# Quantifying Human-land Inequality Using Gini Coefficients

**1.1 Conceptual framework**

The Gini coefficient, introduced by Italian statistician Corrado Gini in 1921[[[1]](#endnote-0)], has been used in a wide variety of resource allocation contexts to measure inequality including income, wealth, credit availability, health care, and energy[[[2]](#endnote-1)]. We adapted this metric to quantify inequalities in construction land across income tiers (Low-Income [LI], Lower-Middle-Income [LMI], Upper-Middle-Income [UMI], and High-Income [HI]).

This metric derives from the Lorenz curve[[[3]](#endnote-2)], which plots the cumulative proportion of construction land area (y-axis) against the cumulative proportion of population (x-axis) (Fig. 1). The line of perfect equality (45° diagonal) represents an idealized distribution where each population percentile occupies an equal proportion of land. In actual inequality analyses, the actual distribution curve typically lies below or above this diagonal (concave or convex shape). In our analysis, we observe convex Lorenz curves where the actual distribution lies above the line of equality.

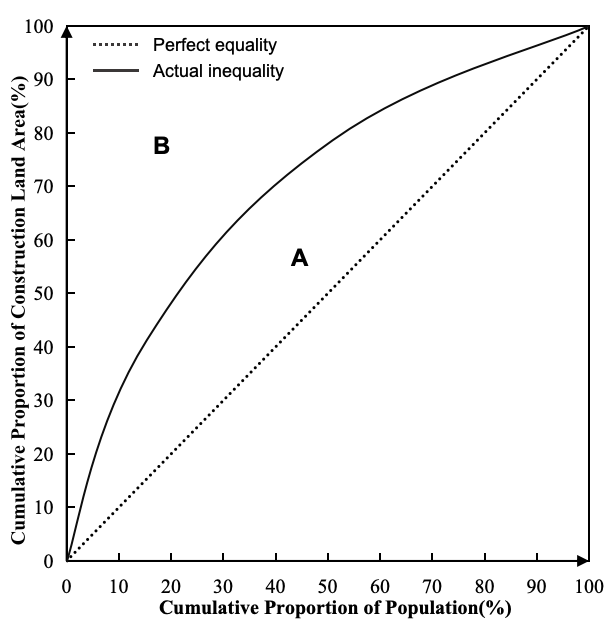


Fig. 1 Lorenz curve

For such convex curves, we implement a modified Gini coefficient (G) calculation (Eq.1):

(1)

where A is the area between the Lorenz curve and the line of equality, and B is the area above the Lorenz curve. The Gini coefficient ranges from 0 (perfect equality) to 1 (maximum inequality).

**1.2 Calculation steps**

**Data Preparation and Sorting.** For n observational units (classified by income tier, n=4) in year t, we sorted regions by ascending population to evaluate how construction land is distributed across population percentiles. This approach directly addresses our core research question: whether less populated areas disproportionately occupy more construction land, a phenomenon that manifests as convex Lorenz curves when plotted.

**Cumulative Proportions and Lorenz Construction.** For each income tier i ∈ {1,2,3,4} in the population-sorted sequence during year t, we computed Eq.2 and Eq.3:

Cumulative Population Proportion (CPᵢ):

(2)

Cumulative Land Proportion (CLᵢ):

(3)

where pk = Population of k-th income tier in the sorted order; lk = Construction land area of corresponding income tier. Boundary conditions: CP0 = CL0 = 0%, CP4 = CL4 = 100%

**Lorenz Curve Construction.** These cumulative proportions form the basis for constructing the Lorenz curve by plotting (CPᵢ, CLᵢ) points and connecting them with linear segments. The resulting curve's deviation from the 45° equality line visually represents the degree of land allocation inequality across population percentiles.

**Gini Coefficient Calculation.** Based on area measurements, we compute the Gini coefficient using G=2A=1-2B (Eq.4). This standardized coefficient ranges [0,1], where G>0.5 indicates inverse inequality (construction land concentration in less populated areas) and G<0.5 shows conventional inequality.

