FIG Working Week

Integrating Generations
Stockholm, Sweden

# DISTORTION MODELING BETWEEN GEODETIC NETWORKS IN BRAZIL: A GRID-BASED APPROACH


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CAPES


## INTRODUCTION

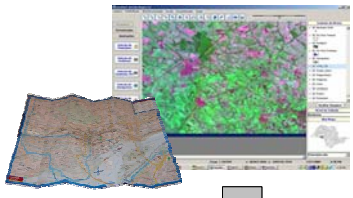
A national geodetic network is the fundamental structure for geodetic positioning and spatial data base in a country.

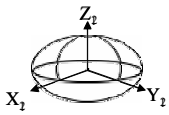
The geodetic networks should be consistent, precise and to accomplish the tendencies and technological evolution.

Following the world tendencies and the technological evolutions, the Geodetic Brazilian System (SGB) has been updated along the years. A consequence
→ the necessity of conversion approaches to change from one frame to another.

The main and most recent change occurred in February 2005 with the adoption of the Geocentric Reference System for the Americas (SIRGAS2000) as the new official referential.

## INTRODUCTION






**Solution:**

$$\begin{bmatrix} X_2 \\ Y_2 \\ Z_2 \end{bmatrix} = \begin{bmatrix} X_1 \\ Y_1 \\ Z_1 \end{bmatrix} + \begin{bmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{bmatrix}$$

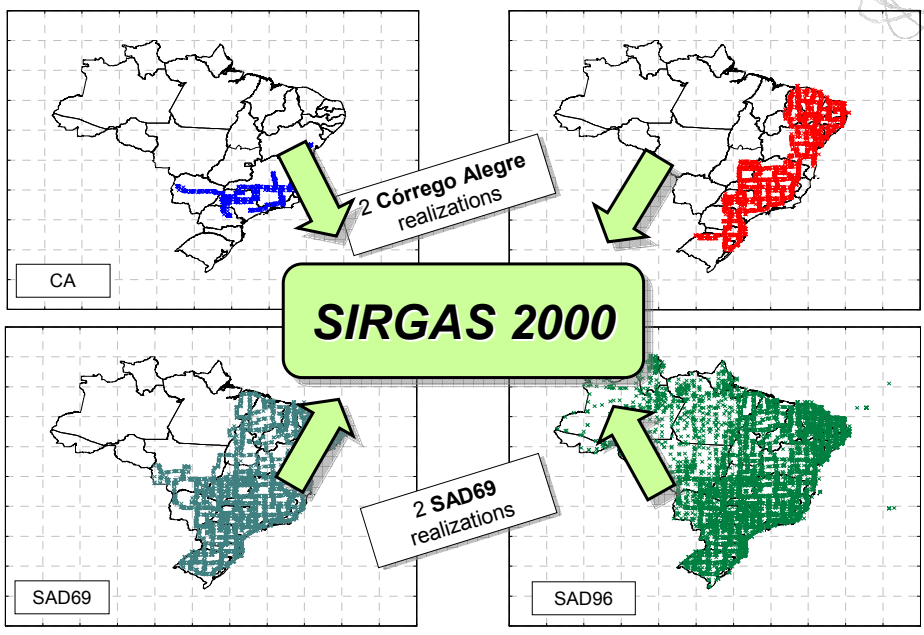
? + distortion model

*There are errors due equipments used in surveying and adjustment methods ...*

*→ distortions*

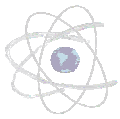


## Reference Frames used in Brazil



# DISTORTION MODELING

## DISTORTION MODELING – GRID-BASED APPROACH



The distortion modeling approach proposed in this research is based on three phases :

- To compute the distortions between the frames
- To generate the regular grid based on the Shepard method
- To interpolate the distortions of the interested points

## GRID-BASED APPROACH – DISTORTION COMPUTATION

The distortions can be defined by the differences between the known coordinates (determined in the network adjustment process) and the calculated coordinates (through the official transformation parameters) for a set of stations.



## GRID GENERATION → SHEPARD METHOD

The distortion grid generation process consists in finding the distortion values of the grid nodes, through the known distortions in the control stations.

