Data Quality Concept for e-Government Web-Map Based Services

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Abstract

WeGovNow (WGN) is a platform combining a number of e-Government web-map based services. The platform is designed to increase citizens' involvement into government of urban areas and collaborative decision making processes. Data quality is one of the most important factors for success of e-Government solutions. A data quality concept for the WGN platform was developed. In the frame of the platform, ground-truth reference datasets are not available. Thus, data quality is assessed intrinsically and comparably. OpenStreetMap (OSM) is a base map for all WGN components; Open Data spatial layers are provided by municipalities. OSM data quality is assessed for tiles; quality of Open Data provided by municipalities is evaluated in comparison to OSM data with defined quality. Additionally, OSM and Open Data with defined quality are utilized to improve users' input. Currently, the following tools for users' input improvement are available: auto completing, spell checking, auto snapping, and object picking.

Keywords: *Data Quality, E-Government, Web-Map Services, OpenStreetMap*

INTRODUCTION

In contrast to regular e-Government solutions, e-Government Web-Map based services provide map-centered functionality. Users expect high quality of data involved in such services. In the real world, services use available data with various quality. The aim of this work is to develop the concept and instances of a web service stuck to the existing e-Government web solutions for data quality assessment, improvement and visualization. The name of the proposing web service is Geo-Spatial Data Repository (GSDR). The service (Noskov and Zipf, 2018) is accessible by the following link: https://wgn.gsdr.gq/. In order to easily memorize the link, the web service can be described as "Geo-Spatial Data Repository for Grand Quality".

GSDR is developed in the frame of the WeGovNow (We Government Now) project funded by EU Horizon-2020 program. WeGovNow (Boella et al., 2018) is a research and innovation action focused on civic participation in local government aiming at using state-of-the-art digital technologies in community engagement platforms to involve citizens in decision making processes within their local neighborhood. WeGovNow (WGN) enables a new type of interactivity in the co-production of citizen-centered services and in the co-development of strategic approaches to community development. WGN provides several e-Government components and related services. The mentioned components provide the following facilities: citizens' urban activities coordination and collaboration, reporting local issues to a public administration, opinion formation on a given issue, and web mapping tools. All components implement map-centered web applications.

GSDR is the common data-quality-aimed service for the described platform. All components and services provide data to GSDR for further processing. WeGovNow's map applications use OpenStreetMap (OSM) as a base map, thus OSM data covered area of pilot sites are intensively utilized by GSDR.

In this work, the data quality concept implemented by GSDR is considered. The concept can be adopted by other map-based services. It is strongly related to the problem of OSM data quality and, specifically, the intrinsic data quality (i.e., evaluation without use of ground-truth reference datasets).

RELATED WORK

The WGN project can be considered as a modern implementation of a smart city initiative. According to (Cocchia, 2014), the term "smart city" is closely related to "digital city" and can be defined as city sustainable initiatives, institution road-maps to enhance green growth and quality of life, the usefulness of ICT infrastructures, the involvement of citizens in public life, the need to reduce digital divide, and so on. Digital/Smart City impacted first by Kyoto Protocol (1997), then, Widespread of Internet (2000), the IBM Smart Planet concept (2008), and the EU launched the Europe 2020 Strategy.

(Meijer and Bolivar, 2015) define smart governance as crafting new forms of human collaboration through the use of ICTs to obtain better outcomes and more open governance processes. They specify the smartness of a city as its ability to attract human capital and to mobilize this human capital in collaborations between the various (organized and individual) actors through the use of ICT.

Smart city initiatives are closely related to e-Government solutions. (Layne and Lee,2001) introduced an four-stage model of e-Government development. According to this model, the following stages can be distinguished: catalogue (online presence and downloadable forms), transaction (online forms and databases), vertical integration (lower level systems linked to higher level systems) and horizontal integration (systems integrated across different functions). One can conclude that the WGN projects acts on the latest stage (i.e., horizontal integration).

According to (Alenezi et al., 2015), the benefits gained from information sharing initiatives are dependent on Information Quality as an enabler and as a factor in increasing the success of e-Government information sharing projects. (Juran, 1988) introduced a very simple definition of information quality as "fitness for use".

(Ali, 2016) provided a comprehensive literature review on volunteered geographic information data quality. Extrinsic and intrinsic data quality assessment approaches are distinguished. In the frame of WGN, reference data are not available. Thus we are mainly focused on the intrinsic data quality assessment. In (Barron et al., 2014) and (Ballatore and Zipf, 2015), advanced complex approaches to intrinsic data quality assessment were introduced. In the former, quality is assessed in the following aspects: general information on the study area, routing and navigation, geocoding, points of interest, map-applications, user information and behavior. In (Ballatore and Zipf, 2015), a framework for evaluation conceptual accuracy, granularity, completeness, consistency, compliance and richness was proposed.