*(4*)

Here, f-1(y) is the inverse function of the Lorenz curve y=f(x), where (x,y) pairs are the cumulative population (CPᵢ, from Eq. 2) and cumulative land (CLᵢ, from Eq. 3) proportions, respectively.

**1.3 Calculation results**

Population (millions) and built-up land area (km²) data by tier (1975-2020) are shown in Tables 1 and 2.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Tier | Qa (millions) | | | | | | | | | |
| **1975** | **1980** | **1985** | **1990** | **1995** | **2000** | **2005** | **2010** | **2015** | **2020** |
| HI | 1063 | 1105 | 1146 | 1188 | 1226 | 1255 | 1291 | 1332 | 1373 | 1409 |
| LI | 176 | 200 | 225 | 256 | 292 | 338 | 389 | 450 | 510 | 581 |
| LMI | 1183 | 1339 | 1523 | 1722 | 1933 | 2148 | 2366 | 2587 | 2814 | 3031 |
| UMI | 1614 | 1766 | 1934 | 2118 | 2269 | 2392 | 2502 | 2612 | 2732 | 2833 |

Tab. 1 Population

Tab. 2 Land Area

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Tier | Qs (km2) | | | | | | | | | |
| **1975** | **1980** | **1985** | **1990** | **1995** | **2000** | **2005** | **2010** | **2015** | **2020** |
| HI | 52573 | 56568 | 60773 | 65166 | 71439 | 78235 | 83610 | 89352 | 94994 | 99481 |
| LI | 1803 | 2087 | 2485 | 2956 | 3260 | 3678 | 4133 | 4809 | 5748 | 7216 |
| LMI | 8820 | 10539 | 12950 | 15876 | 17924 | 20479 | 22833 | 25984 | 29880 | 34821 |
| UMI | 23137 | 26492 | 30781 | 35819 | 41145 | 47456 | 52842 | 59310 | 66289 | 72674 |

*Note: Full raw data available in Supplementary Table S1.*

For each year, we sorted tiers by ascending population to compute population proportions (CPᵢ) and land area proportions (CLᵢ), as presented in Table 3.

