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MAINTENANCE AND UPDATE NATIONAL TOPOGRAPHIC DATA BASE IN HIGH FREQENCY USING MODERN PROCEDURES AND TECHNIQUES

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ABSTRACT:

The state of Israel is a small country, in terms of area, with one the higher population growth rate among all the OECD countries. Hence, each year more than 50,000 housing units built and more than 1,500 km roads constructed in average, each year along the last decade.
The Survey of Israel (SOI) is a National Mapping and Cadastral agency (NMCA) that holds the responsibility to update, maintain and disseminate the National Topographic Data Base (NTDB) to all of the governmental offices and municipalities, to utilize, plan and promote the construction of the public needs.
Today, the reality is dynamic and the changes occurs every day, therefore, the users expect that the existing database will portray the current reality as possible. In order to address the user's requirements for rapid updating rate, the Survey of Israel promote a new and modern initiatives, including:

1. Promote the cooperation and working relationship with the municipalities to rapidly update the streets, address and POI’s.
2. Data Fusion from different governmental and municipalities data sources.
3. Developing change detection techniques to update the buildings and roads layers.
4. Developing new frameworks for the manual inspection and QA/QC procedures.
5. Developing automatic tools to update the height component via high resolution DSM and DTM (50cm GSD).
6. Disseminate quarterly the NTDB products to the users.
7. Develop a modern processes management system for the update and QA workflow

In this article, we will demonstrate the initiatives and techniques that improved our NTDB updating rate to less than a year and a half in a national average.

1. INTRODUCTION

NMCA's all across the world are making great efforts to improve their spatial data infrastructure in local, regional and national level (Najar et al., 2007). Srebro et al (2010) describes the key elements that were identified in Israeli Spatial Data Infrastructure as:

a. Common language.
b. Core geospatial layers
c. A national on-line geo portal
d. Partnership, coordination and policies.

The National Topographic Data Base (NTDB) is one of the most required products by government ministries, various infrastructure companies, local authorities and the private market. The task of updating and maintaining the NTDB is one of the seven goals of SOI, Precise and up-to-date data. This goal is part of the concept of geographical governance that we are aiming for in government ministries and among various government bodies. Table (1) demonstrates the growth in terms of quantity and percentage for some entity types:

2. METHODOLOGY

The NTDB is the infrastructure for every government and public geographic information system, hence, the Survey of Israel has invested many efforts in this field in the last years. The usage growth in the NTDB requires us to make it more qualitative, complete, accurate and up-to-date. The traditional method for updating a topographic database in a national scale is a complex and time consuming process, therefor, the updating cycle was usually 3 to 5 Years, depending on the updated dataset. In order to meet user requirements for rapid updating, we have set targets to reduce the updating cycle as follow:

a. 18 months for building and addresses datasets.
b. 2 years for point of interest and roads datasets.
c. 3 years for other datasets.

Data Type	Sep 2018	Sep 2021	Growth	Percent
Buildings	1,741,271	1,946,203	204,932	12%
Addresses	565,327	725,149	159,822	28%
Paved Roads [Km]	44,805	50,242	5,437	12%
Points of Interest	113,886	141,250	27,364	24%
Street Names	36,986	47,594	10,608	29%

Table 1. NTDB feature growth in last 3 years

2.1 Cooperation with municipalities

Naturally, The NTDB contains non-spatial or alphanumeric information, besides to the spatial data, such as addresses, points of interest, street names, etc. Unlike spatial data that captured

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based on orthophoto from office, the collection of alphanumeric information requires a field survey, by means of driving or walking all around city streets, trails and public open spaces. This mission is time consuming and very expensive. In Israel the municipalities are the entities that promote the construction of housing units, streets, addresses and public buildings. We asset as a target to establish a dedicated working group (called Local Municipalities Staff) to establish and strengthen the cooperation with the municipalities. The main activity of this staff is to contact the local municipalities and create collaborations. It refers to authorities such as municipalities, local councils, regional councils, local and regional planning committees, water and sewage corporations and drainage authorities. Knowing that a huge amount of geospatial data is held by the majority of these authorities.