One can mention that even holistic quality assessment frameworks normally allow users to calculate only separate sets of multiple quality metrics; it is difficult to analyze such multi-dimensional results. Aggregated quality metrics can be derived using one of the following approaches: (Lee, Y. et al., 2002), (Cappiello et al., 2004), (Stvilia, 2007) and (Batini et al. 2009).

DATA QUALITY CONCEPT FOR WEGOVNOW

Data Sources

WGN aims on co-design between public service organisations and citizens designing better public services and effective community initiatives towards local solutions but also on co-management of urban services. WeGovNow deals with a large amount of data, mainly geographical and urban data, collected from public services and local stakeholder initiatives. Besides urban data, WGN, as a crowd-source-based platform, also deals with user/citizen derived data. Users produce and manage data concerning urban entities such as everyday-life issues, proposals, projects, voting reports, local groups, etc. So, in order to assess the quality of data in WGN we need to address:

- The context information provided to end users (urban data), cartographic source (OSM) and open data about the city (including non-geospatial data), and
- The user generated data (user activities and user actions within the WGN ecosystem).

Thus, the general approach towards data quality within WGN is therefore articulated considering two type of data sources, namely; static and dynamic sources. Static sources are not being updated very frequently such as urban data (e.g. schools, parks, traffic lights, etc).

Data quality assessment of urban data is a batch activity procedure aiming at providing quality contextual data to WGN users. The assessment should answer to the question "is the source good enough to support users' activities?". In other words, the cartographic information and open data provided by WGN should not mislead users in their evaluations but should, instead, support the collaboration and cooperation within the platform. Dynamic sources refer to data generated

by users while using/interacting the WGN platform. For that case, the batch process, followed on static sources case, is not suitable. Instead we are following the real-time approach. In this case, user data need to be analysed frequently (at least on daily basis) to assess the internal coherence of users' activities, the revision of urban data and the monitoring of the platform. To approach the analysis and monitoring of users' data, WGN introduces a common logger and translation system. Each component generates different data in their own schema, then the OnToMap (a common WGN web service providing public sector information data and logging users' contributions) logger translates the schema into a common format and it provides a homogeneous source data focused on users'. The assessment and monitoring will be provided by software component, accessible as web service.

The quality assessment of user generated data in WeGovNow OntoMap is therefore the analysis of components logs in a OntoMap-compatible common format, and based on a metaphor in common among current and future components. The implementation of the quality assessment web service will follow the development lifecycle of WeGovNow prototype, and will be tailored on the applicative scenarios collected during the engagement activities on the trial sites.

WGN platform handles the following data sources:

Static:

- OpenStreetMap (OSM) data
- Public Sector Information (PSI) and open data

Dynamic:

- User provided data (including non-geospatial data)

Each of the different type of data is further analysed below. OpenStreetMap (OSM) is utilized mainly as a base map for location based services of WeGovNow. OpenStreetMap is the most popular VGI (Volunteered Geographic Information) project. OSM allows users to digitize new map features and modify existing objects. 3.8 million of users have been registered since 2005. Today OSM's database stores more than 3.5 billion of nodes covering the whole planet. The project is very active and competes with traditional map providers (e.g., state mapping agencies) and popular commercial internet map providers (e.g., Google Maps). OSM allows anyone to download, modify and distribute their data under a liberal open license for any purpose (including commercial). OSM provides the following groups features: roads (including objects related to road infrastructure (e.g., sidewalks), buildings, water objects (e.g., rivers, lakes), land cover or land use data, amenity points, ferry routes, power lines, railways, railway stations. Most of the data are buildings, roads and land cover data. OSM uses a topological data format. Thus, shared borders and nodes of multiple features are stored only once. It allows users to easily input geographical features and prevents topological errors. OSM provides metadata (e.g., usernames, changesets' information, time of creation and modification of an object). Attribute data are provided by tags in a "key-value" format. This approach is flexible and allows users to apply any number of characteristics and any datatypes.