Tab. 3 Proportions and cumulative proportions

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Tier | Population proportions (%) | Land proportions (%) | Cumulative population proportions (%) | Cumulative land proportions (%) |
| 1975 | | | | |
| LI | 0.04 | 0.02 | 4.36 | 2.09 |
| HI | 0.26 | 0.61 | 30.70 | 62.98 |
| LMI | 0.29 | 0.10 | 60.01 | 73.20 |
| UMI | 0.40 | 0.27 | 100.00 | 100.00 |
| 1980 | | | | |
| LI | 0.05 | 0.02 | 4.54 | 2.18 |
| HI | 0.25 | 0.59 | 29.60 | 61.30 |
| LMI | 0.30 | 0.11 | 59.97 | 72.31 |
| UMI | 0.40 | 0.28 | 100.00 | 100.00 |
| 1985 | | | | |
| LI | 0.05 | 0.02 | 4.65 | 2.32 |
| HI | 0.24 | 0.57 | 28.39 | 59.13 |
| LMI | 0.32 | 0.12 | 59.94 | 71.23 |
| UMI | 0.40 | 0.29 | 100.00 | 100.00 |
| 1990 | | | | |
| LI | 0.05 | 0.02 | 4.84 | 2.47 |
| HI | 0.22 | 0.54 | 27.31 | 56.86 |
| LMI | 0.33 | 0.13 | 59.91 | 70.11 |
| UMI | 0.40 | 0.30 | 100.00 | 100.00 |
| 1995 | | | | |
| LI | 0.05 | 0.02 | 5.11 | 2.44 |
| HI | 0.21 | 0.53 | 26.54 | 55.84 |
| LMI | 0.34 | 0.13 | 60.34 | 69.24 |
| UMI | 0.40 | 0.31 | 100.00 | 100.00 |
| 2000 | | | | |
| LI | 0.06 | 0.02 | 5.52 | 2.45 |
| HI | 0.20 | 0.52 | 25.98 | 54.66 |
| LMI | 0.35 | 0.14 | 61.00 | 68.33 |
| UMI | 0.39 | 0.32 | 100.00 | 100.00 |
| 2005 | | | | |
| LI | 0.06 | 0.03 | 5.95 | 2.53 |
| HI | 0.20 | 0.51 | 25.65 | 53.69 |
| LMI | 0.36 | 0.14 | 61.79 | 67.66 |
| UMI | 0.38 | 0.32 | 100.00 | 100.00 |
| 2010 | | | | |
| LI | 0.06 | 0.03 | 6.44 | 2.68 |
| HI | 0.19 | 0.50 | 25.53 | 52.47 |
| LMI | 0.37 | 0.14 | 62.58 | 66.95 |
| UMI | 0.37 | 0.33 | 100.00 | 100.00 |
| 2015 | | | | |
| LI | 0.07 | 0.03 | 6.87 | 2.92 |
| HI | 0.18 | 0.48 | 25.35 | 51.16 |
| UMI | 0.37 | 0.34 | 62.12 | 84.83 |
| LMI | 0.38 | 0.15 | 100.00 | 100.00 |
| 2020 | | | | |
| LI | 0.07 | 0.03 | 7.40 | 3.37 |
| HI | 0.18 | 0.46 | 25.34 | 49.81 |
| UMI | 0.36 | 0.34 | 61.41 | 83.74 |
| LMI | 0.39 | 0.16 | 100.00 | 100.00 |

The calculated Gini coefficients of population-land distribution across income tiers globally (1975-2020) are presented in Table 4 and illustrated in Figure 2.

Tab. 4 Gini coefficients

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 1975 | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 |
| **G** | **0.26** | **0.24** | **0.23** | **0.22** | **0.21** | **0.19** | **0.17** | **0.30** | **0.29** |

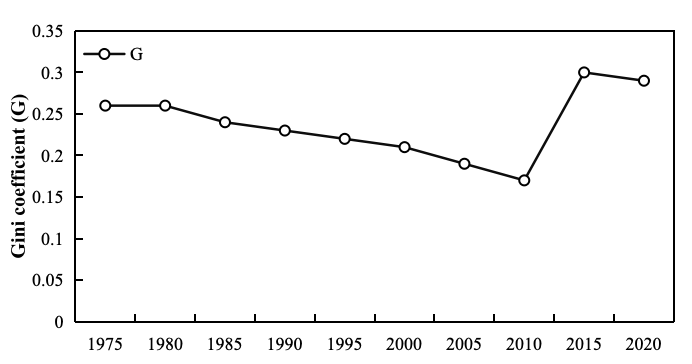


Fig. 2 Gini coefficients of population-land distribution across income tiers globally

# Standard deviational ellipse analysis for transition points dispersion

**1.1 Conceptual framework**

The standard deviational ellipse (SDE)[[[4]](#endnote-3)], introduced by sociologist Welty Lefever in 1926[[[5]](#endnote-4)], quantifies the spatial distribution and directional trends of geographic phenomena. The SDE is a common way of measuring the trend for a set of points or areas is to calculate the standard distance separately in the x- and y- dimensions. These measures define the center coordinates (), axes length(a and b) and theta(θ) of an ellipse encompassing the distribution of features.

We adapt this method to analyze the dispersion of transition points in human-land systems across income tiers (Fig.2). In our implementation:

**Center coordinates** ()**:** they represent the mean values of population change rate () and land use change rate () for countries within each income tier.

