Challenges and Motivations

- In Legal Digital Cadastre (LDC) system the coordinates of the boundary points intend to be the main legal evidence in court.
- In countries with:
  - **Tectonic movements.**
  - Those who used to **upgrade their cadastral control grids**
  - → Cadastral points' Coordinates discontinue describing its correct position after a specific period of time.

⇓

This could be an obstacle for establishing LDC

Monitoring Grid Coordinates Changes Model as a base for Dynamic Digital Cadastre System

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DYNAMIC CADASTRE SYSTEM
As a Possible Solution

- It means that boundary point coordinates are properties that may change by time.
- They are correct in a specific time epoch.
- When the boundaries are dynamically coordinates' changed → The system is a dynamic.

⇓

Legal Dynamic Digital Cadastre - LDDC

(first mentioned by Blick and Grant 1997)

DYNAMIC CADASTRE SYSTEM
As a Possible Solution

- Learning from present and past cadastre systems in countries that have developed and changed their national control grid, like Israel:
  - ➢ Casini old grid to ITM and finally to IG05.
  - ➢ Providing up-to-date grid coordinates for a specific boundary point bases on survived authentic cadastral points.
- This is a **transformation process.** It includes the main solution principle → **coordinates may be changed according to the authentic points new position.**

MONITORING GRID COORDINATES CHANGES MODEL - MCCM

- As base for LDDC system, country may need:
  - Semi-dynamic or full-dynamic datum.
  - a model that enables transforming the LDC database coordinates from epoch of time (t^1) to other (t^2).
- For cadastral uses, **MCCM** must :
  - Be a national scaled.
  - Preserve cadastral important properties, such like:
    - Topology.
    - Physical wedge existence of any authentic boundary point.
    - Cadastral Parcel shape presented by fronts length, when the cadastral parcel locates on rigid area.
    - Provide result error estimations.

DYNAMIC CADASTRE SYSTEM
Meaning and Importance

- Establishing LDDC system means that the system has to be able to provide "correct" grid coordinates for every boundary point (BP), in every epoch of time → 4D coordinates (N, E, H, t) – if we are already agreed about the need for 3D cadastre.
- The question is: **Is LDDC system required only in dynamic nation?**
  - A **legal outlet solution** for updating national control grid which leads to coordinates changes, in any time in the future.

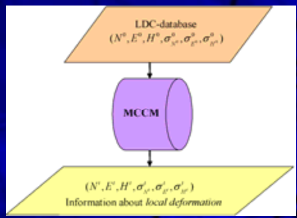
MCCM – Possible Data Sources

– Special geodynamic control network.
– **A**ctive **P**ermanent GPS stations **N**etwork – **APN**.
– Researches on evaluating physical deformation and earth deformations models around the country surface.

- The integration of dynamic physical movement models, derived from researches, → improves the **reliability** of the results, since they were proved physically.

FIG 2006 - Munich

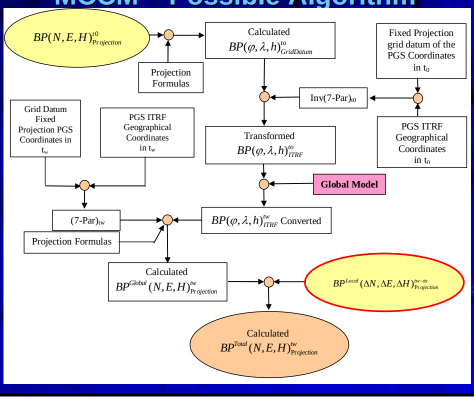
MCCM – Possible Data Sources



- **Ideal solution**: Preserving all the cadastral boundaries' points!!!
- As an **alternative solution**: predicting the point coordinates' changes according to representative surrounding deformation points' data.
- **What are these representative data sources**?