Public Sector Information (PSI) and open data are provided through OnToMap. Point, polyline and polygon features related to a city infrastructure (e.g., bike lanes, urban parks, hospitals, etc.) are provided as PSI datasets. WeGovNow's Location Based Services and Applications will widely utilize PSI data. It allows users to select geospatial objects on an interactive map, derive and manipulate with attribute information (e.g., address of a cinema stored as an attribute), search (e.g., find a shop by its name), etc. PSI data could be retrieved by OnToMap's API. An application of WGN may derive PSI data by this API using different parameters (e.g., bounding box, language, etc.). The datasets are provided in GeoJSON format. Higher level manipulations may be implemented on a side of a specific application. Objects of city infrastructure are provided as point, polygon and polyline features. Currently, the following data types are provided: urban parks, schools, stores, markets, bike lanes, restaurants, museums, places of worship, monuments, libraries, health social services, hospitals, drug stores, law enforcement objects, art galleries, clubs, etc.

Users contributed data and actions are registered by OnToMap's logger to achieve homogeneity and easier querying from the various WGN components. It enables the developers to track activity of users, detect possible problems and possible low-quality input. OnToMap's Logger stores events sent by applications of WGN. Similar to PSI data, OnToMap uses the GeoJSON data format for the logger. WeGovNow's logged relevant events could be displayed by a specific application. The quality of the mentioned data types is assessed in a frame of the WGN platform. A concept of quality evaluation is further presented.

Overall Data Quality Concept

The overall concept of data quality assessment approach on WeGovNow platform is illustrated in the following Figure 1. In the figure, data flows are depicted by black arrows. Data types are presented by blue. Quality assessment processes are shown by red. Results are marked by green. Green dashed arrows depict utilized reference datasets for comparable quality assessment. OSM data are assessed intrinsically. PSI data are evaluated comparably, using OSM and results of its quality assessment as reference datasets. User Contributed Data and Actions are assessed both intrinsically and comparably. OSM and PSI data, as well as results of their assessment, are utilized as reference datasets for comparable assessment of User Contributed Data and Actions quality.

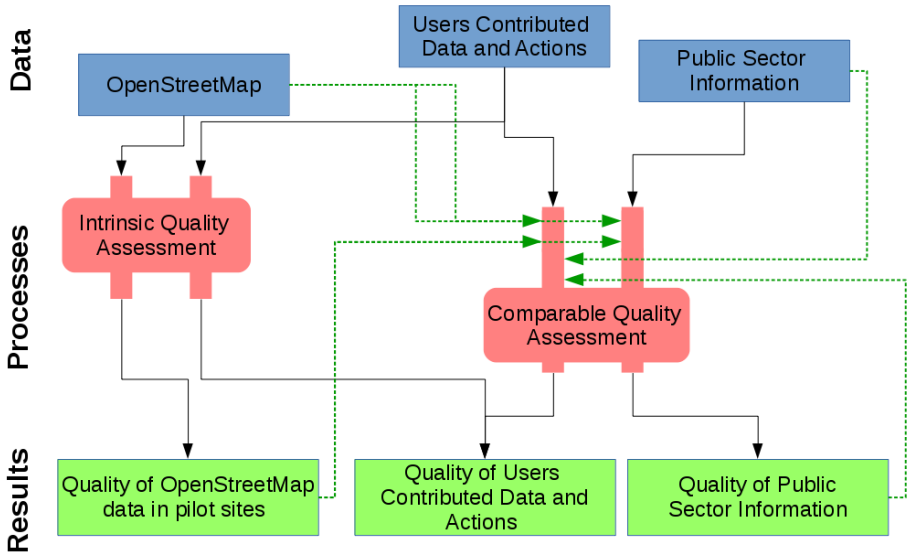

Figure 1. General concept of quality assessment of WeGovNow data.

Data quality is defined in ISO 9000:2015 as the degree to which a set of characteristics (e.g., completeness, validity, accuracy, consistency, availability and timeliness) of data fulfils requirements. In other words, it could be expressed as degree of correspondence of information to user's expectations. Data quality indicators could be defined in the various contexts: completeness, accuracy, precision, trustworthiness, credibility, etc. In order to obtain a comprehensive evaluation of quality, a set of approaches covering wide range of contexts should be utilized.

When making use of data with a geospatial aspect, it is important that users are aware of the underlying quality of the data so that they can make an informed decision that the information is "fit for use". With regards to this data quality, standards are available (such as the ISO 19157 standard on geospatial data quality) that define a number of metrics that can be used to assess this. These metrics include aspects such as geographic accuracy, logical consistency, temporal consistency and data omission/commission.

IMPLEMENTATION: GEO-SPATIAL DATA REPOSITORY FOR QUALITY ASSESSMENT

It has been decided to implement a web service for data quality assessment and improvement. Geo-Spatial Data Repository (GSDR) will play this role. Currently, the developing version and frozen third prototype of the service are accessible by the following link, correspondingly: https://wgn.gsdr.gq and https://wgn-pt3.gsdr.gq (see Figure 2). The service is being developed for WeGovNow project needs and will provide the following functionality:

- Intrinsic data quality assessment,
- Comparable data quality assessment,
- Presenting data quality assessment results in interactive maps and auto-generated report,
- Public APIs for quick data check and retrieval.