The principle of this cooperation is data and knowledge exchange between the two parties, without monetary consideration. At the same time, SOI has developed a wide range of services for the benefit of local authorities.

The main challenge of this activity was how to convince organizations and people to share data? Despite the many barriers, such as legal, security, privacy, copyrights, tradition and so on.

2.2 Data Fusion

A huge amount of geospatial data is collected by means of the collaborations with municipalities, local authorities and other governmental offices. In addition, we started to use open data that is publically published on the Israeli Government databases website (www.data.gov.il).

This collected data contains a considerable amount of information that support us for updating NTDB and improve data accuracy and data integrity. To do so, we use data comparison and data integration tools. Data comparison tools applied between NDTB layers and layers from other sources to detect gaps, non-updated or incomplete data in NTDB. Data integration tools are used to update NTDB layers, automatically or semi-automatically, according to the differences that found by the comparison tools.

Unfortunately, the mission of automatic integrating data from other sources to NTDB is very complicated due to several reasons, for instance: (a) different level of details; (b) different geometry types (for example: street captured as a polygon or centerline, so geometry transformation is needed); (c) different position Accuracy; (d) different location definitions (for example: locating point of interest on the road across the building instead in the building polygon); (e) different coding systems, in some cases code aggregation and disaggregation is needed; (f) discontinuity between zonal data.

Any received data is tested to check how it can assist in updating the NTDB and then to decide which data process to use. The tests include: (a) Check if it is relevant to the NTDB; (b) Test data quality and last update date; (c) Classification by data type, geometry, attributes or both; (d) Check if geometry type and location determining method matches NTDB; (e) Check if it covers the entire country or a specific region. Based on the results of these tests, we decide which data integration process is the most suitable. Data integration process includes data comparison, geometry transformation, transferring attributes between features and generate and adding new features. In complex cases, data integration is done manually. In manual integration, we use automatic data comparison to detect regions that require significant updates. These regions are included in a targeted data update work plan. In this case, the editor can update NTDB layers, among the rest, based on the layers from external sources that are displayed in the background.

Here are some examples for data integrations from other sources:

a. Update roads, buildings, addresses and points of interest based on data from municipalities. The majority of addresses captured by the municipalities are captured as points but in NTDB addresses are captured as lines parallel to the road centerline. Point addresses are converted to lines using point position as a middle point of the line, direction of nearest road link with same street name identifier as the address, and a constant length. Then the address added automatically to the database. Table (2) describes the total area that was updated in the last 3 years based on data received from municipalities.

Product Version	Area [km^2]
2018-12	26.07
2019-03	100.13
2019-06	65.69
2019-09	13.12
2019-12	26.57
2020-06	71.03
2020-09	84.75
2020-12	22.49
2021-03	206.39
2021-06	6.31
2021-09	15.94
Total	**638.50**

Table 2. Area updated based on data from municipalities.

b. Update interurban road numbers based on Netivei Israel, A national transport infrastructure company. The numbers of many roads changed to avoid confusion on road numbers and make it easier for drivers. In this case, road number attribute transferred automatically from external source using conflation tools.
c. Update quarries based on free data from data.gov.il. Quarries in NTDB captured as polygons but the layer from ministry of energy includes points. Detecting new quarries done automatically and then polygons captured manually according up-to-date orthophoto.
d. Updating education institutions based on data from ministry of education. The challenge here was to compare institutions that captured, by the ministry, as points and located on the street with complex polygons, bordering institutions buildings, in NTDB. Besides, names matching algorithm was used, because in most cases names were written in different forms, in both databases. Data comparison to find changes, were implemented automatically, using name and usage type matching and proximity analysis. However, changes were integrated manually.
e. Updating points of interest based on data from ministry of construction and Housing. Here we faced same challenges as education institutions and we used the same processing tools.
f. Updating land cover used data from ministry of agriculture and rural development and from other NTDB layers. Land cover layer generated automatically by data compilation from various data sources, such as agriculture parcels, Fish ponds and livestock from ministry of agriculture and rural development, and settlement areas, complex and road from NTDB. Then, this layer was revised and updated manually if needed based on recent orthophoto instead of mapping a new layer manually from scratch. It should be mentioned that agriculture parcels were extracted from NTDB before

about a decade and then updated and improved by farmer's community.

g. Updating street names – due to lack of monetary resources, the NTDBs' update is based only on orthophotos and external data sources, we do not send teams to the field in order to complete the survey. This caused a gap between the formal street names and codes that were approved by the ministry of internal affairs and the names given to the streets in the NTDB. In order to complete this gap we have developed a procedure which compares the missing street names in the NTDB and retrieves the spatial location from external sources.