FIG 2006 - Munich

MCCM – Possible Algorithm



MCCM – Possible Algorithm

- Point (N, E) in a specific time epoch 't_0' will has final grid coordinates changes equal to $\Delta(EorN)^{Total}$ in epoch 't':

$$\Delta(EorN)^{Total} = \Delta(EorN)^{Global} + \delta(EorN)^{Global} + \Delta(EorN)^{Local} + \delta(EorN)^{Local}$$

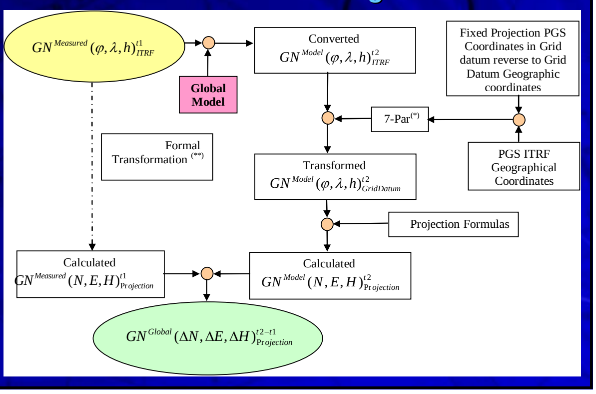
Global, Physical Motions derived from researches and APN and their estimation errors

All other motions derived from unknown sources, such like local (like slide slops) and their estimation errors

$$BP^{Total}(\Delta N, \Delta E, \Delta H)^{tw-to}_{Projection} = BP^{Local}(\Delta N, \Delta E, \Delta H)^{tw-to}_{Projection} + BP^{Global}(\Delta N, \Delta E, \Delta H)^{tw-to}_{Projection} + \delta$$

FIG 2006 - Munich

MCCM – Possible Algorithm



MCCM – Possible Algorithm

- When:

$$BP^{Local}(\Delta N, \Delta E, \Delta H)^{tw-to}_{Projection} = Function\left(sets(GN^{Local}(\Delta N, \Delta E, \Delta H)^{t_i - t_{i-1}}_{Projection}), Global\_Motion\right)$$

GN: Describes the projection coordinates changes of the Geodynamic Network points.

$$GN^{Local}(\Delta N, \Delta E, \Delta H)^{t_{last}-t_0}_{Projection} = GN^{Total}(\Delta N, \Delta E, \Delta H)^{t_{last}-t_0}_{Projection} - GN^{Global}(\Delta N, \Delta E, \Delta H)^{t_{last}-t_0}_{Projection}$$

FIG 2006 - Munich

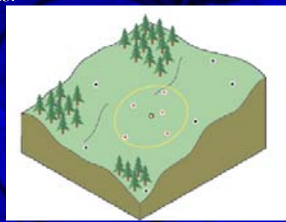
Geostatistics as a Base for Clever Prediction

- The **Geostatistics** science uses:
  - Variogram
  - Covariogram (Covariance)

  for **characterize a random field supposing spatial correlation between the predicted results.**
- **Our variable describes the displacement or velocity vector** of such a physical point in earth surface which is correlated with all its environment → Thus, **the Geostatistical interpolation looks more suitable for the MCCM prediction task.**

Geostatistics as a Base for Clever Prediction

- Calculating STD for predicting results may be done by two statistical methods: **Deterministic** interpolation and **Geostatistical** interpolations.
- **Deterministic**:
  - Only when the model variables are distributed randomly and **uncorrelated**.
  - deals with scalar data with no consideration to the spatial distribution

