ROBOT SOFTWARE

COURSE 7944

MAY 5, 2009

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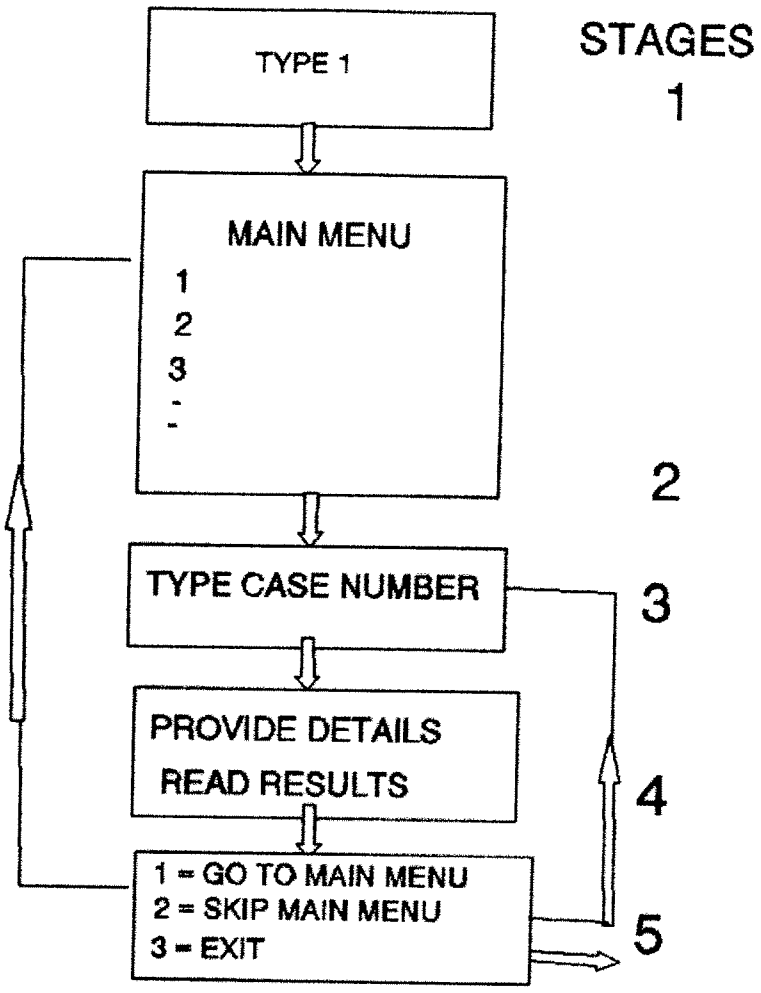

FIG . 1 THE FLOW CHART OF THE PROGRAM

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   ROBOTICS      SOFTWARE


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FOR DESCRIPTION OF VARIOUS TERMS USED IN THIS
                SOFTWARE
TYPE 1 ELSE TYPE ANY NUMBER
1
```

```
************************************************************
************************************************************
***************SELECT FROM THE MAIN MENU********************
************************************************************
************************************************************
ALL INPUT ANGLES IN DEGREES
CASE NUMBER
1= MULTIPLICATION OF A MATRIX AND A VECTOR
2= PRODUCTS OF THREE (4 X 4) EITHER ROTATION OR
   D-H MATRICES
3= INVERSE OF A [T] MATRIX (4 X4)
4= ADDITION OF TWO (N X N) MATRICES , N < 5
5= TRANSPOSE OF A (N x N) MATRIX , N < 5
6= ADDITION OF TWO VECTORS
7= DOT PRODUCT OF TWO VECTORS
8= CROSS PRODUCT OF TWO VECTORS
9= DYNAMICS PROBLEM
10 = GIVEN THETA AND FORMING ROTATION MATRIX
11 = GIVEN A MATRIX AND FINDING THETA
12= MULTIPLICATION OF TWO MATRICES
13= FORMING A [K] MATRIX
15=FORMING EULER ANGLE ROTATION MATRIX
16=GIVEN EULER [R] MATRIX & TO FIND EULER ANGLES
100 = STOP
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ROBOTICS SOFTWARE

