-20805M002.1.xml file has been generated from the ZTD_estimation.TRP file generating one file for each station. It contains 25 data samples which are referenced back to the ZTD_Station_ANKR.1.xml file.

6. List of publications in the field of dissertation

Chapter of a Book

1. Borisov M., Mijić N., Bugarin T., Petrović V.M., Sabo F. (2020) The Concept and Application of the 3D Model Based on the Satellite Images. In: Avdaković S., Mujčić A., Mujezinović A., Uzunović T., Volić I. (eds) Advanced Technologies, Systems, and Applications IV -Proceedings of the International Symposium on Innovative and Interdisciplinary Applications of Advanced Technologies (IAT 2019). IAT 2019. Lecture Notes in Networks and Systems, vol 83. Springer, Cham, https://doi.org/10.1007/978-3-030-24986-1_23
2. Mijić N., Bartha G. (2019) Infrastructure for Spatial Information in European Community (INSPIRE) Through the Time from 2007. Until 2017. In: Avdaković S. (eds) Advanced Technologies, Systems, and Applications III. IAT 2018. Lecture Notes in Networks and Systems, vol 60. Springer, Cham, https://doi.org/10.1007/978-3-030-02577-9_5
3. Mijić N. (2019) Application of the Airborne LIDAR Technology on the Quarry Using AutoCAD Civil 3D Software. In: Avdaković S. (eds) Advanced Technologies, Systems, and Applications III. IAT 2018. Lecture Notes in Networks and Systems, vol 60. Springer, Cham, https://doi.org/10.1007/978-3-030-02577-9_6
4. Borisov M., Mijic N., Ilic Z., Petrovic V.M. (2019) Analysis and Visualization of the 3D Model – Case Study Municipality of Aleksandrovac (Serbia). In: Avdaković S. (eds) Advanced Technologies, Systems, and Applications III. IAT 2018. Lecture Notes in Networks and Systems, vol 60. Springer, Cham, https://doi.org/10.1007/978-3-030-02577-9_10

5. Mijic N., Ateljevic J. (2018) Demographic Analysis Using Modern GIS Software Tools—Case Study of the Republic of Srpska (Bosnia and Herzegovina). In: Hadžikadić M., Avdaković S. (eds) Advanced Technologies, Systems, and Applications II. IAT 2017. Lecture Notes in Networks and Systems, vol 28. Springer, Cham, https://doi.org/10.1007/978-3-319-71321-2_51
6. Mijic N., Sestic M., Koljancic M. (2017) CAD—GIS BIM Integration—Case Study of Banja Luka City Center. In: Hadžikadić M., Avdaković S. (eds) Advanced Technologies, Systems, and Applications. Lecture Notes in Networks and Systems, vol 3. Springer, Cham, https://doi.org/10.1007/978-3-319-47295-9_22

Journal Articles

1. Mijić N., Šestić M., Future development of NSDI based on European INSPIRE Directive – A case study of a Bosnian and Herzegovinian geoportal, International Journal of Spatial Data Infrastructure Research, 2018, Vol. 13, 315-338, Joint Research Centre, European Commission, DOI:10.2902/1725-0463.2018.13art19, http://ijsdir.jrc.ec.europa.eu/index.php/ijsdir/article/view/472

Conference Papers

1. Mijić N., Šestić M., ECONOMIC IMPACT ASSESSMENT OF THE INFRASTRUCTURE REQUIRED BY THE INSPIRE DIRECTIVE, 6th REDETE Conference - RESEARCHING ECONOMIC DEVELOPMENT AND ENTREPRENEURSHIP IN TRANSITION ECONOMIES, April 2018, Banja Luka, Bosnia and Herzegovina, pp 236-246, ISBN 978-99938-46-80-2, http://www.redete.org/
2. Mijić N., Bartha G., Vujičić M. T., INSPIRE CONCEPT AND DIGITAL DATA MODELS, 6th INTERNATIONAL CONFERENCE CONTEMPORARY ACHIEVEMENTS IN CIVIL ENGINEERING 2018, page 673-683, April, Subotica, Serbia.
3. Mijic N., Bartha G., INSPIRE INFRASTRUCTURE FOR SPATIAL DATA - MAIN ASPECTS OF FUTURE DEVELOPMENT, MultiScience – XXXI. MicroCAD International Multidisciplinary Scientific Conference, University of Miskolc, Miskolc, Hungary, 20-21 April 2017. ISBN 978-963-358-132-2
4. Mijic N, Preradovic D, Sestic M, STRATEGIC DEVELOPMENT OF INFRASTRUCTURE FOR SPATIAL INFORMATION BASED ON EUROPEAN INSPIRE DIRECTIVE, 5TH REDETE Conference, 28 – 30 October 2016, Belgrade, Serbia, http://www.redete.org, pp 301-317
5. Mijic N, DEVELOPMENT OF BOSNIAN AND HERZEGOVINIAN GEOPORTAL THROUGH INSPIRE STANDARDS, PhD Forum, Faculty of Earth Science and Engineering, University of Miskolc, 16th of November 2016, Miskolc, Hungary.

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