2.3 Change Detection

Several methods and procedures have been described in the literature for change detection. Some of these methods were based on comparing rasters from different periods (Im et al. 2008) and some methods were comparing classified imagery with features from the NTDB with or without the use of DSM (Keinan et al. 2016). When sequential dense DSM's are available, it is more applicable to detect the changes. Since SOI produce dense DSM's we choose to detect changes by using the data. The difference between the dense DSM's can be expressed by formula (1):

$$\Delta DSM = DSM_t - DSM_{t-1} \tag{1}$$

We assume that an area change when the average ΔDSM is higher than 2 meter and the area size is higher than 25 m^2. The main purpose of that technique is to detect the changes in the building and paved roads layers. Usually the changes in the building and roads layers can indicate construction in these areas. Since the DSM is based on image matching, many areas were detected, hence we prioritize areas with high frequency of changes. Figure 1 demonstrates the procedure.

2.4 New Frameworks for manual inspection and QA\QC Procedures

The purpose of using quality assurance (QA) and quality control (QC) procedures is to ensure that the data meets the data capture specifications and quality requirements; describe the quality of the final product, which help users to evaluate how well the datasets meets their needs; and to examine the suitability and acceptance of new processes and technologies for updating data. As part of quality assurance, an effort has been made in writing the data capture specifications that includes clear and unambiguous guidelines, including examples, to ensure the capturing and editing of data with maximum compliance with the requirements of users in the NTDB data. For each data capture guideline, a quality rule was defined to apply in the error identification process.

The specification of NTDB quality management system based on the principles for describing the quality of geographic data under ISO-19157.

The quality rules classified according to data quality elements and categories, such as: (a) Completeness, e.g all addresses must be in the database, only buildings that are bigger than 9 sq.m should be captured; (b) Conceptual consistency, e.g mismatched field values, such as a highway link with low speed limit; (c) Domain consistency, e.g field value out of range; (d) Format consistency, e.g check of replica schema after update; (e) Topological consistency, e.g undershoot, overshoot, gaps, overlaps; (f) Positional accuracy, relative and absolute accuracy of horizontal and vertical feature coordinates; (g) Thematic accuracy – the accuracy of quantitative and non-quantitative attributes, e.g incorrect feature type or number of lanes; and (h) Usability, e.g how the dataset is suitable for route analysis. So that for each element a different level of Acceptable Quality Limit (AQL) can be set, instead of setting AQL for each quality rule. The AQL defined the maximum number of allowed errors depending on total number of features and the required significance level. Some of quality rules defined as critical and an updated data cannot be accepted, even if a single error was detected. E.g invalid geometry, field value out of domain, missing value for mandatory field, duplicate geometry, repeated unique identity numbers and so on.

Figure 1a. DSM_t

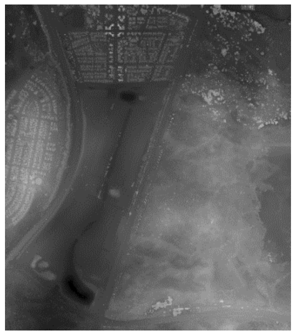

Figure 1b. DSM_{t-1}

Figure 1c. dense DSM's change detection result

Each quality rule is translated to a manual or an automatic check. Automatic checks configured using ArcGIS Data Reviewer extension and python scripts developed in house. Manual checks are performed on data sample which generated by python scripts according to ISO-19157.

In order to take advantage of database normalizations, which used to improve data integrity, NDTB separated into two different versions. The first for data collection and the other for products. Production version structure normalized and adapted to the requirements of data collection and quality control during the update activity. The structure of the products formulated in order to meet the requirements of the users. The products database produced automatically by a dedicated system that we use to generate products quarterly, as mentioned in subsection 2.6.

