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MODERN METHOD OF COMPASS ERROR CALCULATION BY THE CELESTIAL BODIES USING MATLAB ENVIRONMENT

O.G. Kupraty
Senior Lecturer at the Department "Navigation and Marine Safety",
Odessa National Maritime University, Odessa, Ukraine,
ORCID ID: 0000-0003-3519-504X

Summary

In modern conditions, the role of information technology for safe navigation is growing. The article works out a method for calculating the compass error through the interaction of the MATLAB software environment and the MS Excel software environment. Modern navigation requires new approaches to solving the problem of calculating the compass error for celestial bodies. To implement these approaches, the author developed an algorithm and wrote the code in the above software environment. The MATLAB software environment allows you to take data from an electronic astronomical almanac and process it automatically according to the algorithm. Great importance is attached to the signs of parameters A and B. The program code contains the conditions for selecting a sign for parameter A by latitude, for parameter B by the local time angle and declination.

The work used an almanac in the format in MS Excel. Analyzing the almanac, an algorithm was developed that starts from the winter and summer solstice, that is, 2 declinations, 2 points, from which the direction of the declination graph changes from growth to descending and vice versa.

The solstice is the moment in time at which the center of the Sun passes either through the northernmost point of the ecliptic, which has a declination of +23° 27', or through its southernmost point, which has a declination of -23° 27'.

The algorithm uses 5 dates: the solstice of last year, 2 solstices of the year in which the observation took place, the day of observation and the last day of the year. Data on the Sun on the day of observation are combined into matrices, from which are then selected the required value.

Key words: *compass error, MATLAB, solstice, declination, true bearing (TB).*

СУЧАСНИЙ МЕТОД РОЗРАХУНКУ ПОПРАВКИ КОМПАСУ ПО НЕБЕСНИМ ТІЛАМ З ВИКОРИСТАННЯМ СЕРЕДОВИЩА MATLAB

О.Г. Купратий
старший викладач кафедри «Судноводіння і морської безпеки»,
Одеський національний морський університет, Одеса, Україна,
ORCID ID: 0000-0003-3519-504X

Анотація

В сучасних умовах зростає роль інформаційних технологій для безпечної навігації. У статті опрацьовується метод розрахунку поправки компасу через взаємодію програмного середовища MATLAB та програмного середовища MS Excel.

Сучасна навігація потребує нових підходів до розв'язання задачі розрахунку поправки компасу по небесним тілам. Для реалізації цих підходів автором було розроблено алгоритм і прописано код у вище зазначеному програмному середовищі. Програмне середовище MATLAB дозволяє брати дані з електронного астрономічного альманаху і опрацьовувати їх в автоматичному режимі згідно алгоритму. Велике значення приділено знакам параметрів A і B. В програмному коді прописано умови вибору знаку для параметру A за широтою, для параметру B за місцевим часовим кутом LHA та схиленням DEC.

У роботі було використано альманах у форматі в MS Excel. Аналізуючи альманах, було розроблено алгоритм, що відштовхується від зимового і літнього сонцестояння, тобто 2 схилення, 2 точки, від яких змінюється напрям графіку схилення від зростання на спадання і навпаки.

Сонцестояння – момент часу, у який центр Сонця проходить або через найпівнічнішу точку екліптики, що має схилення +23° 27', або через найпівденнішу її точку, що має схилення -23° 27'.

В алгоритмі використовуються 5 дат: сонцестояння минулого року, 2 сонцестояння року, в якому відбулася обсервація, день обсервації і останній день року. Дані по Сонцю в день обсервації комбінуються в матриці, з яких потім вибирається необхідне значення.

Ключові слова: *поправка компаса, MATLAB, сонцестояння, схилення, справжній пеленг (СП).*

Introduction and problem statement

Nautical astronomy (Celestial navigation) as a subject is going through difficult times, electronic navigation instruments displace the need to use it to determine the location of the vessel, but according to the Bridge Procedure Guide, the determination of the correction of the magnetic and gyroscopic compass must be carried out regularly.

It is important to pay attention to the requirements prescribed in the STCW Convention, in Table A-II/1 [1], and Section B-II/1 for the level of ship operation and management. These tables summarize the minimum requirements for competence, which include skills in nautical astronomy.

Determining the compass error by celestial bodies is a standard procedure carried out by the navigator regularly, in the presence of a cloudless sky. Figure 1 below shows the algorithm for calculating the true bearing on the star using the MS Excel and MATLAB environments.

