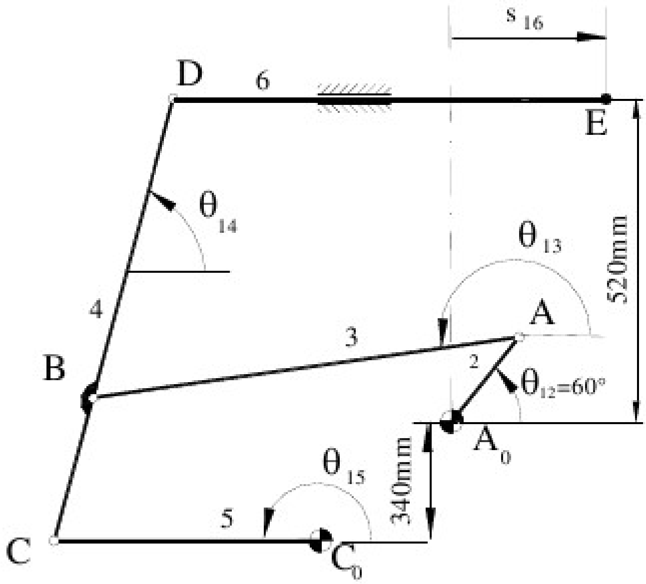
MAT-202E NUMERICAL METHODS
HOMEWORK 3

Due date for source code submission via e-mail: 30.11.2008 @ 12 pm
Due date for the submission of the report: 01.12.2008

In the figure a six-link mechanism used in textile machines is presented. Associated link lengths are provided below;

$A_0A=a_2=210$ mm.
$C_0C=a_5=600$ mm.
$CB=a_4=350$ mm.
$BD=b_4=600$ mm.
$A_0C_0=c_1=710$ mm.
$AB=a_3=1225$ mm. and,
$DE=a_6=1100$ mm.
$a_1=340$ mm., ($b_1=\sqrt{c_1{}^2-a_1{}^2}$)
d1=520 mm.

You are to determine s_{16}, when $\theta_{12}=60^\circ$.



The loop equations,(i.e. the equations that determine the relation between the variables due to the geometry of the mechanism) are given in terms of four non-linear equations such as,

$$a_2\cos\theta_{12}+a_3\cos\theta_{13}+b_1-a_5\cos\theta_{15}-a_4\cos\theta_{14}=f_1(\theta_{13},\theta_{14},\theta_{15})=0$$
$$a_2\sin\theta_{12}+a_3\sin\theta_{13}+a_1-a_5\sin\theta_{15}-a_4\sin\theta_{14}=f_2(\theta_{13},\theta_{14},\theta_{15})=0$$
$$a_2\cos\theta_{12}+a_3\cos\theta_{13}+b_4\cos\theta_{14}+a_6-s_{16}=f_3(\theta_{13},\theta_{14},s_{16})=0$$
$$a_2\sin\theta_{12}+a_3\sin\theta_{13}+b_4\sin\theta_{14}-d_1=f_4(\theta_{13},\theta_{14})=0$$

Here the unknowns are θ_{12}, θ_{14}, θ_{15} and s_{16}.

You can assume $\theta_{13}=200^\circ$, $\theta_{14}=80^\circ$, $\theta_{15}=180^\circ$ and $s_{16}=400$ mm. as the initial guesses for the positions. (Important Note: Please do remember that you will be working with radians rather than degrees while solving these equations).

If one uses Newton-Raphson method for several variables the following parameter update formula is obtained.

$$\begin{bmatrix} \frac{\partial f_1}{\partial \theta_{13i}} & \frac{\partial f_1}{\partial \theta_{14i}} & \frac{\partial f_1}{\partial \theta_{15i}} & \frac{\partial f_1}{\partial s_{16i}} \\ \frac{\partial f_2}{\partial \theta_{13i}} & \frac{\partial f_2}{\partial \theta_{14i}} & \frac{\partial f_2}{\partial \theta_{15i}} & \frac{\partial f_2}{\partial s_{16i}} \\ \frac{\partial f_3}{\partial \theta_{13i}} & \frac{\partial f_3}{\partial \theta_{14i}} & \frac{\partial f_3}{\partial \theta_{15i}} & \frac{\partial f_3}{\partial s_{16i}} \\ \frac{\partial f_4}{\partial \theta_{13i}} & \frac{\partial f_4}{\partial \theta_{14i}} & \frac{\partial f_4}{\partial \theta_{15i}} & \frac{\partial f_4}{\partial s_{16i}} \end{bmatrix} \begin{bmatrix} \delta\theta_{13i} \\ \delta\theta_{14i} \\ \delta\theta_{15i} \\ \delta s_{16i} \end{bmatrix} = \begin{bmatrix} -f_{1i} \\ -f_{2i} \\ -f_{3i} \\ -f_{4i} \end{bmatrix}$$

Consequently the new values of the variables can be obtained as,

$$\theta_{13i+1} = \theta_{13i} + \delta\theta_{13i}\ ,\ \theta_{14i+1} = \theta_{14i} + \delta\theta_{14i}\ ,$$
$$\theta_{15i+1} = \theta_{15i} + \delta\theta_{15i}\ ,\ s_{16i+1} = s_{16i} + \delta s_{16i}$$

i. Write function routines to evaluate each of the functions for a given set of parameters.
ii. Write a subroutine that determines the coefficients of the unknown matrix.
iii. Write another subroutine (which may contain a number of subroutines within itself) to solve a set of linear equations using Gauss elimination method. The subroutine must be able to handle ***any number of equations***.
iv. From the main program read in the initial estimates of the variables from an ***input file*** and perform Newton-Raphson method to find the roots of the set of non-linear equations. As a stopping rule you can end the program if,
   a. $\delta\theta_{13}$, $\delta\theta_{14}$, $\delta\theta_{15}$ and δs_{16} values are less than 10^{-5} radians or 10^{-4} mm.
   b. If the number of iterations is more than 100.

   Solution is θ_{13}=190.5125°, θ_{14}=182.795°, θ_{15}=69.400° and s_{16}=211.688 mm.

v. **EXTRA CREDIT** When the position of the links for a particular crank angle can be found, one can then increment the crank angle (by 5 degrees in counter-clockwise direction let us say). Now in this stage you can use your solution found in the previous step as a new initial guess value for the cranck angle incremented by 5 degrees. Thus the input cranck angle can be rotated for a whole cycle and the values of all position variables. Write a main program for the complete anaysis of the mechanism. **Plot your results!**

Homework Rules

You should present your own work during the course. Any unethical behaviour shall be penalized seriously.

You will post your homework in a zip file named as 'HW#-ID#.zip' to the address tuncero@itu.edu.tr

The zip file should include the necessary source codes and executables (m-files, FORTRAN codes, etc.)

Homework Format

Homework should consist of the following parts. Problem Definition and Discussion and Conclusion parts should be typed up using a word processor software. Neatness counts.

1. Cover Page (The cover page should state the name and ID number of the student clearly, cover page also needs to include the course name and homework number)

In addition, cover page must also include the following statement at the bottom;
"I have neither given nor received any unauthorized help for this assignment"

Your Signature

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2. Problem Definition
3. Results (In Numerical or Graphical Format)
4. Discussion
5. Appendix (Source Code, etc.)

Source code should include the necessary comments and results should be presented with at least 5 digits.