NTDB update Architecture based on versions and replications according to ArcSDE technology. NTDB consists from several

layers, but the updating projects performed according to partial contents of these layers, and sometimes only some of the attributes or types within an individual layer. Therefore, one of the main challenges of quality management system is to deal with topology and consistency checks between layers and attributes participating in the update process and the non-participating layers or attributes.
Once the QA\QC stages are over and the data is given a passing grade, the data is integrated back into the main database. At this stage we perform automatic procedure in order to calculate variables and arrange the data to fit international navigation protocols such as GDF.

2.5 Using High Dense DSM&DTM

The demand for three-dimensional mapping is growing in rapid pace. It has many uses such as emergency management, urban planning, modern cartography, navigation systems and etc. Photogrammetry is the traditional and most accurate technique to map large areas, this technique in highly expensive and not as fast as required for nationwide mapping. Three-dimensional mapping also requires skilled human resources.
In todays' market you can find many companies offering automatic three-dimensional mapping products. These products are also highly expensive.
The budget of SOI is limited and in order to conserve public money, we decided to map two-dimensional geometry based on orthophoto and then correct and convert the 2D geometry to 3D geometry using high dense DSM and DTM.
The SOI holds national wide high resolution DSM and DTM at 50cm GSD. In order to improve our 3D data, automatic procedures have been developed and implemented on the layers that take part: buildings, buildings height points, railways, paved roads and unpaved roads. This procedure uses orthophoto of the exact same region with the same resolution as the DTM and DSM. In order to avoid the heights from trees which are close to the buildings the procedure uses the NDVI formula as described in formula (2):

$$NDVI = \frac{NIR - RED}{NIR + RED} \quad (2)$$

Areas that had high NDVI value excluded from the original DSM. Algorithm (1) describes the procedure:

Input : Orthophoto, DSM
Output: A raster with DSM values that are not vegetation

```
foreach cell in OrthoPhoto do
|  if cell value >0.1 then
|     cell value = NoData
|  Else
|     cell value = DSM cell value
```

Algorithm 1. Creating Corrected DSM

With the corrected DSM we created a statistics table for each feature in the buildings layer. The statistics included the maximum value and the value that occurs the most inside the buildings' border. Each vertex of the feature's border gets the value of the most frequent DSM value. Each of the buildings get the maximum value and the minimum value of the DTM (from the cells inside the feature's border). Algorithm 2 describes the elevation implementation in the raw Buildings layer:

Input : Output of algorithm 1 (C_DSM), DTM, Buildings layer
Output: Buildings layer with Z information, CenterPoints layer

```
 foreach geometry in Buildings layer do
|  land heights data = zonal statistics by DTM
|  building heights data = zonal statistics by C_DSM
|  create CenterPoint_Floor
|  CenterPoint_Floor = Min(value in land heights data)
|  create CenterPoint_Roof
|  CenterPoint_Roof = Max(building heights data)
|  foreach vertex in geometry do
|  | vertex z value = frequent(building heights data)
end
```

Algorithm 2. Z implementation in the raw Buildings layer

Figure (2) demonstrates the height retrieval from the Height elevation models:

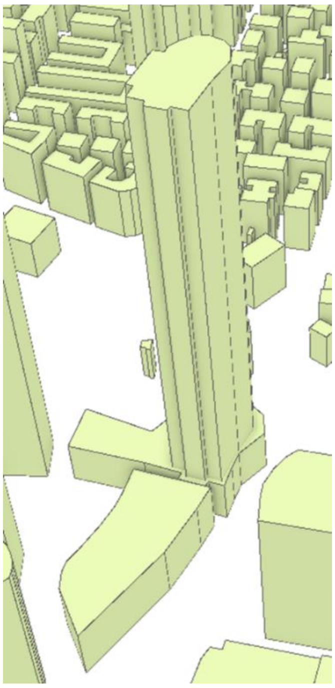

Figure 2. Moshe Aviv Tower: declared height: 235 meters, calculated height: 235.74 meters.