Considering the Earth stationary, the celestial sphere is given a rotation inverse to the daily rotation (from E to W).

As a result, all the bodies distant from the celestial equator by the magnitude of the conjugation of δ describe the daily parallels. This is the visible movement of luminaries due to the rotation of the Earth, convenient for presenting the physics of phenomena and solving problems. During the daily movement, the rapid line zn, the meridian observing the true horizon remain stationary.

The beginning of the stellar day is taken as the moment of the upper culmination of the point spring equinox.

Analysis of recent research and publications

Section B-II/1 for the level of operation and management of the response [1] notes such requirements for training: correctly adjust sextant for adjustable errors, determine corrected reading of the sextant altitude of celestial bodies, accurate sight reduction computation, using a preferred method, calculate the time of meridian altitude of the sun, calculate latitude by Polaris or by meridian altitude of the sun, accurate plotting of position line(s) and position fixing, determine time of visible rising/setting sun by a preferred method, identify and select the most suitable celestial bodies in the twilight period, determine compass error by azimuth or by amplitude, using a preferred method, nautical astronomy as required to support the required competence, that required above

Training in celestial navigation may include the use of electronic nautical almanac and celestial navigation calculation software. [1]

Works of Aleksyshyn V.G., Dolgochub V.T., Belov O.V. [4] and Kudryavtsev V.G., Mikhailov V.S. [21-23] are devoted to modern theoretical and practical research in the field of nautical astronomy. But they do not highlight the possibilities of modern information technology.

The purpose of the work: to assess the possibilities of interaction between the software environment MATLAB and MS Excel for calculating the compass error by celestial bodies.

Tasks:

1. Develop an algorithm for calculating the compass error by the Sun
2. Create a program code for calculating the compass error in MATLAB, which takes basic values from MS Excel
3. Test the program code by calculation 4 examples

Modern method of calculating the compass error

Development of an algorithm for calculating the correction of a compass for the Sun

Using the explanation of the Norie's Nautical Table for parameters A, B and C, the corresponding patterns are analyzed. [2] Figure 1 below shows the algorithm for calculating TB finding on the star using the MS Excel and MATLAB environment.

Parameter A is determined by latitude and local time angle, respectively, the calculation formula: A = |tg lat/tg LHA|. Parameter B is determined by declination and local time angle, respectively, the calculation formula B = |tg DEC/sin LHA|.

And then determine the sign of these parameters by MATLAB function sign().

The program code for calculating the compass error for the Sun in the MATLAB environment

```
GMTh=**; m=**; s=*; GMTm=m+s/60; % using Greenwich meridian time
lat=**.********; %N/S
long=***.********; %E/W
OB=***; %Observed bearing
DAY=xlsread('2022_Nautical_Almanac.xlsx','nautical_almanac','O10');
MONTH=xlsread('2022_Nautical_Almanac.xlsx','nautical_almanac','O12');
Today=datetime(2022,MONTH,DAY,GMTh,m,s)
Date1=datetime(2021,12,21,12,0,0); %winter solstice in 2021
Date2=datetime(2022,06,21,12,0,0); %summer solstice in 2022
Date3=datetime(2022,12,21,12,0,0); %winter solstice in 2022
Lastday=datetime(2022,12,31); %lastday in 2022
```