MODEL CALCULATION

CASE NUMBER 1

1) MULTIPLICATION OF A MATRIX AND A VECTOR

INPUT PARAMETERS
THETA , AXIS (INTEGER) , PV-B (ORIGIN) AND THE VECTOR
30. 1 2. 1. 1. 3. 1. 2.
AXIS
1 { ROTATION ABOUT X-AXIS }

$$\begin{bmatrix} 1 & 0 & 0 & 2 \\ 0 & \cos 30^\circ & -\sin 30^\circ & 1 \\ 0 & \sin 30^\circ & \cos 30^\circ & 1 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 3 \\ 1 \\ 2 \\ 1 \end{bmatrix} = \begin{bmatrix} 5.0 \\ 0.866 \\ 3.232 \\ 1.0 \end{bmatrix}$$

CASE NUMBER 2

2) PRODUCTS OF THREE (4x4) EITHER ROTATION OR D-H MATRICES

USE 1 FOR ORDINARY 4x4 MATRICES
USE 2 FOR D-H MATRICES

TYPE ?
1
THETA VECTOR ?
30. 25. 40. { RESPECTIVELY FOR EACH ROTATION MATRICES }

AXIS VECTOR ?
2 3 1 { RESPECTIVELY THE AXIS OF ROTATION FOR EACH MATRICES }

(2)

POSITION VECTOR OF AXIS 2 IS ?
2. 1. 1.
POSITION VECTOR OF AXIS 3 IS ?
3. 0. 1.
POSITION VECTOR OF AXIS 1 IS ?
1. 2. 2.

$$\begin{bmatrix} \cos 30 & 0 & \sin 30 & 2 \\ 0 & 1 & 0 & 1 \\ -\sin 30 & 0 & \cos 30 & 1 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos 25 & -\sin 25 & 0 & 3 \\ \sin 25 & \cos 25 & 0 & 0 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 1 \\ 0 & \cos 40 & -\sin 40 & 2 \\ 0 & \sin 40 & \cos 40 & 2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} 0.784 & 0.0412 & 0.6182 & 6.1508 \\ 0.422 & 0.694 & -0.582 & 3.235 \\ -0.453 & 0.718 & 0.527 & 2.0668 \\ 0.0 & 0.0 & 0.0 & 1.00 \end{bmatrix}$$

→ TYPE ?
2
FIRST D-H MATRIX
ALPHA, a, d, THETADH
30. 2. 1. 40.
SECOND D-H MATRIX
25. 1. 2. 35.
THIRD D-H MATRIX
60. 2. 4. 10.

$$T_1 = \begin{bmatrix} 0.7658 & -0.6430 & 0.00 & 2.000 \\ 0.5567 & 0.6631 & -0.500 & -0.500 \\ 0.3216 & 0.3830 & 0.8659 & 0.8659 \\ 0.000 & 0.0 & 0.0 & 1.0 \end{bmatrix}$$

(3)

$$T_2 = \begin{bmatrix} 0.8190 & -0.5737 & 0.0000 & 1.0000 \\ 0.5199 & 0.7422 & -0.4227 & -0.8455 \\ 0.2425 & 0.3462 & 0.9062 & 1.8124 \\ 0.0 & 0.0 & 0.0 & 1.0 \end{bmatrix}$$

$$T_3 = \begin{bmatrix} 0.9847 & -0.1737 & 0.0000 & 2.000 \\ 0.0867 & 0.4920 & -0.8662 & -3.4649 \\ 0.1504 & 0.8662 & 0.5000 & 1.998 \\ 0.0 & 0.0 & 0.0 & 1.0 \end{bmatrix}$$

$T_1 * T_2 * T_3$

$$= \begin{bmatrix} 0.2498 & -0.2664 & 0.9298 & 7.6149 \\ 0.5587 & -0.7537 & -0.3661 & -1.5163 \\ 0.7908 & 0.6192 & -0.0350 & 3.6383 \\ 0.0 & 0.0 & 0.0 & 1.0 \end{bmatrix}$$

→ CASE #3

INVERSE OF A ROTATION MATRIX:

1. NON-STANDARD MATRIX BUT ORTHONORMAL
2. STANDARD MATRIX (ORTHONORMAL)

1. NON-STANDARD MATRIX

ENTER THE MATRIX ROW BY ROW?

0.933 0.067 0.354 −1.13
0.067 0.933 −0.354 1.13
−0.354 0.354 0.866 0.05
0.00 0.0 0.0 1.0

(4)

THE INVERSE OF THE MATRIX IS

0.933	0.067	-0.354	0.9962
0.067	0.933	0.354	-0.9962
0.354	-0.354	0.866	0.7567
0.0	0.0	0.0	1.0

2. STANDARD MATRIX

THETA?
25.
THE AXIS OF ROTATION?
3
POSITION VECTOR?
3. 0. 1.

