Establishing an Accurate Continuous Nationwide Cadastre Based on the Cadastral Triangulation Method

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INTRODUCTION

- Cadastre - method of land property registration and land parcels information
- Principles of Israeli cadastre (Torrens principles) - parcel boundaries are determined based on ground surveying
- Currently, the Israeli cadastre is based on block maps, mutation plans and parcel boundaries - and ground marks having legal validity

CADASTRAL CHARACTERISTICS

- Based on various geodetic control networks in preparing cadastral works (in the past - Cassini-Soldner, Israeli TM, local systems; presently - IG05 based on implementation of satellites)
- Low accuracy of parcel points coordinates due to systematic errors of geodetic control networks in the past
- Great difficulty in integrating adjoining blocks into a spatial cadastral continuity
- Not too many existing cadastral control points due to urban development activity and construction

POSSIBLE SOLUTION

- Transition from:
  the existing graphical based cadastre
- To
  a coordinate based cadastre
  optimal turning point positions
  improved accuracy

→→ Mathematical analytical / analogical adjustment procedures and processes

PROPOSED METHOD

Cadastral Triangulation (CT) Method:

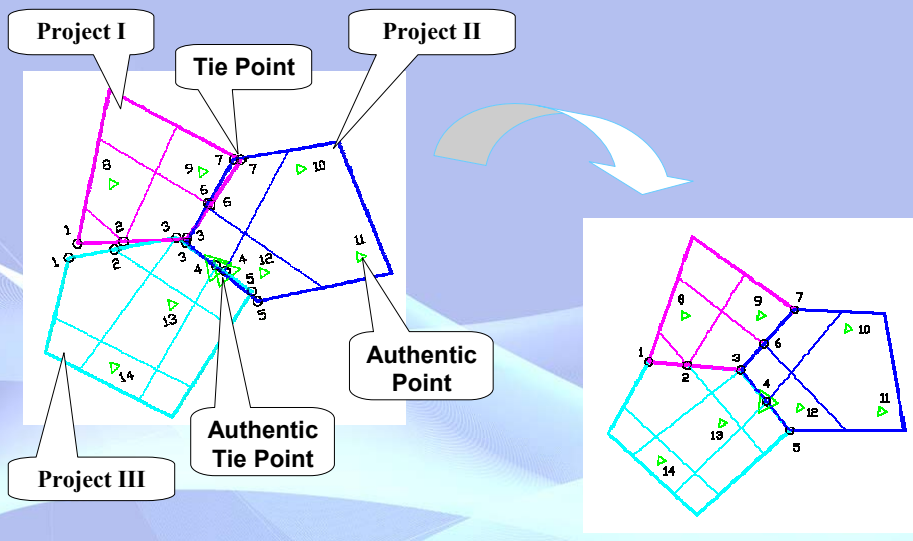
- Global transformation of separate cadastral projects aiming to create a homogeneous seamless space by applying the Block Adjustment method by Independent Models
- The method is based on Chained Transformation by applying the Generalized Least Squares Adjustment

PROPOSED METHOD

CT Method Principles:

- Refers to separate cadastral projects (blocks and mutation plans) optimally pre-processed, determined in various coordinate systems (origin grids)
- Defines - ***tie points*** - peripheral common turning points belonging to adjoining cadastral projects
- Defines - ***control ("authentic") points*** - cadastral project points remained in the field and re-measured (in the target grid)

PROPOSED METHOD



MATHEMATICAL MODEL

Planar Similarity Transformation

$$\begin{bmatrix} Y_t \\ X_t \end{bmatrix} = \begin{bmatrix} a & -b \\ b & a \end{bmatrix} \begin{bmatrix} Y_o \\ X_o \end{bmatrix} + \begin{bmatrix} c \\ d \end{bmatrix} \Leftrightarrow \boxed{y_t = F(\beta)}$$

where

- Y_t, X_t - point coordinates in target grid $\Rightarrow y_t$
- Y_o, X_o - point coordinates in origin grid
- a, b - parameters of scale and rotation
- c, d - shift parameters $\Rightarrow \beta$

MATHEMATICAL MODEL

Tie Point

Non-authentic: $y_{ti}^{j} - y_{ti}^{k} = 0$

Authentic:
$$\begin{cases} y_{ti}^{j} - y_{ti}^{s} = 0 \\ y_{ti}^{k} - y_{ti}^{s} = 0 \end{cases}$$

Authentic Point

Non-tie: $y_{ti}^{j} - y_{ti}^{s} = 0$

Where

y_{ti}^{j} y_{ti}^{k} - adjusted coordinates of point "i" in parcellations "j" & "k"

y_{ti}^{s} - known (authentic) coordinates of point "i"

MATHEMATICAL MODEL

Generalized LS Adjustment

$$X\beta + Z\varepsilon + w = 0$$

Where

X Z - partial derivatives

ε - point position residuals

$w = y_{ti}^{j} - y_{ti}^{k}$ - for tie points

$w = y_{ti}^{j} - y_{ti}^{s}$ - for authentic points

SCOPE ESTIMATION

- Approximate number of valid parcellations (blocks and mutation plans) in Israel ~ 75,000
- Number of unknown parameters per parcellation – 4/6
- Number of tie points and authentic points ~ millions
- Y & X unknown coordinates of tie points ~ millions