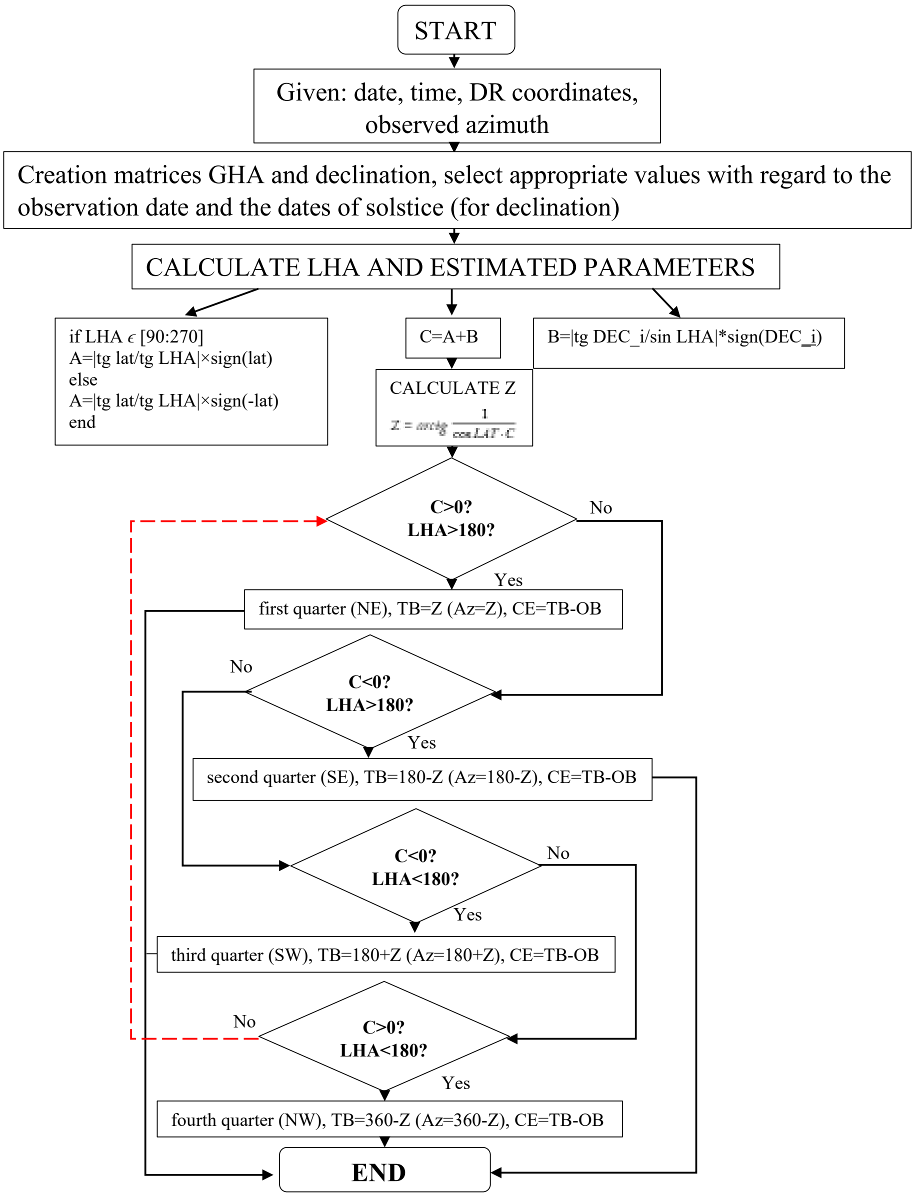


Fig. 1. CE calculation algorithm (declination selection can be simplified for other celestial bodies)

```
GHA_degrees1=xlsread('2022_Nautical_Almanac.xlsx','nautical_almanac','C16:C21');
GHA_degrees2=xlsread('2022_Nautical_Almanac.xlsx','nautical_almanac','C23:C28');
GHA_degrees3=xlsread('2022_Nautical_Almanac.xlsx','nautical_almanac','C30:C35');
```

```
GHA_degrees4=xlsread('2022_Nautical_Almanac.xlsx','nautical_almanac','C37:C42');
GHA_degrees5=xlsread('2022_Nautical_Almanac.xlsx','nautical_almanac','C44');
GHA_minutes1=xlsread('2022_Nautical_Almanac.xlsx','nautical_almanac','D16:D21');
GHA_minutes2=xlsread('2022_Nautical_Almanac.xlsx','nautical_almanac','D23:D28');
GHA_minutes3=xlsread('2022_Nautical_Almanac.xlsx','nautical_almanac','D30:D35');
GHA_minutes4=xlsread('2022_Nautical_Almanac.xlsx','nautical_almanac','D37:D42');
GHA_minutes5=xlsread('2022_Nautical_Almanac.xlsx','nautical_almanac','D44');
GHA=[GHA_degrees1+GHA_minutes1./60; GHA_degrees2+GHA_minutes2./60; GHA_degrees3+GHA_minutes3./60; GHA_degrees4+GHA_minutes4./60; GHA_degrees5+GHA_minutes5./60];
GHA_gt=GHA(GMTh+1,1) %GHA FOR GIVEN TIME
DEC_degrees1_6=xlsread('2022_Nautical_Almanac.xlsx','nautical_almanac','G16');
DEC_degrees7_12=xlsread('2022_Nautical_Almanac.xlsx','nautical_almanac','G23');
DEC_degrees13_18=xlsread('2022_Nautical_Almanac.xlsx','nautical_almanac','G30');
DEC_degrees19_24=xlsread('2022_Nautical_Almanac.xlsx','nautical_almanac','G37');
DEC_degrees25=xlsread('2022_Nautical_Almanac.xlsx','nautical_almanac','G44');
DEC_minutes1=xlsread('2022_Nautical_Almanac.xlsx','nautical_almanac','H16:H21');
DEC_minutes2=xlsread('2022_Nautical_Almanac.xlsx','nautical_almanac','H23:H28');
DEC_minutes3=xlsread('2022_Nautical_Almanac.xlsx','nautical_almanac','H30:H35');
DEC_minutes4=xlsread('2022_Nautical_Almanac.xlsx','nautical_almanac','H37:H42');
DEC_minutes5=xlsread('2022_Nautical_Almanac.xlsx','nautical_almanac','H44');
if Today>Date1 && Today<Date2