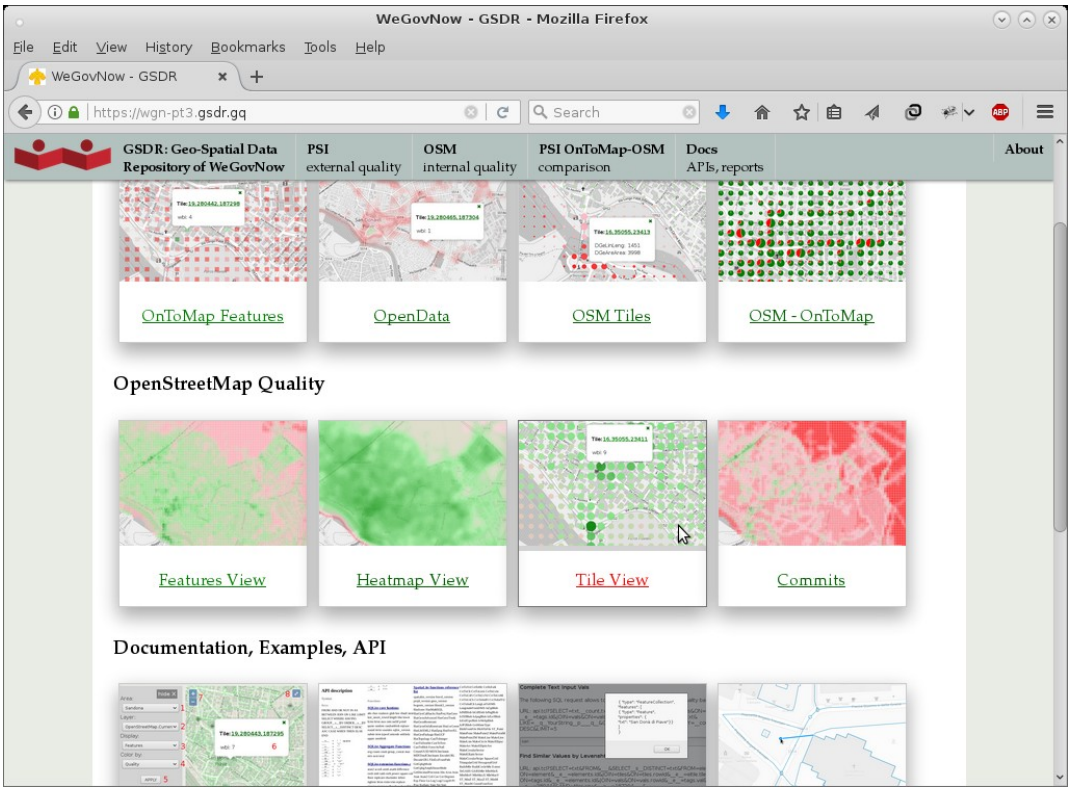

Figure 2. The main page of GSDR (the 3rd prototype).

Ground truth reference datasets are not available in frame of the project. Despite this, data quality could be evaluated and improved by the methods mentioned above. Intrinsic quality assessment allows defining data quality of OSM data (e.g., road network completeness). Additionally, the service is designed for detecting errors in PSI and WGN apps' data. These errors will be reflected in interactive maps and auto-generated reports. Quality and imperfections of PSI and WGN apps' data will be defined by a comparison with OSM data with known quality calculated intrinsically.

It should be mentioned that the service is not developed for geo-spatial data only. Many elements could be utilized for non-spatial data as well: completeness, logical consistency (excluding topological consistency), thematic accuracy and temporal quality. Since WGN provides mainly location based services though, our attention is concentrated on geo-spatial data quality.

The core component of GSDR is a database. The main harvesting data types are as follows: (1) OpenStreetMap (OSM) covering pilot sites, (2) PSI data provided by OnToMap and (3) OnToMap Logger data. OSM is a very dynamic map, thus OSM data need to be updated periodically. This functionality will be supported by the aforementioned web service.

In Figure 3, the conceptual architecture of GSDR is presented. Spatial database's components are marked by blue. GSDR's components responsible for interaction with external applications are depicted on yellow. External components are distinguished with green colour. Black arrows represent data flows.

