The new IAU recommended transformation between the Celestial and Terrestrial Reference Frame and its implementation in Matlab

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Outline

- Theory of the transformation
  - celestial intermediate pole
  - celestial/terrestrial ephemeris origin, earth rotation angle
- Implementation in Matlab
- Conclusions

Theory of the transformation

Motivation:

- VLBI outmatches the accuracy of the old precession-nutation model ($1\,\mathrm{mas}$).
  $\Rightarrow$ Need for more precise definitions of time-space transformations

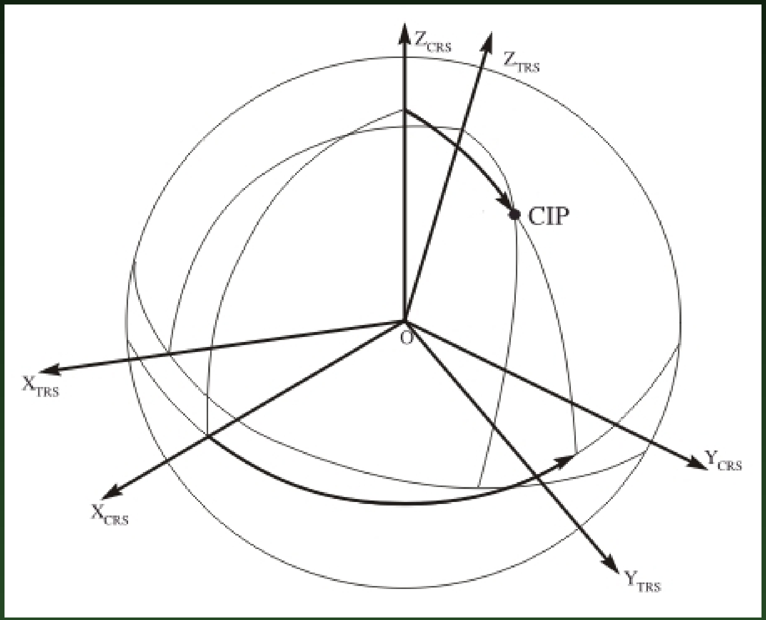
- IERS uses the new model since January 1st, 2003

Basic formula:

$$\mathbf{x}_{\mathsf{CRS}} = Q(t)R(t)W(t)\mathbf{x}_{\mathsf{TRS}}$$

$Q(t)$	precession-nutation
$R(t)$	earth rotation
$W(t)$	polar motion

Usage of the Celestial Intermediate Pole (CIP)

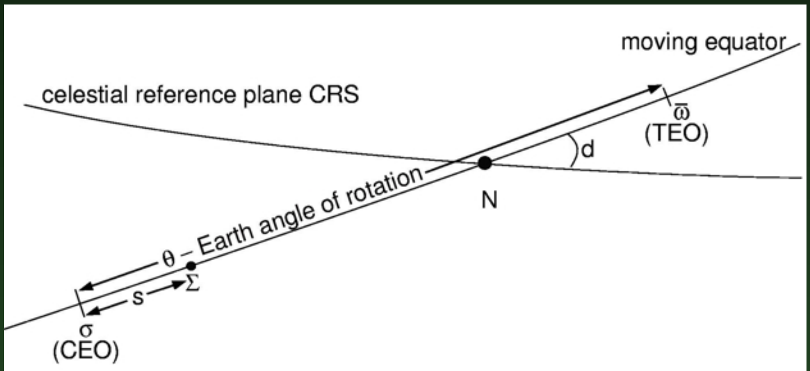


(source: IERS Technical Notes No.29)

- its motion in the CRS is specified by the motion of the Tisserand mean axis of the Earth with periods greater than two days,
- precession-nutation model:
  - IAU2000A: $0.2\,\mathrm{mas}$
  - IAU2000B: $1\,\mathrm{mas}$
- its motion in the TRS is provided by observations and by a model including high frequency variations,
- separates the celestial (precession-nutation) from the terrestrial (polar motion) components.

Usage of the Celestial/Terrestrial Ephemeris Origin (CEO/TEO) and the Earth Rotation Angle (ERA)

- separates precession-nutation from the Earth rotation
- independent from the theory of Earth's orbital motion around the Sun and the precession-nutation model



(source: IERS Technical Notes No.29)

- ERA is the angle between the TEO and the CEO along the equator reckoned from the TEO
- ERA is linearly related to UT1 and is used instead of the Greenwich Sidereal Time

Implementation

Why using Matlab?

- ubiquity in the scientific research area
- ease of use

Possible ways of implementation:

1. Use the classical procedures and apply corrections for precession and nutation.
2. Use the new approach (CIP,CEO,TEO,ERA)

Preparation

1. Import EOP-data from file `finals2000A.data` (provided by IERS)

2. Time:

   - TT as input time
   - derivation of MJD
   - derivation of UT1 $\longrightarrow$ ERA
   - derivation of GMST $\longrightarrow$ arguments

3. Arguments:

   - luni-solar nutation
   - planetary nutation

Polar Motion and ERA

- Motion of the CIP in the ITRS:

$$\begin{pmatrix} x_p \\ y_p \end{pmatrix} = \begin{pmatrix} x_{\text{IERS}} \\ y_{\text{IERS}} \end{pmatrix} + \begin{pmatrix} x_{\text{tidal}} \\ y_{\text{tidal}} \end{pmatrix} + \begin{pmatrix} x_{\text{nutation}} \\ y_{\text{nutation}} \end{pmatrix}$$

$$s' = -47\,\mu\text{as} \cdot t$$

- Transformation from the ITRS to the intermediate system:

$$W(t) = R_3(-s') \cdot R_2(x_p) \cdot R_1(y_p)$$

- Transformation due to the Earth rotation using ERA θ:

$$R(t) = R_3(-\theta)$$

Motion of the CIP in the CRS

- Series development for X,Y and s
  - IAU2000A: 1365 values
  - IAU2000B: 81 values

- Transformation from the intermediate system to the CRS:

$$Q(t) = \begin{pmatrix} 1 - aX^2 & -aXY & X \\ -aXY & 1 - aY^2 & Y \\ -X & -Y & 1 - a(X^2 + Y^2) \end{pmatrix} \cdot R_3(s)$$

where:

$$a = \frac{1}{1+Z} \approx \frac{1}{2} + \frac{1}{8}\left(X^2 + Y^2\right)$$

- Possibility of including observed corrections as provided by the IERS

Conclusions

- Need for more precise definitions of time-space transformations
- Usage of CIP, CEO, TEO, ERA
- Two possible ways of calculation
- Step by step implementation in Matlab
- Accuracy:
  - IAU2000A: $0.2\,\mathrm{mas}$
  - IAU2000B: $1\,\mathrm{mas}$

Questions ?