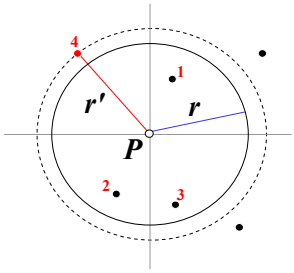
Shepard's interpolation method:

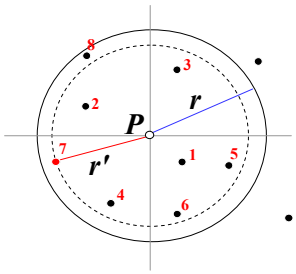
- variable search radius;
- weighting by the distance and relative position of the nearest points.

## GRID GENERATION → SHEPARD METHOD

Selection of the interpolation points:

Example: $n_{min}$ = 4 e $n_{max}$ = 7



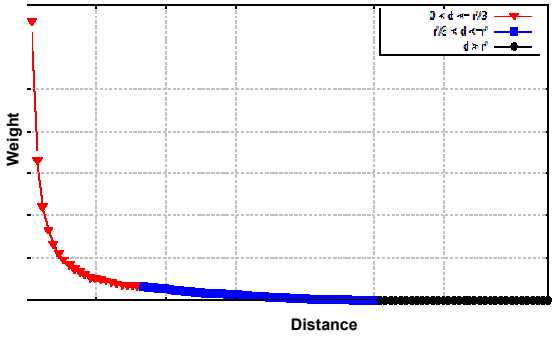






## GRID GENERATION → SHEPARD METHOD

The distance weighting

$$s(d) = \begin{cases} \dfrac{1}{d} & if\ 0 < d \le \dfrac{r'}{3} \\ \dfrac{27}{4r'}\left(\dfrac{d}{r'} - 1\right)^2 & if\ \dfrac{r'}{3} < d \le r' \\ 0 & if\ r' < d \end{cases}$$



## GRID GENERATION → SHEPARD METHOD

The directional weighting

The direction weighting has the intension of representing the “shadowing” of the influence of a data point *P* by the nearest one in the same direction.

$$t_i = \frac{\sum_{D_j \in C'} s_j [1 - \cos(D_i P D_j)]}{\sum_{D_j \in C'} s_j}$$



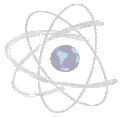
## GRID GENERATION → PRECISION INDICATOR

It is also important to know the precision of the interpolated points.

The computation of the precision indicator is given as:

$$P = \sqrt{\frac{\sum w_i^2}{\left(\sum w_i\right)^2} \cdot \frac{\sum \left(\delta_i - \bar{\delta}\right)^2}{n-1}}$$

## DISTORTION INTERPOLATION OF THE INTERESTED POINTS



For each given point is performed the bilinear interpolation to compute the distortion and the precision indicator.



# EXPERIMENTS AND RESULTS

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To perform the experiments, 7297 homologous stations in SAD96 and SIRGAS2000 were made available by Brazilian Institute of Geographic and Statistic (IBGE). In this data set:

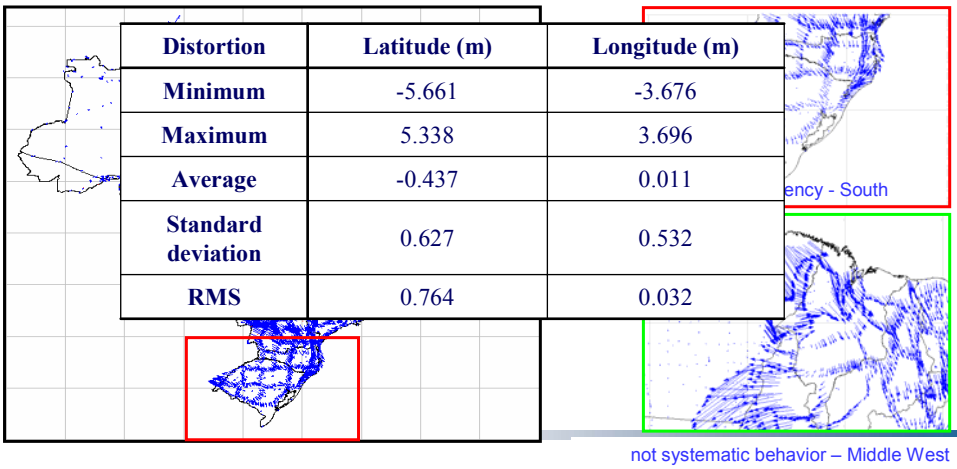
- 6634 stations were used in the distortions computation;
- 663 stations (≈ 10%) were used to perform the quality control (test stations).