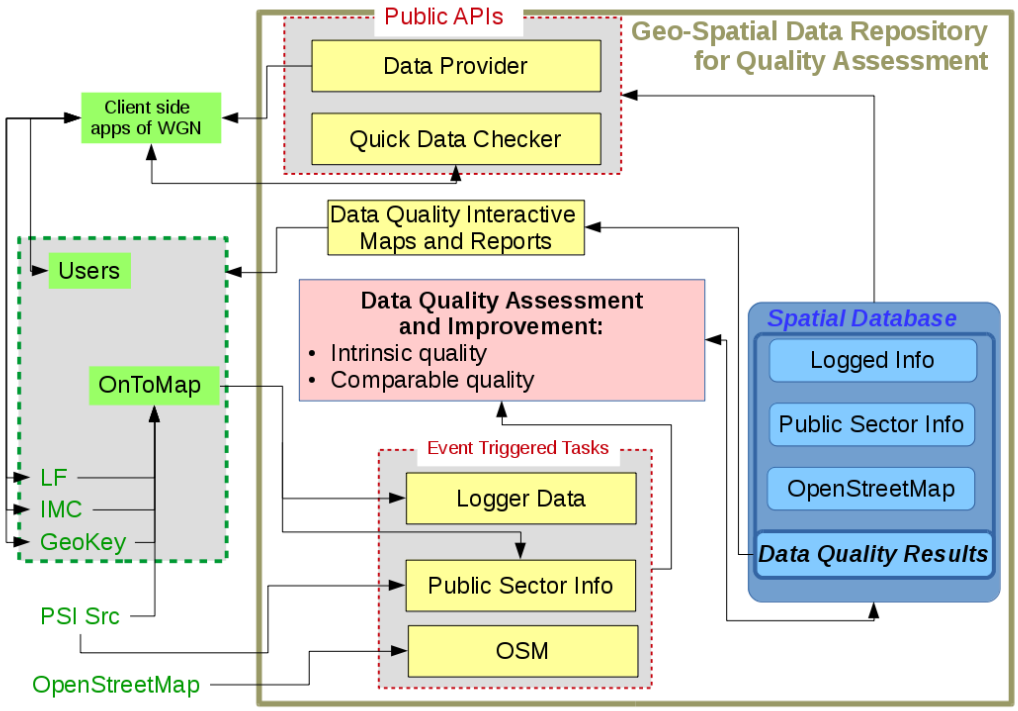

Figure 3. Conceptual architecture of GSDR

In general, a process of quality evaluation may be described as follows. First, quality of OSM data will be defined intrinsically at the first step. Next, quality of PSI data will be evaluated using shared objects of OSM data with known quality. It should be mentioned that many objects provided by the PSI datasets of OnToMap are presented in OSM. These shared objects will be used for external quality evaluation of the PSI data. OSM is utilized as a reference dataset in this case. It allows us to apply approaches to data quality assessment described in the ISO 19157-2013. Logger data will be assessed using both OSM and PSI datasets.

Intrinsic data quality assessment

OpenStreetMap project provides different types of data: OSM Weekly Planet XML file, full history dump, tiles logs, Wiki documentation. This allows us to evaluate quality of data intrinsically without reference dataset. Many different approaches could be utilized.

Intrinsic assessment based on an idea that data may be assessed without external datasets. E.g., degree of road network completeness may be evaluated as follows. If historical data show that no one modifies major roads when neighbour minor roads are modified actively, one can conclude that major roads are complete. Logical consistency is evaluated intrinsically as well. In contrast, to the previous example historical data is not required for logical errors detection. E.g., topological errors may be found without external knowledge.

One can notice that logger data provided by OnToMap could be processed as OSM full history dump. Thus, the mentioned intrinsic approaches could be applied to logger data as well. Logger and OSM data will be periodically updated by event triggered tasks. OSM data will be periodically updated. If it will be defined that data in pilot sites were significantly changed after the last update, new data will be added to the database. Before import to database, data pass Quality Assessment and Improvement module. It calculates intrinsically data quality related measures. Data and quality assessment results are stored in database. Logger data pass the same procedure, it requires more frequent updates. OnToMap's Logger (Boella et al., 2018) collects data from WGN apps (e.g., LiquidFeedback (LF), ImproveMyCity (IMC), GeoKey, etc). Then, GSDR obtains and analyse the Logger data. Quality assessment results are stored in the GSDR's spatial database.