DEC=[DEC_degrees1_6-DEC_minutes1./60; DEC_degrees7_12-DEC_minutes2./60; DEC_degrees13_18-DEC_minutes3./60; DEC_degrees19_24-DEC_minutes4./60; DEC_degrees25-DEC_minutes5./60]; % before summer solstice
elseif Today>=Date2 && Today<Date3
DEC=[DEC_degrees1_6+DEC_minutes1./60; DEC_degrees7_12+DEC_minutes2./60; DEC_degrees13_18+DEC_minutes3./60; DEC_degrees19_24+DEC_minutes4./60; DEC_degrees25+DEC_minutes5./60]; % after summer solstice
elseif Today>=Date3 && Today<=Lastday
DEC=[DEC_degrees1_6-DEC_minutes1./60; DEC_degrees7_12-DEC_minutes2./60; DEC_degrees13_18-DEC_minutes3./60; DEC_degrees19_24-DEC_minutes4./60; DEC_degrees25-DEC_minutes5./60]; % after winter solstice
end
```

```
DEC_gt=DEC(GMTh+1,1) %DEC for given time (without minutes taking in account)
dif_gha=(GHA(12,1)-GHA(1,1))/11
dif_dec=(DEC(25,1)-DEC(1,1))/24
if GHA_gt+dif_gha*(GMTm/60)>360 GHA_wm=GHA_gt+dif_gha*(GMTm/60)-360
else GHA_wm=GHA_gt+dif_gha*(GMTm/60) %GHA with minutes taking in account
end
DEC_wm=DEC_gt+dif_dec*(GMTm/60);
DEC_i=DEC_wm
if GHA_wm+long>360 LHA=GHA_wm+long-360
else LHA=GHA_wm+long %local hour angle calculation
end
if LHA >270
A=abs(tan(lat*pi/180)/tan(LHA*pi/180))*(-sign(lat))
elseif LHA<90
A=abs(tan(lat*pi/180)/tan(LHA*pi/180))*(-sign(lat))
else
A=abs(tan(lat*pi/180)/tan(LHA*pi/180))*sign(lat)
end
B=abs(tan(DEC_i*pi/180)/sin(LHA*pi/180))*sign(DEC_i)
C=A+B
Z=abs(atan(1/(cos(lat*pi/180)*C))*180/pi)
if C>0 && LHA>180  %first quarter
  TB=Z
elseif  C<0 && LHA>180 %second quarter
  TB=180-Z
elseif C<0 && LHA<180 %third quarter
  TB=180+Z
elseif C>0 && LHA<180 %fourth quarter
  TB=360-Z
end
CE=TB-OB % compass error
```

Data is taken from the electronic almanac in MS Excel format (Fig. 2).

Therefore, after taking values from MS Excel MATLAB constructs matrices GHA and DEC, from which the appropriate values will be selected in CE calculations.

Examples of calculating the compass error by the Sun

Examples that given in this paragraph have same given values, but different date, to illustrate the changes of Sun declination.

Example 1.