THE INVERSE OF MATRIX IS

$$\begin{bmatrix} 0.9912 & -0.1323 & 0.000 & -2.9736 \\ 0.1323 & 0.9912 & 0 & -0.3970 \\ 0. & 0. & 1.0 & -1.0 \\ 0. & 0. & 0. & 1 \end{bmatrix}$$

→ CASE 4

ADDITION OF TWO (N×N) MATRICES, N<5
ENTER ROW BY ROW
ROW(M), COLUMN(N)
3 3
THE FIRST MATRIX?
1 ROW
3. 2. 4
4. 3. 1.
2. 1. 0.

(5)

THE SECOND MATRIX ?

$$\begin{bmatrix} 3. & 1. & 0. \\ 2. & 2. & 4. \\ 0. & 5. & 1. \end{bmatrix}$$

RESULTANT MATRIX

$$\begin{bmatrix} 6. & 3. & 4. \\ 6. & 5. & 5. \\ 2. & 6. & 1. \end{bmatrix}$$

→ CASE 5:

TRANSPOSE OF A N x N MATRIX

THE ORDER OF MATRIX M x N

ENTER ROW BY ROW

ROW(M), COLUMN(N)

3 3

1 ROW

$$\begin{bmatrix} 4. & 3 & 2 \\ 1. & 0. & 0. \\ 5. & 6. & 1. \end{bmatrix}$$

TRANSPOSE OF A MATRIX

$$\begin{bmatrix} 4. & 1. & 5. \\ 3. & 0. & 6. \\ 2. & 0. & 1. \end{bmatrix}$$

→ CASE 6:

ADDITION OF TWO VECTORS

VECTOR NO 1 ?

2. 3. 4.

VECTOR NO 2 ?

1. 4. 7.

RESULTANT VECTOR IS

3. 7. 11.

(6)

→ CASE 7:

DOT PRODUCT OF TWO VECTORS ?
VECTOR NO 1 ?
2. 3. 4.
VECTOR NO 2 ?
1. 4. 7.
DOT PRODUCT
42.00

→ CASE 8:

CROSS PRODUCT OF TWO VECTORS
VECTOR NO 1 ?
2. 3. 4.
VECTOR NO 2 ?
1. 4. 7

$$\begin{vmatrix} i & j & k \\ 2 & 3 & 4 \\ 1 & 4 & 7 \end{vmatrix} = i(21-16) + j(4-14) + k(8-3)$$
$$\therefore 5i + j(-10) + k(5)$$

CROSS PRODUCT OF VECTORS :
5. -10. +5.

→ CASE 10:

GIVEN THETA AND FORMING ROTATION MATRIX
THETA ?
30.
AXIS OF ROTATION ?
1
ENTER THE POSITION VECTOR
2. 1. 3.

(7)

THE ROTATION MATRIX IS:

$$\begin{bmatrix} 1 & 0. & 0 & 2. \\ 0 & \cos 30 & -\sin 30 & 1. \\ 0 & \sin 30 & \cos 30 & 3. \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} 1.0 & 0.0 & 0.0 & 2.0 \\ 0.0 & 0.866 & -0.5 & 1.0 \\ 0.0 & 0.5 & 0.866 & 3.0 \\ 0.0 & 0.0 & 0.0 & 1.0 \end{bmatrix}$$

→ CASE II:

BEFORE PROCEEDING IDENTIFY THE MATRIX

1: ROTATION ABOUT X-AXIS?

2: ROTATION ABOUT Y-AXIS?

3: ROTATION ABOUT Z-AXIS?

ENTER THE AXIS OF ROTATION

1

ENTER MATRIX(3,2)

0.5

ENTER MATRIX(2,2)

0.866

THETA IS 29.98860:

→ CASE 12:

MULTIPLICATION OF TWO MATRICES?

ENTER NO OF ROWS OF I MATRIX

3

ENTER NO OF COLUMNS/ROWS OF II MATRIX

3

ENTER NO OF COLUMNS OF II MATRIX

3

(3)

ENTER FIRST MATRIX ROW BY ROW?
3. 4. 2.
1. 2. 3.
3. 1. 1.
ENTER SECOND MATRIX ROW BY ROW?
4. 1. 2.
3. 2. 2
1. 2. 4.
PRODUCT IS:

$$\begin{bmatrix} 26.000 & 15.000 & 22.00 \\ 13.000 & 11.000 & 18.00 \\ 16.00 & 7.00 & 12.00 \end{bmatrix}$$