The outcome of this procedure is still in the NTDBs' raw database. In order to expose this data to our clients and customers, the data goes through a few steps. The Z values were calculated into the layers attributes and a relative height is calculated. Algorithm 3 describes the procedure we implemented for customers' needs:

Input : Buildings layer with Z information, CenterPoints layer
Output: a building layer height attributes

```
foreach geometry in layer do
|  if CenterPoints  Intersects geometry then
|     | land_height = min(CenterPoints)
|     | top_height = max(CenterPoints)
|     | building_height = avreage(geometry.Z)
|     | relative_height = building_height- land_height
end
```

Algorithm 3. Attributes calculation

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In order to validate the procedure we compared the results of those algorithms with the traditional photogrammetry methods for the roof height above MSL, land height above MSL and the building height about ground level, using RMSE formula (3):

$$\sigma = \sqrt{\frac{\Sigma(x_a - x_p)^2}{n}} \tag{3}$$

The validation checks examine on several case studies with division of the areas for different landscapes (mountainous, hilly, plain) and different settlement types (rural, urban, dense urban) as describe in Table (3).
Overall, we have checked 5,725 buildings. The accuracy of the calculation of the top roof of the buildings is ±1.60 meters.

	Type	Place	Count	Z difference [m]	
				Mean	RMSE
Mountainous landscape	Rural	Isfiya	779	0.52	1.78
	Urban	Haifa	769	0.89	1.06
	Dense urban	Jerusalem	910	0.90	1.56
Hilly landscape	Rural	Ein Harod	376	1.88	2.42
	Urban	Harish	584	0.92	1.31
	Dense urban	Shefraam	759	0.88	1.09
Plain landscape	Rural	Atlit	481	0.53	1.20
	Urban	Afula	483	1.12	2.03
	Dense urban	Ramat Gan	584	1.73	1.80

Table 3. Heights Differences between photogrammetry mapping and the developed algorithm.

Figure (3) demonstrates the buildings polygons after the automatic Z calculation on a 3D elevation model from drone footage:

Figure 3. Buildings polygons over 3D model

The second procedure projects the elevation data to the paved and unpaved roads features' vertexes. Most of roads in Israel are not covered by vegetation, thus we decided not to include the NDVI data. In this procedure, we have divided the paved and unpaved roads to two groups as follow:
Group A consists of the road types such as bridges and will be calculated by the DSM, Group B consists of all the other road types except for tunnels and will be calculated by the DTM.
Opposed to the buildings layer these layers are not being further processed. Algorithm (4) describes the procedure we implemented for the Z implementation in the raw Paved Roads and Unpaved Roads layers:

```
Input : Paved Roads/UnPaved Roads layer, DSM, DTM
Output: Paved Roads/UnPaved Roads layer

foreach feature in layer do
|  if feature.road_type In Group A then
|  |  | foreach vertex in feature do
|  |  |  vertex z value = cell value(DSM)
|  |    end
|  elif feature.type In Group B then
|  |  | foreach vertex in feature do
|  |  |  vertex z value = cell value(DTM)
|  |    end
end
```

Algorithm 4. Z implementation in raw Paved Roads/UnPaved Roads layers

2.6 Quarterly Dissemination NTDB

Every quarter the SOI publish the latest version of its NTDB. The publication is a set of 22 datasets that are referred to as products. Each dataset is a unique product with a specified schema and contents. These products are delivered to governmental offices, municipal authorities and etc.
The creation of these products requires the transformation of the raw data schema to the products schema. This transformation is performed by a set of processes and tools. Among these are the calculation buildings heights as described in section 2.5, the calculation of postcode for each buildings, the creation of geocode data, the combination of addresses and buildings and etc.
Such processes used to take up to four weeks including QA/QC checks with over than 50 computer hours. A new development of this application reduced the process to less than 8 computer hours to run and another day for QA/QC checks.
Reducing the work and computer times of these processes has helped the delivery time of new data to our customers, while with the old processes it could have taken up to 4 months from update to delivery now it takes up to 3 months from update to delivery.
Needless to say that this update rate has increased the publicity and importance of the NTDB. With the decrease of time from update to delivery we have succeeded to increase the number of cooperation with municipalities.
The increase of production speed will allow us to produce a new set of products whenever we wish without stopping the update process for long periods. It is a huge step for the SOI towards weekly or even nightly updates to the national map portal (govmap.gov.il).