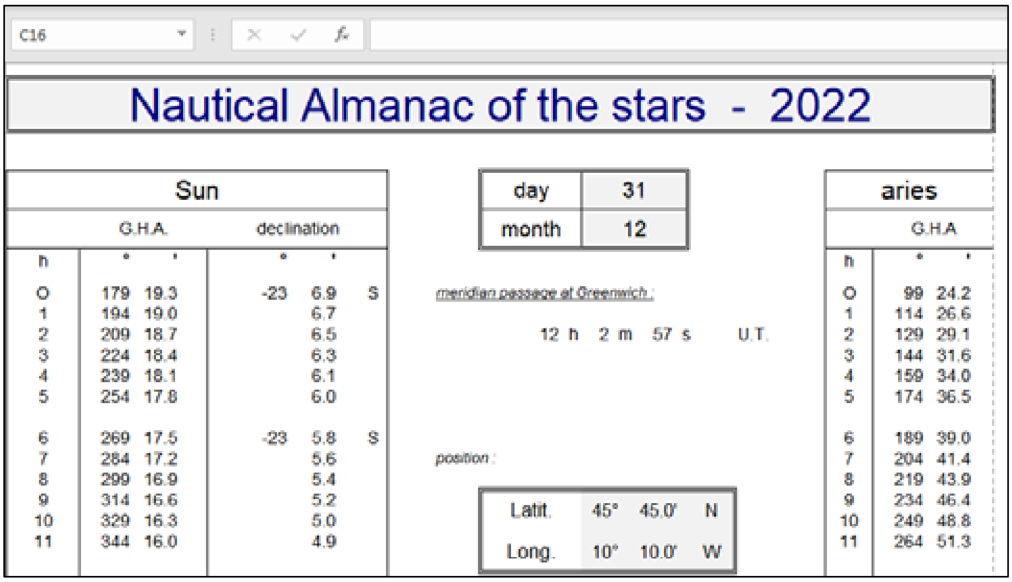
Given:

Today = datetime 21-May-2022 04:30:24 (before summer solstice)

lat=25° N

long=156°E

OB=273°



C16

Nautical Almanac of the stars - 2022

day	31
month	12

Sun			
h	G.H.A. ° '	declination ° '	
0	179 19.3	-23 6.9	S
1	194 19.0	6.7	
2	209 18.7	6.5	
3	224 18.4	6.3	
4	239 18.1	6.1	
5	254 17.8	6.0	
6	269 17.5	-23 5.8	S
7	284 17.2	5.6	
8	299 16.9	5.4	
9	314 16.6	5.2	
10	329 16.3	5.0	
11	344 16.0	4.9	

meridian passage at Greenwich :

12 h 2 m 57 s U.T.

position :

Latit.	45°	45.0'	N
Long.	10°	10.0'	W

aries	
h	G.H.A ° '
0	99 24.2
1	114 26.6
2	129 29.1
3	144 31.6
4	159 34.0
5	174 36.5
6	189 39.0
7	204 41.4
8	219 43.9
9	234 46.4
10	249 48.8
11	264 51.3

Fig. 2. Nautical Almanac 2022

Solution

GHA_gt = 240.8531
DEC_gt = 19.8284
GHA_wm = 248.4528
DEC_i = 19.8242
LHA = 44.4528
A = -0.4753
B = 0.5148
C = 0.0395
Z = 87.9517
TB = 272.0483
CE= - 0.9517

Answer: CE = - 0.9517°.

Example 2.

Given:

lat = 25° N
long = 156° E
OB=276°
Today = datetime 22-Jun-2022 04:30:24 (after summer solstice)

Solution

GHA_gt = 239.5090
DEC_gt = 23.4357
GHA_wm = 247.1079
DEC_i = 23.4356
LHA = 43.1079
A = -0.4982

B = 0.6343
C = 0.1361
Z = 82.9658
TB = 277.0342
Answer: CE=1.0342°

Example 3.
Given:
lat =25°N
long = 156°E
OB= 225°
Today = datetime 22-Dec-2022 04:30:24 (after winter solstice)
Solution
GHA_gt = 240.4095
DEC_gt = -23.4378
GHA_wm = 248.0069
DEC_i = -23.4377
A = -0.4828
B = -0.6240
C = -1.1068
Z = 44.9123
TB = 224.9123
CE = -0.0877
Answer: CE = -0.0877°

Example 4.
Given:
lat = 25° N
long = 156° E
Today = datetime 31-Dec-2022 04:30:24 (last day in year)
OB=225°
Solution
GHA_gt = 239.3013
DEC_gt = -23.4378
GHA_wm = 246.8987
DEC_i = -23.4377
A = -0.5018
B = -0.6369
C = -1.1387
Z = 44.0974
TB = 224.0974
CE = -0.9026
Answer: CE = -0.9026°

According to the test program code is working according to algorithm, without any problem.

Conclusions

The algorithm was created in accordance with the Norie's Nautical Tables. It can be used for other celestial bodies just by changing the value localization in function xlsread() and simplified the declination selection procedure.

The program code in MATLAB takes in account summer and winter solstice and changes of declination sign, also defines the signs of parameters A and B by latitude sign and declination sign respectively.

In article was explained how to calculate true azimuth (true bearing) according to the sign of parameter C and LHA value.

Therefore, proposed method of compass error calculation using MATLAB and MS Excel environments is very effective and can be use in marine practice.

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