Simplified Data Quality Indicator (SDQI) is a mock data quality indicator implemented in the frame of GSDR. It was designed to evaluate prospective of aggregated data quality indicators and their visualization and utilization. The idea if the SDQI is very simple. A set of parameters are defined. Each parameter represents an essential aspect of data or

metadata. Moreover, lower value indicates lower fitness-of-use and vise versa. The following parameters were defined: number of points, number of lines, length of lines, number of polygons, length of polygons' boundaries, area of polygons, number of attributes. The mentioned parameters could be calculated for almost any vector spatial data. In addition, the following parameters were calculated for OSM data: number of tile hits (represents an OSM tile popularity; it is delivered by OSM planet portal), number of contributors, number of changesets, average version, average timestamp. SDQI is calculated as follows:

$$SDQI = \frac{\left(\sum_{i=0}^{n} \frac{v_i - minv_i}{(maxv_i - minv_i)/10}\right) - minc}{(maxc - minc)/10}$$

where, i is a parameter's index, $minv_i$ and $maxv_i$ are minimal and maximal values of a parameter, correspondingly. $minc$ and $maxc$ are minimal and maximal class numbers. One can mention that data are split into 10 classes. Lower value indicates lower data quality and vise versa. SDQI is calculated for OSM tile rectangle areas in zoom level 19.

In Figure 4, interactive maps of OSM data quality (SDQI) and source parameters are presented. Currently, three types of views are supported: feature, heatmap and tile views. In order to represent a parameter in the feature and heatmap views, classic bounding box request to a server is applied. For the tile view, requests are implemented separately for each tile visible on a map. This approach is very scalable, because it aggregates requested data according to a tile and, thus, it applicable to all zoom levels.