→ CASE 9: DYNAMICS
RECURSIVE NEWTON-EULER ALGORITHM

IS JOINT TRANSLATIONAL OR ROTATIONAL?
TYPE 1 FOR TRANSLATIONAL
TYPE 2 FOR ROTATIONAL
2
THE JOINT IS ROTATIONAL
STEP 1:
TYPE ROTATIONAL MATRIX [R] NOT ITS TRANSPOSE
ENTER THE MATRIX (3x3) ROW BY ROW:
FIRST ROW?
0.866 −0.5 0.0
0.5 0.866 0.0
0.0 0.0 1.0
ENTER OMEGA[I-1] VECTOR?
0. 0. 0.
ENTER QDOTDOT (SCALAR)
3.0

(9)

ENTER QDOT (SCALAR)
2.0
ANGULAR VELOCITY OMEGA[I] IS
0.0 0.0 2.0

STEP 2:

ENTER ALPHA[I-1] VECTOR?
0. 0. 0.
ANGULAR ACCELERATION ALPHA[I] IS
0.0 0.0 3.00

STEP 3:

ENTER A[I-1] VECTOR?
0. 9.81 0.
ENTER P[I-1] VECTOR?
0. 0. 0.
THE A[I] VECTOR?
4.905 8.4954 0.0

STEP 4:

ENTER SI[I] VECTOR?
1. 0. 0.
THE AC[I] VECTOR IS
0.905 11.495 0.00

STEP 5:

ENTER MABS M?
2.0

(10)

THE FORCE VECTOR IS ?
1.81 22.99 0.0

STEP 6
ENTER I MATRIX (3x3) ROW BY ROW ?
FIRST ROW ?
0. 0. 0.
0. 0. 0.
0. 0. 0.

THE TORQUE VECTOR IS
0. 0. 0.

ENTER
1=CONTINUE
2=OVER
2
THE FORWARD ITERATION IS OVER
BACKWARD ITERATION STARTS HERE

STEP 7:
ENTER [R] MATRIX FOR I TO I+1 ?
ENTER 1 ROW ?
0.707 -0.707 0.0
0.707 0.707 0.0
0.0 0.0 1.0
ENTER VECTOR fo[I+1] ?
0.0 0.0 0.0
ENTER VECTOR f OF LINK I ?
-105.97 81.708 0.0
f VECTOR OF LINK I
-105.97 81.708 0.0

(11)

STEP 8

ENTER N(I) VECTOR?
0. 0. 0.
ENTER n(I+1) VECTOR?
0. 0. 0
ENTER S(I) VECTOR?
1.5 0. 0. 0.0
ENTER P(I) VECTOR
30 0.0 0.0
n(I) VECTOR IS?
0.0 0 0 122.566

CASE 10

```
13= FORMING A [K] MATRIX
15=FORMING EULER ANGLE ROTATION MATRIX
16=GIVEN EULER [R] MATRIX & TO FIND EULER ANGLES
100 = STOP
10 → CASE NUMBER
 GIVEN THETA AND TO FIND ROTATION MATRIX


ENTER THETA ?
30
ENTER THE AXIS OF ROTATION ?
3

ENTER THE POSITION VECTOR ?
1  2  1
 THE ROTATION MATRIX IS
   8.659200E-01   -5.001825E-01    0.000000E+00          1.000000
   5.001825E-01    8.659200E-01    0.000000E+00          2.000000
   0.000000E+00    0.000000E+00        1.000000          1.000000
   0.000000E+00    0.000000E+00    0.000000E+00          1.000000

1= TO GO TO MAIN MENU
2= TO SKIP MAIN MENU
3= TO EXIT FROM THE PROGRAM
```

CASE 11

13

```
 1= TO GO TO MAIN MENU
 2= TO SKIP MAIN MENU
 3= TO EXIT FROM THE PROGRAM
 2
 TYPE CASE NUMBER=
 11
  BEFORE PROCEEDING IDENTIFY THE MATRIX
  1: ROTATION ABOUT X-AXIS
  2: ROTATION ABOUT Y-AXIS
  3: ROTATION ABOUT Z-AXIS
  ENTER THE AXIS OF ROTATION ?
 3
  ENTER MATRIX(2,1)
 5.001825E-01
  ENTER MATRIX(1,1)
 8.659200E-01
  THETA IS :        30.000000

 1= TO GO TO MAIN MENU
 2= TO SKIP MAIN MENU
 3= TO EXIT FROM THE PROGRAM
```