2.7 Developing Modern Management System

In order to support the production flow for the NTDB continuous update process, a management system was developed. The new system also produces statistical information about the data that was updated. These statistics were done by a list of procedures (Python scripts, each procedure ran separately by the NTDB group manager. With the new system these procedures are ran automatically right after the implementation of the work are back to the main database. The system enables to initialize the annual planning process, for new update zones, and prioritize them.

Each zone is divided to specific update portions polygons. Each polygon within zone is defined with the layers and/or feature types to include in the process. The manager assigns the polygon to a specific GIS specialist, with detailed instructions and period for concluding the update process.

The GIS specialists will sign in to the system and will be able to review all the assignments awaiting for each of them, and their work status. The system supports both tabular view and spatial view.

This part of the system was developed based on POSTGRES/POSTGIS, and GEOSERVER for the spatial viewing and querying. For the tabular and UI/UX, ANGULAR 11, When the analysts choose a specific assignment from the list, the ARCMAP session initialized, focused on the update area, as defined by the manager. The spatial data is stored in ORACLE 11g&ARCSDE.

The entire update process is monitored within the system DB in order to enable up to date production status reports for zones and portions. Figure (4) demonstrate the NTDB update management system:

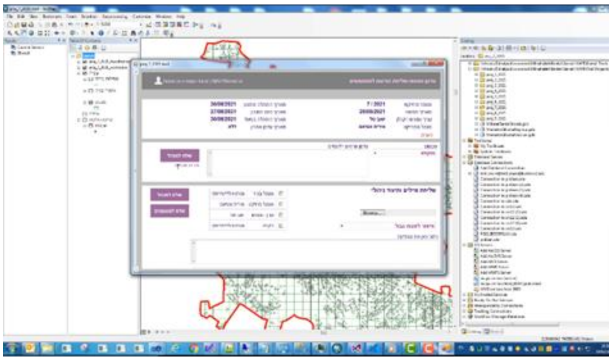

Figure 4. The NTDB update management system

Before the new system was developed, each update zone was opened manually using ARCMAP Work Flow Manager, with no possibility to track the works' status and work progress. The new system not only improved significantly work management and enabled the managers a convenient, simple and clear view of the work progress.

3. SUMMERY AND FURTHER WORK

Todays' reality is dynamic and the changes occur every day, therefore, the users expect that the existing database will portray the current reality as possible. The relevance of the usage in geospatial database in the governmental offices and municipalities is influenced by the updating and accuracy of the data. Hence, the SOI has decided to change the strategy of the workflows.

The development in the field of smart city, smart mobility and digital twins will increase the demands of the users and the market for more accurate, available, accessible and up to date geospatial data. Hence, every NMCA should do a new examination of its strategy in order to be relevant to the technology development in the era.

This paper describes and shows the means by which SOI has decided to upgrade its NTDB and make it a more updated and relevant spatial resource for the state ministries, local municipalities and the public.

REFERENCES

Keinan, E., Felus, Y. A., Tal, Y., Zilberstien, O., Elihai, Y., 2016. UPDATING NATIONAL TOPOGRAPHIC DATA BASE USING CHANGE DETECTION METHODS, Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLI-B7, 529–536, https://doi.org/10.5194/isprs-archives-XLI-B7-529-2016, 2016.

Felus Y., Srebro H., Tal, Y., 2010. GIS Versioning Management – The approach of the Survey of Israel. ISPRS Archive Vol. XXXVIII, "Core spatial Databases – Updating, Maintenance and Services – from Theory to Practice", Haifa, Israel, 2010.

Srebro, H., Felus, Y., Tal, Y., 2010. New Initiatives in ISDI (Israel NSDI), ISPRS Archive Vol. XXXVIII, "Core spatial Databases – Updating, Maintenance and Services – from Theory to Practice", Haifa, Israel, 2010.

Im, J., Jensen, J.R., Tullis, J.A., 2008. Object-based change detection using correlation image analysis and image segmentation. International Journal of Remote Sensing 29, p. 399-423.

Najar, C., Rajabifard, A., Willaimson, I.P., Giger, C., 2007. A framework for comparing Spatial Data.