**Axes length(*a* and *b*):** the semi-major axis (*a*) always represents x-direction (population) variation, while the semi-minor axis (*b*) represents y-direction (land) variation. When population variation dominates (*σₓ² > σᵧ²*), *a* becomes the longer axis; when land variation dominates (*σᵧ² > σₓ²*), *b* becomes the longer axis.

**Theta(*θ*):** the angle of the ellipse's longer axis with the x-axis. θ ≈ 0° when population variation dominates. θ ≈ 90° when land variation dominates.

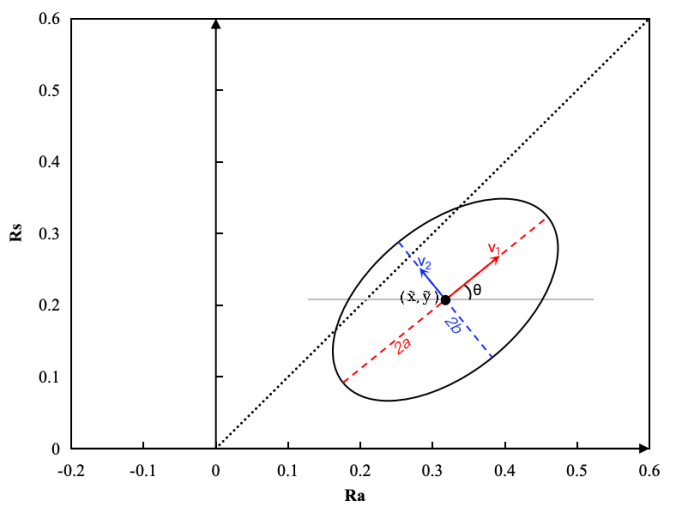


Fig. 2 The standard deviational ellipse

**1.2 Calculation steps**

**Central coordinates Calculation.** The geometric center of the standard deviational ellipse (SDE) corresponds to the mean transition state, calculated as the arithmetic mean of population (Ra) and land-use (Rs) change rates across all countries within each income tier. The centroid coordinates () are determined by:

(5)

(6)

where n denotes the country count per income category, and (xᵢ, yᵢ) represent the respective growth rates (Ra, Rs) for the i-th country.

**Covariance Matrix Estimation.** The covariance matrix quantifies the joint variability between population (Ra) and land-use (Rs) transition rates.

(7)

with components:

(8)

(9)

(10)

Diagonal elements (*σₓ², σᵧ²*) measure independent variability in population/land transitions. Off-diagonal captures their synergistic relationship.

**Eigenvalue Decomposition.** The covariance matrix Σ undergoes eigenvalue decomposition to determine the ellipse's principal axes. For the real symmetric covariance matrix Σ ∈ ℝ²ˣ², there exist eigenvalue-eigenvector pairs (λᵢ, vᵢ) satisfying:

(11)

where, λ1 ≥ λ2 > 0 are real eigenvalues (variance along principal axes), v1, v2 are orthogonal eigenvectors (axis directions).

Substituting Eq.8-10 into Eq.11 and solving for λ and v (Eq.12-14), we can obtain the eigenvalues and standardized eigenvectors (Eq.14).

(12)

(13)

(14)

**Standard deviational ellipse (SDE) parameterization.** The SDE is fully characterized through the following geometric parameters derived from eigenvalue decomposition (Eq.15~17):

(if *σₓ²>σᵧ²，i=1 otherwise i=2*) (15)

(if *σᵧ²>σₓ²，i=1 otherwise i=2*) (16)

(17)

where represent the x and y coordinates of the vector.

According to Eq.15~17, the ellipse equation is as follows (Eq.18):

*(18)*

*Note: The k value is a parameter used to determine the size of the confidence ellipse. It is proportional to the lengths of the semi-major and semi-minor axes of the standard deviation ellipse. The larger the k value, the larger the ellipse, indicating a greater probability of containing the data point[[[6]](#endnote-5)] (Tab. 5).*

This study adopts k=1 (1σ standard deviational ellipse) because: (1) The axis ratio a/b is mathematically invariant to k-scaling, preserving cross-group comparability of dispersion geometry; and (2) The analysis prioritizes relative human-land transition patterns over absolute confidence levels.

