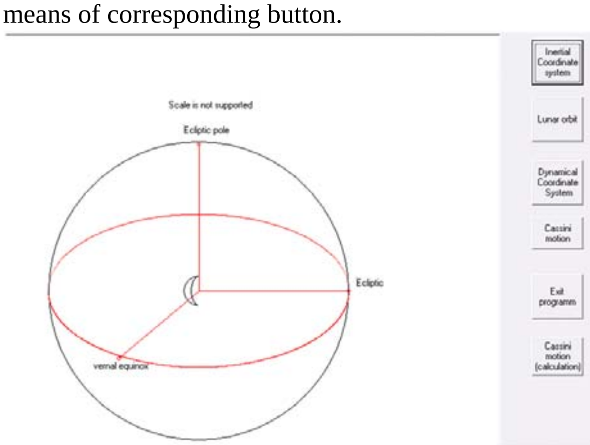
VISUALIZATION OF THE EFFECTS OF ORBITAL AND ROTATIONAL MOTION OF THE MOON BY MEANS OF VISUAL BASIC. N.K. Petrova[1,2] and A.A. Zagidullin[1], [1]Kazan Federal university, Kazan, Russia, nk_petrova@mail.ru, [2]Kazan Power Engineering university, Kazan, Russia.

Introduction: Study of the Moon, of its spin-orbital characteristics and parameters of the lunar interior is one of the traditional fields of the Kazan astronomical school [1]. However, despite the incredible successes in space investigations of the planets and of the Moon, in last years the interest to celestial mechanics, ephemerides astronomy and astrometry is significantly decreased, especially among the young scientists and students. Therefore, it is encouraging to see the work of the third-year student, which is devoted to the study of the physical libration of the Moon.

Results of the program of visualization of the Cassini's laws: This report presents the results of the first stage of the above study associated with the study of Cassini's laws in the rotation of the Moon and the visualization of these laws by means the programming language Visual Basic [2].

On the Form (Fig. 1) the celestial sphere is shown. The inertial selenocentric coordinate system, determined by ecliptic and vernal equinox, is constructed by means of corresponding button.



The Earth moves on the Moon's orbit (green frame) in selenocentric frame. Dynamic coordinate system (blue frame) is based on the principal axes of inertia of the Moon. The x-axis is directed along the longest principal axis of inertia A, the axis z is a dynamic pole of the Moon associated with the smallest principal axis of inertia C.

According to the first Cassini's law the lunar pole is inclined relatively to the ecliptic pole at a constant angle approximately equal to 1.5 degree. The ascending node of the orbit is coincides with descending node of the lunar equator (the second Cassini's law) and, as a result, the ecliptic pole lies between the orbit pole and spin pole. Therefore the three vectors directed from the lunar centre of mass to orbit pole, ecliptic pole and spin pole form a single plane (Fig. 2).

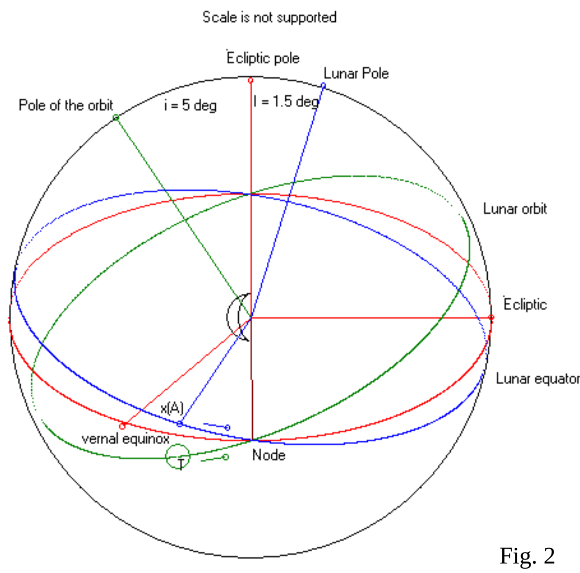


Fig. 2

The third Cassini's law reflects the uniform rotation of the Moon synchronised with orbital motion of the Moon around the Earth (in the selenocentric frame the Earth moves around the Moon).

It's necessary a significant time to calculate the corresponding coordinates of the points, which move synchronously on the orbit and on the equator. Therefore the results of the calculation are written in the file. And, when dynamics of the synchronised motion is demonstrated, the coordinates are taken from the file. As a result, the imaging of the third law can be reproduced without unnecessary waiting.