Estimated size of adjustment matrix

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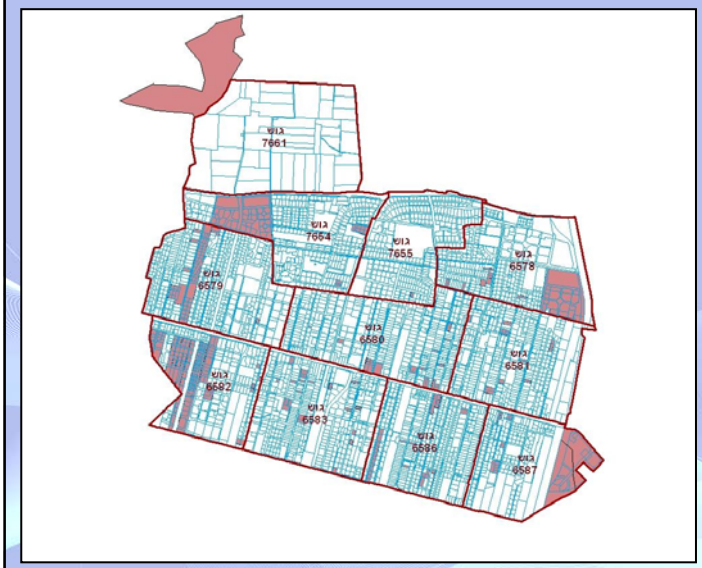
Number of Rows ~ several Millions
Number of Columns ~ 300,000/450,000

REAL DATA PROCESSING



Mutation plans

Cadastral block boundaries

Parcel boundaries

REAL DATA PROCESSING

- Group of 11 adjacent cadastral blocks (digitized from maps at scale of 1:2,500)
- Origin grid – local grid of digitization; target grid – the accurate mutation plans' grid (point coordinates serving as authentic points)
- The estimated accuracy of the digitization – 0.8 mm on the map (2 meters on the ground)
- The estimated accuracy of mutation plan coordinates - 0.1 meter

REAL DATA PROCESSING

- Two methods have been compared:
  - Existing: separate transformation and joining of adjacent cadastral blocks by computing the average position of peripheral common points (the current method used by the Survey of Israel)
  - Proposed: simultaneous transformation and joining of adjacent cadastral blocks by the CT adjustment process
- Two kinds of transformation:
  - Similarity - 4 parameters
  - Affine - 6 parameters

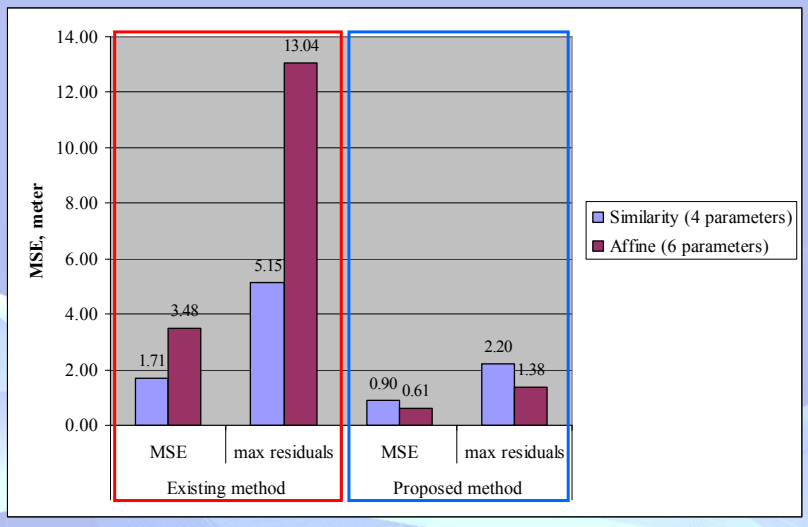
REAL DATA PROCESSING

Type of transformation	Existing method (meters)		Proposed method (meters)		Improvement Ratio (existing vs. proposed)	
	MSE	Max residuals	MSE	Max residuals	MSE	Max residuals
Similarity (4 parameters)	1.71	5.15	0.90	2.20	1.9	2.3
Affine (6 parameters)	3.48	13.04	0.61	1.38	5.7	9.4

Notes:

1. Residuals of the existing method - differences between positions of transformed peripheral block points and their average positions; MSE - sum of squared differences divided by number of points
2. Residuals and MSE of the proposed method – from adjustment process

REAL DATA PROCESSING



CONCLUSION

Applying CT method enabled to:

- Convert separate cadastral blocks digitized in origin (local) grid into cadastral continuity in a uniform geodetic target grid
- Reduce considerably the position discrepancies between adjoining cadastral blocks
- Increase the position accuracy of parcel boundary turning points compared to the existing boundaries matching methods

FUTURE WORK

An additional study is planned to analyze:

- The optimal number of transformation parameters referring to separate blocks during the global transformation and the adjustment of the adjoining boundaries
- The optimal scattering scheme and number of authentic points in the adjusted area
- How to improve the computational algorithm in order to deal with tens and hundreds of thousands of unknowns on a nationwide implementation process

Thank You