Tab. 5 k-value selection for confidence ellipses (based on normal distribution)

|  |  |  |
| --- | --- | --- |
| Confidence Level | k-value | Coverage Probability |
| 1σ | 1 | 68% |
| 2σ | 2 | 95%) |
| 3σ | 3 | 99.7% |

**1.3 Calculation results**

The centroid coordinates of standard deviational ellipses are presented in Table 6.

Tab. 6 Centroid coordinates ()

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Tier | Mean | *Δ*T1 | *Δ*T2 | *Δ*T3 | *Δ*T4 | *Δ*T5 | *Δ*T6 | *Δ*T7 | *Δ*T8 | *Δ*T9 |
| HI |  | 0.0913 | 0.0988 | 0.0879 | 0.0620 | 0.0585 | 0.0541 | 0.0656 | 0.0486 | 0.0356 |
|  | 0.1072 | 0.1094 | 0.1136 | 0.0869 | 0.0884 | 0.0612 | 0.0633 | 0.0642 | 0.0691 |
| LI |  | 0.1528 | 0.1310 | 0.1350 | 0.1112 | 0.1666 | 0.1567 | 0.1610 | 0.1333 | 0.1271 |
|  | 0.1791 | 0.2128 | 0.2059 | 0.1070 | 0.1311 | 0.1260 | 0.1633 | 0.1883 | 0.2330 |
| LMI |  | 0.1375 | 0.1451 | 0.1468 | 0.1336 | 0.1092 | 0.1043 | 0.1001 | 0.1069 | 0.0912 |
|  | 0.1657 | 0.1897 | 0.1862 | 0.1126 | 0.1295 | 0.1025 | 0.1250 | 0.1356 | 0.1476 |
| UMI |  | 0.1088 | 0.1056 | 0.1002 | 0.0677 | 0.0576 | 0.0537 | 0.0468 | 0.0470 | 0.0361 |
|  | 0.1296 | 0.1402 | 0.1414 | 0.0920 | 0.0969 | 0.0763 | 0.0819 | 0.0834 | 0.0866 |

*Note: Time intervals ΔT1-10 represent 5-year periods from 1975 to 2020.*

Covariance matrices for population-land change rates across income levels from 1977 to 2020 appear in Table 7.

Tab. 7 The covariance matrix

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Tier |  | *Δ*T1 | *Δ*T2 | *Δ*T3 | *Δ*T4 | *Δ*T5 | *Δ*T6 | *Δ*T7 | *Δ*T8 | *Δ*T9 |
| HI |  | 0.016 | 0.022 | 0.018 | 0.008 | 0.008 | 0.006 | 0.021 | 0.009 | 0.004 |
|  | 0.004 | 0.004 | 0.007 | 0.004 | 0.004 | 0.001 | 0.001 | 0.001 | 0.004 |
|  | 0.001 | 0.003 | 0.002 | 0.001 | 0.001 | 0.000 | 0.001 | 0.001 | 0.001 |
| LI |  | 0.005 | 0.005 | 0.004 | 0.016 | 0.009 | 0.002 | 0.003 | 0.005 | 0.003 |
|  | 0.003 | 0.004 | 0.003 | 0.002 | 0.002 | 0.003 | 0.005 | 0.009 | 0.031 |
|  | -0.000 | 0.001 | 0.001 | 0.001 | 0.000 | 0.001 | 0.001 | 0.002 | -0.002 |
| LMI |  | 0.009 | 0.002 | 0.003 | 0.004 | 0.004 | 0.003 | 0.003 | 0.004 | 0.003 |
|  | 0.004 | 0.006 | 0.005 | 0.006 | 0.006 | 0.003 | 0.005 | 0.007 | 0.013 |
|  | 0.000 | 0.000 | 0.001 | 0.001 | 0.001 | 0.000 | 0.001 | -0.000 | 0.001 |
| UMI |  | 0.005 | 0.004 | 0.004 | 0.005 | 0.005 | 0.005 | 0.004 | 0.004 | 0.004 |
|  | 0.004 | 0.007 | 0.007 | 0.003 | 0.003 | 0.001 | 0.001 | 0.002 | 0.005 |
|  | -0.000 | 0.001 | 0.001 | 0.000 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |

Eigenvalues and corresponding eigenvectors from covariance decomposition are shown in Tables 8 and 9.