In any time t the Earth moves with the mean velocity n and forms the angle $n{\cdot}t$ in the orbit plane. At the same time, according to the third law, the axis x forms the same angle $\varphi = n{\cdot}t$ in equatorial plane (Fig. 3). In other words the longest axis of the Moon is always "looking" at the Earth.

We demonstrate the program code of some subroutines. For example, to draw the colour vectors the following code is written as:

```
Sub vector(x1, y1, x2, y2, color1)
Picture1.Line (x1, y1)-(x2, y2), color1
Picture1.Circle (x2, y2), 0.1, color1
End Sub
```

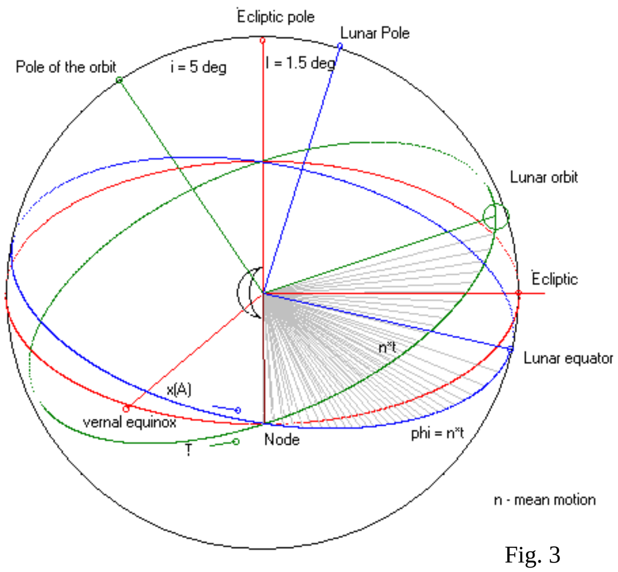


Fig. 3

The following subroutine constructs the motion of the Earth and axis *x* on the basis of coordinates read from the file

```
Private Sub Command6_Click( )              'open file
Picture1.Scale (-20, 20)-(20, -20)
'clean old pictures
Picture1.PSet (x0o, y0o), vbWhite
Picture1.Circle (x0o, y0o), 0.5, vbWhite
Open "orbit.txt" For Input As #1
Do Until EOF(1)
Input #1, x, y, x1, y1
Call vectorE(0, 0, x1, y1, QBColor(2))
Call vector(0, 0, x, y, vbBlue)
Sleep 500
Call vectorE(0, 0, x1, y1, vbWhite)'point of the Erath
Call vector(0, 0, x, y, vbWhite)' point of the vextor x
Picture1.Line (0, 0)-(x1, y1), QBColor(7)
Picture1.Line (0, 0)-(x, y), QBColor(7)
Abscissa  ' reconstruction of the frame lines
Moon ' reconstruction of the equator line
Earth ' reconstruction of the orbit line
Loop
Close #1
Call vectorE(0, 0, x1, y1, QBColor(2))
Call vector(0, 0, x, y, vbBlue)
Picture1.PSet (4.5, -2.1), vbWhite
Picture1.Print "n*t"
Picture1.PSet (5.8, -6#), vbWhite
Picture1.Print "phi = n*t"
Picture1.PSet (9, -9), vbWhite
Picture1.Print ("n - mean motion")
Picture1.Line (0, 0)-(0.1, -6), QBColor(4)
Picture1.PSet (0.1, -6.3), vbWhite
Picture1.Print "Node"
End Sub
```

Exit from the application is executed by the button with program code:

```
Private Sub Command5_Click()
Dim answer As Byte
  answer = MsgBox("Do you want to quit now?", 4)
  If answer = 6 Then
     MsgBox ("Terminating program")
     Form1.Hide
     End
  End If
End Sub
```

Unfortunately, Visual Basic opportunities are severely limited for creating three-dimensional images. Because of this we could not support real scale in angles and time. This application will be further developed to demonstrate of some, most significant, harmonics of the lunar physical libration.

References: [1] *Petrova N.* Analytical extension of Lunar libration tables. // Earth, Moon and Planets, Vol. 73, 1996. No 1, p. 71-99. [2] *Safronov I.K.* Visual Basic: tasks and examples. Book, S-Petersburg, 2008, 411 p. (in Russian).