14

{ CASE 12

CASE 12

ENTER THE NUMBER OF ROWS OF I MATRIX

4

ENTER THE NUMBER OF COLUMNS/ROWS OF II MATRIX

4

ENTER THE NUMBER OF COLUMNS OF II MATRIX

2

ENTER THE FIRST MATRIX ROW BY ROW

1 4 3 2
7 6 5 1
2 6 3 1
1 4 2 7

ENTER THE SECOND MATRIX ROW BY ROW

2 4
3 6
7 9
8 1

PRODUCT IS

51 57
75 110
51 72
84 53

1 TO GO TO MAIN MENU
2 TO SKIP MAIN MENU
3 TO EXIT FROM THE PROGRAM

```
        71.000000        69.000000
        78.000000        27.000000

 1= TO GO TO MAIN MENU
 2= TO SKIP MAIN MENU
 3= TO EXIT FROM THE PROGRAM
 2
 TYPE CASE NUMBER=
 13
  ENTER ROTATION ANGLE ?
 40
  ENTER K VECTOR ?
 .6 .7 .1
  ENTER POSITION VECTOR ?
 1 2 1
  THE [K] MATRIX IS :
    8.501529E-01    3.403693E-02    4.641502E-01         1.000000
    1.626375E-01    8.805905E-01   -3.694122E-01         2.000000
   -4.360538E-01    4.021913E-01    7.682052E-01         1.000000
    0.000000E+00    0.000000E+00    0.000000E+00         1.000000

 1= TO GO TO MAIN MENU
 2= TO SKIP MAIN MENU
 3= TO EXIT FROM THE PROGRAM
```

CASE 15


```
 2
(TYPE CASE NUMBER=
(15

1: X-Y-Z   ?
ENTER EULER ANGLES ?
GAMMA - ABOUT X-AXIS
BETA  - ABOUT Y-AXIS
ALPHA - ABOUT Z-AXIS
GAMMA ?
30
BETA  ?
40
ALPHA ?
70
ROTATION MATRIX IS

   2.615869E-01   -7.039927E-01    6.602776E-01
   7.198052E-01    5.980387E-01    3.524628E-01
  -6.430029E-01    3.830717E-01    6.631768E-01

1= TO GO TO MAIN MENU
2= TO SKIP MAIN MENU
3= TO EXIT FROM THE PROGRAM
```

CASE 16

(17)

```
   -6.430029E-01     3.830717E-01     6.631768E-01

 1= TO GO TO MAIN MENU
 2= TO SKIP MAIN MENU
 3= TO EXIT FROM THE PROGRAM
 2
 TYPE CASE NUMBER=
 16
 ENTER THE EULER ROTATION MATRIX (3X3) ?
 2.615869E-01  -7.039927E-01  6.602776E-01
 7.198052E-01  5.980387E-01  3.524628E-01
 -6.430029E-01  3.830717E-01  6.631768E-01
 EULER ANGLES ARE :
 GAMMA - ABOUT X-AXIS
 BETA  - ABOUT Y-AXIS
 ALPHA - ABOUT Z-AXIS

 GAMMA =        30.000000
 BETA  =        40.000010
 ALPHA =        69.999990

 1= TO GO TO MAIN MENU
 2= TO SKIP MAIN MENU
 3= TO EXIT FROM THE PROGRAM
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THEORY OF MACHINES (TM.EXE) SOFTWARE

COURSE 7944

MAY 5, 2009

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CASE NO. 18 (2 OR 3 UNKNOWNS → K = 2, OR 3)

SOLUTION OF $[A]\{x\} = \{B\}$

NUMBER OF EQUATIONS ?

2

A11, A12, A21, A22, B1, B2 ?

1 1 2 4 4 14

DATA ENTERED FOR EQUATIONS

SOLUTION OF $[A]\{x\} = \{B\}$

X1 = 1.00

X2 = 3.00

$$\left.\begin{aligned} x_1 + x_2 &= 4 \\ 2x_1 + 4x_2 &= 14 \end{aligned}\right\} \quad -I$$

CAN BE WRITTEN AS

$$[A]\{x\} = \{B\}$$

$$\begin{bmatrix} 1 & 1 \\ 2 & 4 \end{bmatrix} \begin{Bmatrix} x_1 \\ x_2 \end{Bmatrix} = \begin{Bmatrix} 4 \\ 14 \end{Bmatrix}$$

$x_1 = 1$; $x_2 = 3$ SATISFIES THE EQUATIONS