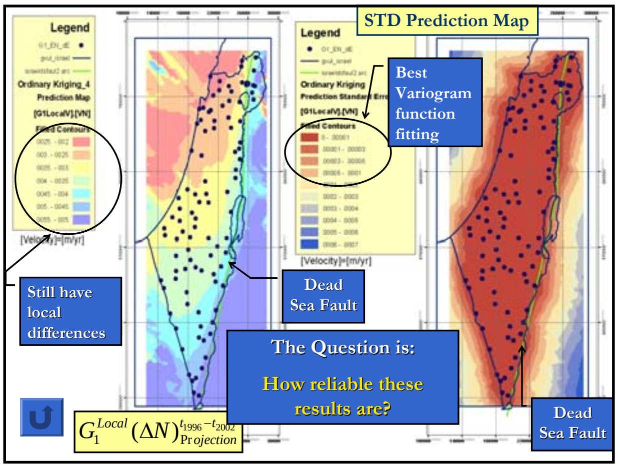


Preliminary Tests

- It aims to evaluate the displacements and the velocities of points around the Dead Sea Fault by using a locked fault model: $v(x) = v_0 \cdot \frac{1}{\pi} arctg(\frac{x}{D})$
- Decompose it to N and E components:
- Az =Azimuth of the fault: $v_n = \cos(Az)\left(v_0 \cdot \frac{1}{\pi} arctg(\frac{x}{D})\right)$ $v_e = \sin(Az)\left(v_0 \cdot \frac{1}{\pi} arctg(\frac{x}{D})\right)$
  - Using the "Geostatistics" Interpolation method. $\gamma_{Semi-variogram}(Gaussian) = C_0\left[1-\exp\left(-3\left(\frac{h}{\theta_r}\right)^2\right)\right] + Nuggets$ $C_{Covariance}(Gaussian) = C_0 \exp\left(-3\left(\frac{h}{\theta_r}\right)^2\right) + Nuggets$

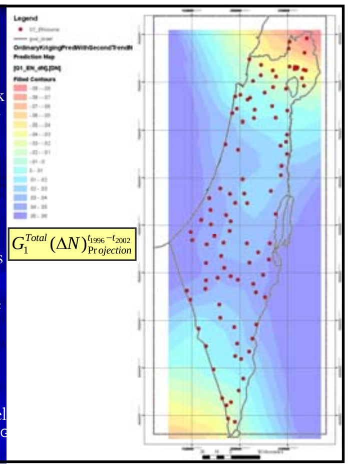
Preliminary Tests

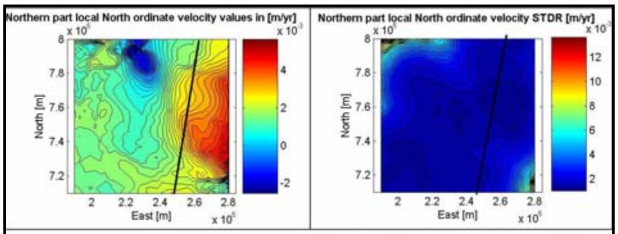
- For checking :
  - The applicability degree of the proposed algorithms.
  - The essentially of the integration between the physical model and the Geostatistical interpolation bases on **GN**:
- We used Israel country surface as a case study using:
  - Its **G**eodynamic **N**etwork named **G1**, with 100 points measured in 1996 and 2002. Typical Distance between points are about 10 km.
  - Using physical motion model produced by Wdowinski et al. (2004) as the main tectonic motion model:
    - Based on The Israeli APN.



First Test - KRIGING

- Building a map for the North displacement of the **G1** network between 1996 -2002. "Ordinary Kriging" was used.
- There is a tendency in the results.
- It is a result of such significant surface movement.
- "ArcGIS Geos. Module" enables users to model the tendency.
- Such modeling, aims to activate a function for every point before the interpolation process.
- It imitates our algorithm of the integration with a motion model and local movement.





- Results are similar to "Kriging" with tendency function.
- STD map shown insignificant movement:
  - Because of considering the physical movement model STD parameters.

Second Test - COLLOCATIONS

- Using :
  - The same Gaussian covariogram function parameters, used in the "Kriging" ArcGIS module interpolation.
  - Wdowinski model …
  - Taking into consideration the Wdowinski model parameter STD.
  - Concentrating on the northern part of Israel.
  - Collocation interpolation of Moritz.

Thank you

for listening…

Conclusions

- The proposed **MCCM** could play the major role in the future **LDDC** , since it concentrated in grid coordinates.
- The proposed algorithm enables used any datum options (semi or full dynamic)
- In dynamic countries: Using **Physical Motion** model with such **Geostatistical Interpolation** is not only essential but it is almost obligatory → much more reliable.
- **Geostatistics** is the address
- The **STD map** could be used to maintain the GN in a country.