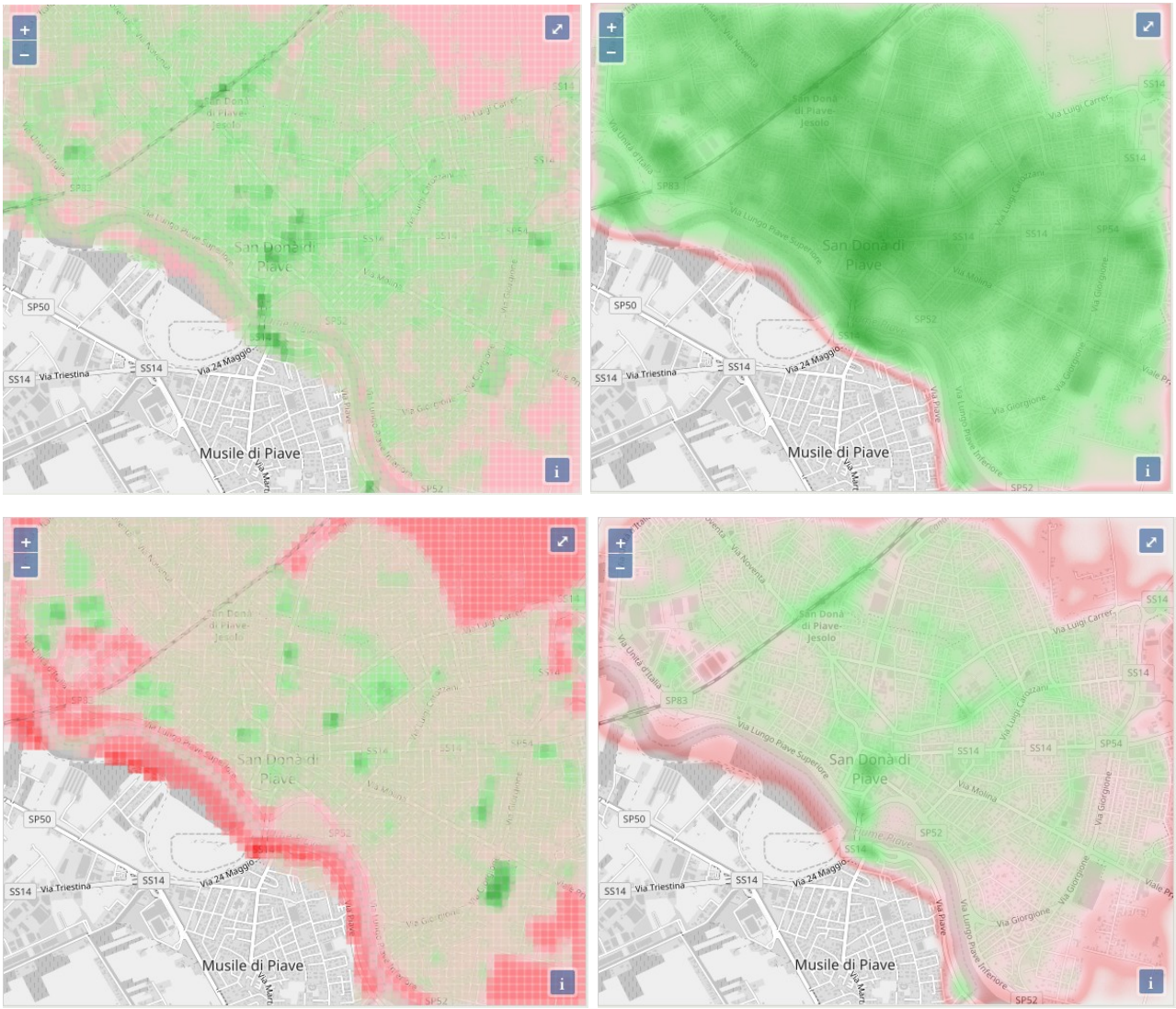

Figure 4. Top: SDQI in the feature and heatmap view. Bottom: area of polygons (left), number of changesets (right). Red and green represent minimal and maximal values, correspondingly. Zoom level 14. San Donà di Piave, Italy.

Comparable data quality assessment

Comparable data quality assessment will be utilized for the following tasks:

- Import correctness evaluation of PSI data to OnToMap,
- Comparison of PSI derived from different sources (OpenData and OSM).

PSI data provided my municipalities comprise some features types provided by OSM as well (e.g., bike lanes, amenity objects, etc.). Thus, it is possible to evaluate completeness of PSI features comparably. In order to implement this, specific data types were extracted from OSM data. In Figure 5, maps for OSM and PSI comparison are presented.

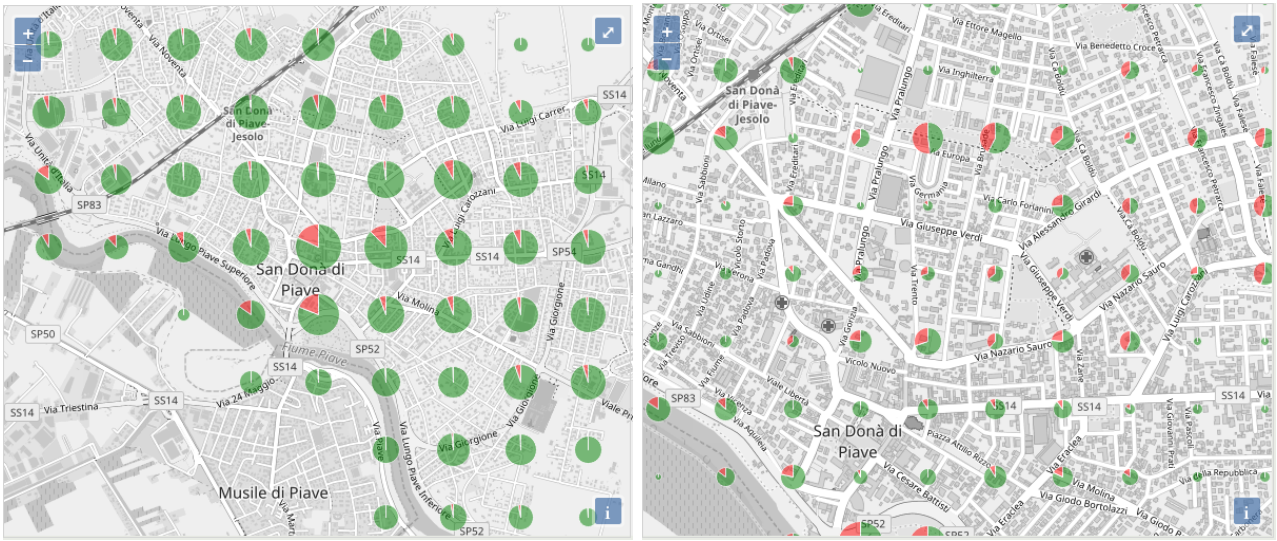

Figure 5. Comparison of OSM (red) and PSI (green) data. Left (zoom level 14):data quality, size represents the sum of quality classes. Right (zoom level 15):area of polygons, size represents the sum of areas. San Donà di Piave, Italy.

Data quality assessment module: Public APIs for quick data check and retrieval

Data Quality Interactive Maps and Reports (yellow rectangle in Figure 3) is GSDR's module allows to presenting data quality assessment results in interactive maps and also allows autogenerated reports. It is designed to report data quality results and show data errors. The module can be used by WeGovNow components to improve data and algorithms. Any user concerning data quality of WeGovNow will be able to obtain results using this module.

Two APIs are provided by GSDR:

- Data Provider,
- Quick Data Checker.

Both APIs are designed to improve and evaluate users' input. Data Provider API allows us to evaluate data of client side applications. For instance, user reports a traffic light problem. Client side application downloads a small piece of OSM data covering the current map extent. It allows the developer to implement a snapping functionality. User's input may be snapped to the nearest road intersection using a defined threshold.