Tab. 8 The eigenvalues

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Tier |  | *Δ*T1 | *Δ*T2 | *Δ*T3 | *Δ*T4 | *Δ*T5 | *Δ*T6 | *Δ*T7 | *Δ*T8 | *Δ*T9 |
| HI |  | 0.0161 | 0.0220 | 0.0184 | 0.0078 | 0.0080 | 0.0063 | 0.0213 | 0.0088 | 0.0050 |
|  | 0.0036 | 0.0036 | 0.0068 | 0.0037 | 0.0034 | 0.0008 | 0.0008 | 0.0009 | 0.0024 |
| LI |  | 0.0048 | 0.0056 | 0.0043 | 0.0160 | 0.0091 | 0.0032 | 0.0059 | 0.0100 | 0.0307 |
|  | 0.0029 | 0.0032 | 0.0023 | 0.0015 | 0.0023 | 0.0016 | 0.0023 | 0.0035 | 0.0030 |
| LMI |  | 0.0086 | 0.0062 | 0.0054 | 0.0060 | 0.0063 | 0.0030 | 0.0051 | 0.0067 | 0.0132 |
|  | 0.0044 | 0.0022 | 0.0031 | 0.0039 | 0.0034 | 0.0027 | 0.0025 | 0.0039 | 0.0033 |
| UMI |  | 0.0050 | 0.0069 | 0.0075 | 0.0050 | 0.0052 | 0.0047 | 0.0040 | 0.0047 | 0.0057 |
|  | 0.0044 | 0.0041 | 0.0033 | 0.0024 | 0.0028 | 0.0010 | 0.0013 | 0.0013 | 0.0035 |

