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# Computer simulating observations of the Lunar physical libration for the Japanese Lunar project ILOM

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In the frame of the second stage of the Japanese space mission SELENE-2 (Hanada et al. 2009) the project ILOM (In-situ Lunar Orientation Measurement) planned after 2017years is a kind of instrument for positioning on the Moon. It will be set near the lunar pole and will determine parameters of lunar physical libration by positioning of several tens of stars in the field of view regularly for longer than one year.

Presented work is dedicated to analyses of computer simulating future observations. It's proposed that for every star crossing lunar prime meridian its polar distance will be to measure. The methods of optimal star observation are being developed for the future experiment. The equations are constructed to determine libration angles $\tau$ *(t),ρ(t),σ(t)*- on the basis of observed polar distances $p_{obs}$:

$$\begin{cases} f_1(\tau,\rho,I\sigma,p_{obs})=0 \\ f_2(\tau,\rho,I\sigma,p_{obs})=0 \\ f_3(\tau,\rho,I\sigma,p_{obs})=0 \end{cases} \text{ or } f(X)=0, \text{ where } ; f=\begin{bmatrix} f_1 \\ f_2 \\ f_3 \end{bmatrix} \quad X=\begin{bmatrix} \tau \\ \rho \\ I\sigma \end{bmatrix} \quad (1)$$

At the present stage we have developed the software for selection of stars for these future polar observations. Stars were taken from various stellar catalogues, such as the UCAC2-BSS, Hipparcos, Tycho and FK6. The software reduces ICRS coordinates of star to selenographical system at the epoch of observation (Petrova et al., 2009). For example, to the epochs 2017 - 2018 more than 50 stars brighter than m = 12 were selected for the northern pole. In total, these stars give about 600 crossings of the prime meridian during one year. Nevertheless, only a few stars (2-5) may be observed in a vicinity of the one moment. This is not enough to have sufficient sample to exclude various kind of errors.

The software includes programmes which can determine the moment of transition of star across the meridian and theoretical values of libration angles at this moments.

A serious problem arises when we try to solve equations (1) with the purpose to determine libration angles on the basis of simulated $p_{obs.}$. Polar distances are calculated using the analytical theory of physical libration Petrova et al. (2008; 2009).

We cannot use Newton's method for solution of the equation, because the Jacobian

$$J(X)=\begin{vmatrix} \frac{\partial f_1}{\partial x_1} & \frac{\partial f_1}{\partial x_2} & \frac{\partial f_1}{\partial x_3} \\ \frac{\partial f2}{\partial x_1} & \frac{\partial f_2}{\partial x_2} & \frac{\partial f_2}{\partial x_3} \\ \frac{\partial f_3}{\partial x_1} & \frac{\partial f_3}{\partial x_2} & \frac{\partial f_3}{\partial x_3} \end{vmatrix} = 0.$$

We transformed equations to the iteration form $x_i=\varphi_i(X)$. Used iteration methods have unsatisfactory convergence: inaccuracy in polar distance of 1 milliseconds of arc causes inaccuracy of 0.01arcsec in $\rho$ and in $I\sigma$, and 0.1 arcsec in $\tau$.

Results of our computer simulating showed

It's necessary to carry out measuring of polar distances of stars in several meridians simultaneously to increase sample of stars.

It's necessary to find additional links (relations) between observed parameters and libration angles to have stable

mathematical methods to receive solutions for lunar rotation with high accuracy.

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