Quick Data Checker allows us to evaluate users' input directly on the server and immediately return a result. For instance, user filled a form with a word "Schol". Client side application sends a request to Quick Data Checker. It detects that in the considering context there is a term in Logger data with Levenshtein distance equals 1 (it identifies possible error in user's input). The correct term is "School". A client side application may recommend changing text in a form field.

In Figure 6, examples of APIs' utilization are illustrated. The API is implemented as a universal tool; it allows source data retrieval, visualization of quality assessment results, obtaining various statistical data, text input improvement (auto completing and spell checking), spatial snapping functionality, etc.

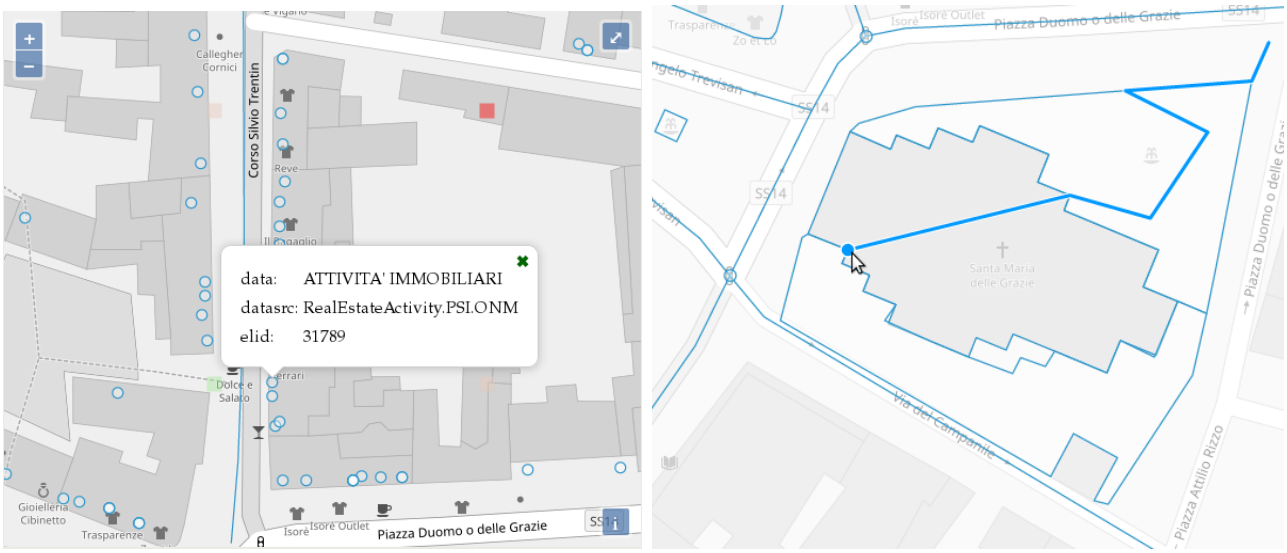

Figure 6. Data retrieval (left), snapping functionality (right).

CONCLUSIONS

In this paper, a data quality concept for map-centered e-Government web services is introduced. Taking into account the lack of reference datasets, data quality is assessed intrinsically and comparably. Simplified Data Quality Indicator (SDQI) has been introduced. Approaches to quality assessment of various data types (i.e., OSM, PSI, users contributed data and actions) have been provided.

The concept has been implemented in the frame of the Geo-Spatial Data Repository web service. GSDR evaluates data evolved in the WeGovNow. Results of quality assessment are delivered in a form of interactive web maps. Parameters are calculated for OSM rectangle tile areas in zoom level 19. Various map views are available. The tile view allows multi-level data visualization and aggregation; data are portrayed by the color and symbols size. Advanced interactive thematic maps are offered by the service.

GSDR's database and API allows retrieving any data (including OSM and PSI source spatial layers) directly from the database. GSDR is developed in the free open source manners. Data can be obtained through the main API. Most of useful functionality and libraries developed in the frame of GSDR are available as the following open source projects. First, IGIS.TK (http://igis.tk) provides data conversion tools, functions for quality assessment and a programming environment with the classic graphic user interface. Second, Tiles.CF (http://tiles.cf) is a library for tile related processing functions. To be applicable in other works, the both projects were designed in a generic manner.

The current version of GSDR is a prototype version. SDQI is a mock aggregated data quality indicator. In the nearest future, real data quality indicators should be developed and implemented in the frame of the web service. The GSDR's main API should be adopted by the WGN applications for users input improvement.

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BIOGRAPHY

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