Tab. 9 The eigenvectors and standardized eigenvectors

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Tier |  | *Δ*T1 | *Δ*T2 | *Δ*T3 | *Δ*T4 | *Δ*T5 | *Δ*T6 | *Δ*T7 | *Δ*T8 | *Δ*T9 |
| HI |  | 0.0008 | 0.0027 | 0.0024 | 0.0010 | 0.0014 | 0.0004 | 0.0015 | 0.0013 | 0.0013 |
|  | 0.0000 | 0.0004 | 0.0005 | 0.0003 | 0.0004 | 0.0000 | 0.0001 | 0.0002 | 0.0013 |
|  | 0.0008 | 0.0027 | 0.0024 | 0.0010 | 0.0014 | 0.0004 | 0.0015 | 0.0013 | 0.0013 |
|  | -0.0124 | -0.0180 | -0.0111 | -0.0039 | -0.0041 | -0.0055 | -0.0203 | -0.0077 | -0.0013 |
|  | 0.9981 | 0.9886 | 0.9781 | 0.9689 | 0.9501 | 0.9977 | 0.9973 | 0.9872 | 0.6993 |
| y | 0.0609 | 0.1507 | 0.2082 | 0.2473 | 0.3119 | 0.0673 | 0.0733 | 0.1596 | 0.7148 |
|  | 0.0609 | 0.1507 | 0.2082 | 0.2473 | 0.3119 | 0.0673 | 0.0733 | 0.1596 | 0.7148 |
| y | -0.9981 | -0.9886 | -0.9781 | -0.9689 | -0.9501 | -0.9977 | -0.9973 | -0.9872 | -0.6993 |
| LI |  | -0.0004 | 0.0009 | 0.0009 | 0.0006 | 0.0001 | 0.0008 | 0.0012 | 0.0024 | -0.0018 |
|  | 0.0001 | 0.0004 | 0.0005 | 0.0000 | 0.0000 | 0.0009 | 0.0030 | 0.0055 | 0.0276 |
|  | -0.0004 | 0.0009 | 0.0009 | 0.0006 | 0.0001 | 0.0008 | 0.0012 | 0.0024 | -0.0018 |
|  | -0.0019 | -0.0019 | -0.0014 | -0.0145 | -0.0068 | -0.0007 | -0.0005 | -0.0011 | -0.0001 |
|  | -0.9813 | 0.9030 | 0.8598 | 0.9992 | 0.9999 | 0.6468 | 0.3804 | 0.4018 | -0.0660 |
| y | 0.1927 | 0.4296 | 0.5107 | 0.0400 | 0.0149 | 0.7626 | 0.9248 | 0.9157 | 0.9978 |
|  | -0.1927 | 0.4296 | 0.5107 | 0.0400 | 0.0149 | 0.7626 | 0.9248 | 0.9157 | -0.9978 |
| y | -0.9813 | -0.9030 | -0.8598 | -0.9992 | -0.9999 | -0.6468 | -0.3804 | -0.4018 | -0.0660 |
| LMI |  | 0.0000 | 0.0003 | 0.0006 | 0.0007 | 0.0008 | 0.0001 | 0.0005 | -0.0001 | 0.0007 |
|  | 0.0000 | 0.0039 | 0.0021 | 0.0018 | 0.0026 | 0.0000 | 0.0025 | 0.0028 | 0.0098 |
|  | 0.0000 | -13.3287 | -3.5177 | -2.6183 | -3.3130 | -0.2053 | -4.9505 | 37.3425 | -14.0001 |
|  | -0.0042 | -0.0000 | -0.0002 | -0.0003 | -0.0002 | -0.0003 | -0.0001 | -0.0000 | -0.0000 |
|  | 1.0000 | 0.0748 | 0.2734 | 0.3568 | 0.2890 | 0.9796 | 0.1980 | -0.0268 | 0.0712 |
| y | 0.0036 | 0.9972 | 0.9619 | 0.9342 | 0.9573 | 0.2011 | 0.9802 | 0.9996 | 0.9975 |
|  | 0.0036 | -1.0000 | -1.0000 | -1.0000 | -1.0000 | -1.0000 | -1.0000 | 1.0000 | -1.0000 |
| y | -1.0000 | -0.0000 | -0.0000 | -0.0001 | -0.0001 | -0.0015 | -0.0000 | -0.0000 | -0.0000 |
| UMI |  | -0.0001 | 0.0006 | 0.0009 | 0.0005 | 0.0007 | 0.0007 | 0.0007 | 0.0010 | 0.0010 |
|  | 0.0000 | 0.0026 | 0.0040 | 0.0001 | 0.0002 | 0.0001 | 0.0002 | 0.0003 | 0.0014 |
|  | -0.0001 | 0.0006 | 0.0009 | 0.0005 | 0.0007 | 0.0007 | 0.0007 | 0.0010 | 0.0010 |
|  | -0.0006 | -0.0001 | -0.0002 | -0.0024 | -0.0022 | -0.0036 | -0.0025 | -0.0030 | -0.0008 |
|  | -0.9747 | 0.2272 | 0.2225 | 0.9802 | 0.9578 | 0.9822 | 0.9591 | 0.9473 | 0.6067 |
| y | 0.2234 | 0.9738 | 0.9749 | 0.1978 | 0.2875 | 0.1878 | 0.2832 | 0.3204 | 0.7950 |
|  | -0.2234 | 0.9738 | 0.9749 | 0.1978 | 0.2875 | 0.1878 | 0.2832 | 0.3204 | 0.7950 |
| y | -0.9747 | -0.2272 | -0.2225 | -0.9802 | -0.9578 | -0.9822 | -0.9591 | -0.9473 | -0.6067 |

Based on the mean, eigenvalue, and eigenvector, the center point, axis length, and key parameters of the standard deviation ellipse are obtained. The calculation results are shown in Tab. 10.