## EXPERIMENTS AND RESULTS – DISTORTION ANALYSIS

There is a great variability in the distortion behavior along the Brazilian territory

| Distortion | Latitude (m) | Longitude (m) |
|---|---|---|
| Minimum | -5.661 | -3.676 |
| Maximum | 5.338 | 3.696 |
| Average | -0.437 | 0.011 |
| Standard deviation | 0.627 | 0.532 |
| RMS | 0.764 | 0.032 |




not systematic behavior – Middle West

## EXPERIMENTS AND RESULTS – DISTORTION GRID

The distortion modeling was carried out by a distortion grid with a spacing of 1º x 1º, covering the Brazilian territorial limits

Shepard's method parameters:

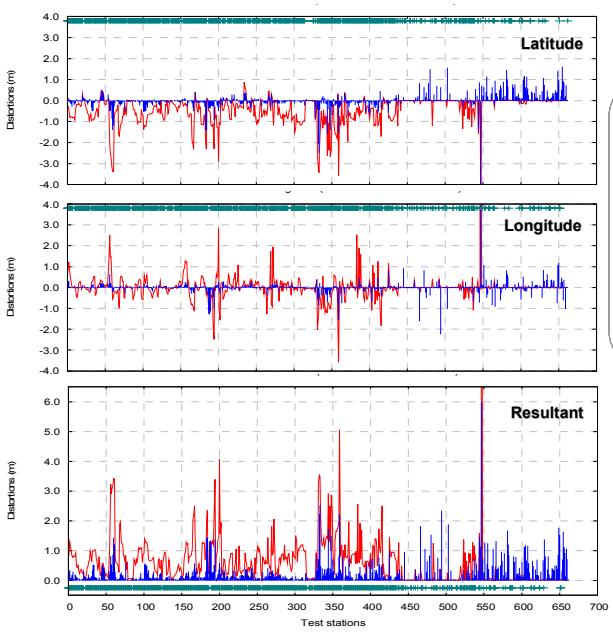
- $n_{min}$ = 4 e $n_{max}$ = 10
- Inicial radius = 60 km

| | | Latitude | Longitude |
|---|---|---|---|
| **Distortion (m)** | Minimum | -3.053 | -1.943 |
| | Maximum | 1.479 | 1.885 |
| | Average | 0.254 | 0.080 |
| **Precision Indicator (m)** | Average | 0.152 | 0.092 |
| | Nodes number | 2024 | |



## EXPERIMENTS AND RESULTS – ANALYSES IN THE TEST STATIONS

To check the modeling results it was computed the distortions in the test stations and performed the comparison of the computed coordinates and the known ones.




These stations are in the great majority derivated from GNSS



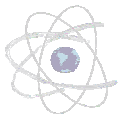
## EXPERIMENTS AND RESULTS – ANALYSES IN THE STATIONS TEST

Statistics for the test stations without satellite techniques

| | | Distortions | | |
|---|---|---|---|---|
| | | Latitude | Longitude | Resultant |
| Before | Average (m) | -0.6221 | -0.0199 | 0.8187 |
| | Standard (m) | 0.6488 | 0.5848 | 0.6947 |
| | RMS (m) | 0.8983 | 0.5845 | 1.0732 |
| After | Average (m) | -0.1155 | -0.0336 | 0.2179 |
| | Standard (m) | 0.2847 | 0.2564 | 0.3382 |
| | RMS/Improvement | 0.3069 (-66%) | 0.2583 (-56%) | 0.4020 (-63%) |
| | Number of improved stations | 398→91.49% | 401→92.18% | 418→96.09% |
| | Test stations | 435 | | |

# FINAL CONSIDERATIONS AND CONCLUSIONS

## FINAL CONSIDERATIONS AND CONCLUSIONS



In this paper, a contribution related to the modeling distortion process was realized, considering SAD69 (realization of 1996) and SIRGAS2000 reference frames

The average distortion computed was of about 0.254m with a precision indicator of 0.152m

The experiments using the test stations showed that the stations originated from satellites techniques do not require corrections.

The good results obtained show that the approach used appears to be very promising, as well as the Shepard method looks appropriated to the grid generation

## FINAL CONSIDERATIONS AND CONCLUSIONS

This is one of the 6 approaches that have been evaluated by IBGE as a new official Brazilian distortion model.



## ACKNOWLEDGEMENT

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**THANKS BY THE ATTENTION**

**OBRIGADO!**