Tab. 10 Parameters of ellipse

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Tier |  | *Δ*T1 | *Δ*T2 | *Δ*T3 | *Δ*T4 | *Δ*T5 | *Δ*T6 | *Δ*T7 | *Δ*T8 | *Δ*T9 |
| HI |  | 0.0913 | 0.0988 | 0.0879 | 0.0620 | 0.0585 | 0.0541 | 0.0656 | 0.0486 | 0.0356 |
|  | 0.1072 | 0.1094 | 0.1136 | 0.0869 | 0.0884 | 0.0612 | 0.0633 | 0.0642 | 0.0691 |
| a | 0.1268 | 0.1483 | 0.1357 | 0.0882 | 0.0894 | 0.0795 | 0.1458 | 0.0940 | **0.0487** |
| b | 0.0599 | 0.0598 | 0.0826 | 0.0604 | 0.0586 | 0.0283 | 0.0286 | 0.0299 | **0.0706** |
| θ゜ | 3.49 | 8.67 | 12.02 | 14.32 | 18.17 | 3.86 | 4.20 | 9.18 | 45.63 |
| LI |  | 0.1528 | 0.1310 | 0.1350 | 0.1112 | 0.1666 | 0.1567 | 0.1610 | 0.1333 | 0.1271 |
|  | 0.1791 | 0.2128 | 0.2059 | 0.1070 | 0.1311 | 0.1260 | 0.1633 | 0.1883 | 0.2330 |
| a | 0.0693 | 0.0746 | 0.0654 | 0.1266 | 0.0952 | **0.0406** | **0.0484** | **0.0588** | **0.0550** |
| b | 0.0534 | 0.0566 | 0.0482 | 0.0387 | 0.0479 | **0.0569** | **0.0768** | **0.1001** | **0.1752** |
| θ゜ | 168.89 | 25.44 | 30.71 | 2.29 | 0.85 | 49.70 | 67.64 | 66.31 | 93.78 |
| LMI |  | 0.1375 | 0.1451 | 0.1468 | 0.1336 | 0.1092 | 0.1043 | 0.1001 | 0.1069 | 0.0912 |
|  | 0.1657 | 0.1897 | 0.1862 | 0.1126 | 0.1295 | 0.1025 | 0.1250 | 0.1356 | 0.1476 |
| a | 0.0928 | **0.0472** | **0.0557** | **0.0627** | **0.0580** | 0.0545 | **0.0498** | **0.0626** | **0.0579** |
| b | 0.0662 | **0.0786** | **0.0732** | **0.0777** | **0.0791** | 0.0516 | **0.0715** | **0.0821** | **0.1148** |
| θ゜ | 0.21 | 85.71 | 74.13 | 69.10 | 73.20 | 11.60 | 78.58 | 91.53 | 85.91 |
| UMI |  | 0.1088 | 0.1056 | 0.1002 | 0.0677 | 0.0576 | 0.0537 | 0.0468 | 0.0470 | 0.0361 |
|  | 0.1296 | 0.1402 | 0.1414 | 0.0920 | 0.0969 | 0.0763 | 0.0819 | 0.0834 | 0.0866 |
| a | 0.0708 | **0.0644** | **0.0576** | 0.0705 | 0.0723 | 0.0685 | 0.0632 | 0.0685 | **0.0591** |
| b | 0.0665 | **0.0832** | **0.0868** | 0.0494 | 0.0531 | 0.0318 | 0.0356 | 0.0365 | **0.0752** |
| θ゜ | 167.09 | 76.87 | 77.14 | 11.41 | 16.71 | 10.83 | 16.45 | 18.68 | 52.65 |

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