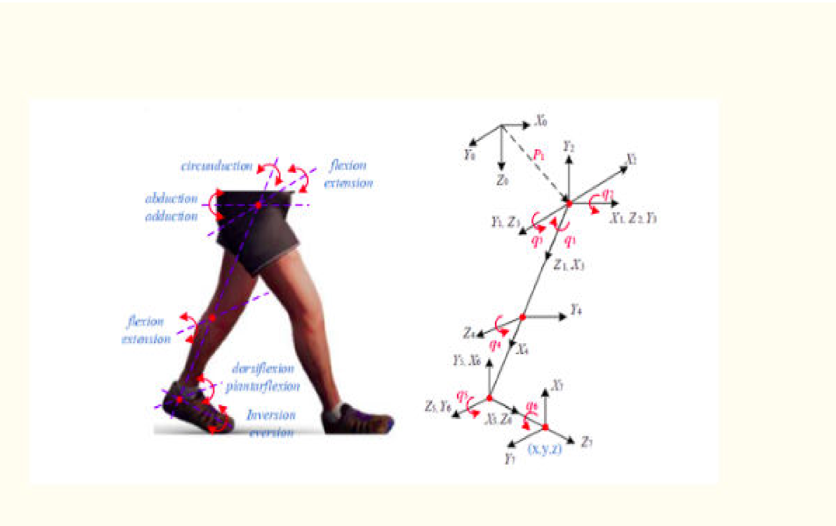
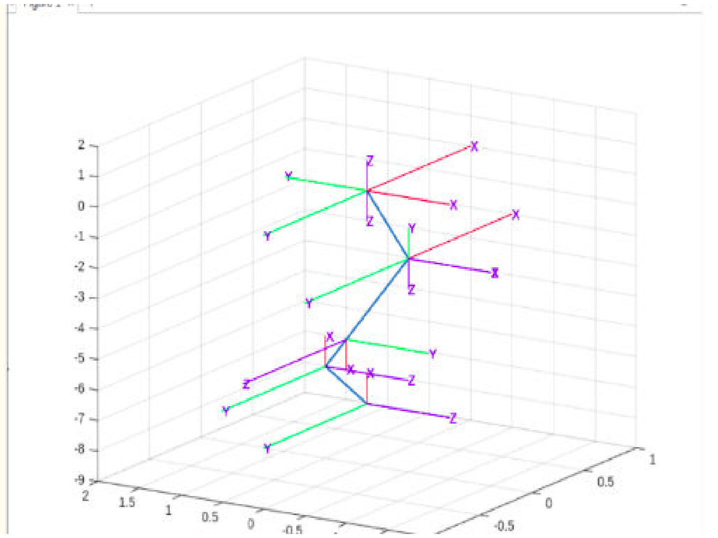
Presentación Final: Ejercicio 2

En esta actividad final se obtiene la matriz de transformación T empleando variables simbólicas y de esta manera obtener la cinemática diferencial con la velocidad lineal y angular. El sistema que se analizará es el siguiente modelo de piernas robóticas:





```
%Limpieza de pantalla
clear all
close all
clc

%Declaración de variables simbólicas
syms th1(t) th2(t) th3(t) th4(t) th5(t) th6(t) th7(t) th8(t) %Angulos de
syms t
% cada articulación
syms th1p(t)  th2p(t) th3p(t) th4p(t) th5p(t) th6p(t) th7p(t) th8p(t)
%Velocidades
% de cada articulación
syms a0 a1 a2 a3 a4 a5 a6 a7 a8 %longitudes

%Configuración del robot
RP=[0 0 0 0 0 0];

Q= [th1; th2; th3; th4; th5; th6 ;th7; th8];
%disp('Coordenadas generalizadas');
pretty (Q);
```

```
/ th1(t) \
|        |
| th2(t) |
|        |
| th3(t) |
|        |
```

```
| th4(t) |
|        |
| th5(t) |
|        |
| th6(t) |
|        |
| th7(t) |
|        |
\ th8(t) /
```

```
%Creamos el vector de velocidades generalizadas
%Qp= diff(Q, t);
Qp=[th1p; th2p; th3p; th4p; th5p; th6p; th7p; th8p];
%disp('Velocidades generalizadas');
pretty (Qp);
```

```
/ th1p(t) \
|         |
| th2p(t) |
|         |
| th3p(t) |
|         |
| th4p(t) |
|         |
| th5p(t) |
|         |
| th6p(t) |
|         |
| th7p(t) |
|         |
\ th8p(t) /
```

```
%Número de grado de libertad del robot
GDL= size(RP,2);
GDL_str= num2str(GDL);

%H1
%Posición de la articulación 1
P(:,:,1)= [a0;a0;a0];
%Matriz de rotación de la junta 1.
R(:,:,1)= [(cos(th1+th2)+cos(th1-th2))/2  (-sin(th1+th2)+sin(th1-th2))/2
sin(th1);
           sin(th2)  cos(th2)  0;
           (-sin(th1+th2)-sin(th1-th2))/2  (-cos(th1+th2)+cos(th1-th2))/2
cos(th1)];

%H2
%Posición de la articulación 2
P(:,:,2)= [a1; 0; a2];
%Matriz de rotación de la junta 2  NO HAY ROTACIÓN
R(:,:,2)= [1 0 0;
           0 1 0;
           0 0 1];
```

```
%H3
%Posición de la articulación 3
P(:,:,3)= [0; 0; 0];
%Matriz de rotación de la junta 3
R(:,:,3)=   [cos(th3) (-cos(th3+th4)+cos(th3-th4))/2  (sin(th3+th4)+sin(th3-
th4))/2;
              0  cos(th4)  -sin(th4);
            -sin(th3)    (sin(th3+th4)-sin(th3-th4))/2
(cos(th3+th4)+cos(th3-th4))/2];

%H4
%Posición de la articulación 4
P(:,:,4)= [0; a3; a4];
%Matriz de rotación de la junta 4
R(:,:,4)=   [cos(th5) (-sin(th5+th6)-sin(th5-th6))/2  (-cos(th5+th6)+cos(th5-
th6))/2;
             sin(th5)  (cos(th5+th6)+cos(th5-th6))/2  (-sin(th5+th6)+sin(th5-
th6))/2;
              0         sin(th6)        cos(th6)];

%H5
%Posición de la articulación 5
P(:,:,5)= [a5; a6; 0];
%Matriz de rotación de la junta 5
R(:,:,5)=   [cos(th7) (-sin(th7+th8)-sin(th7-th8))/2  (-cos(th7+th8)+cos(th7-
th8))/2;
             sin(th7)  (cos(th7+th8)+cos(th7-th8))/2  (-sin(th7+th8)+sin(th7-
th8))/2;
              0         sin(th8)        cos(th8)];

%H6
%Posición de la articulación 6
P(:,:,6)= [a7; 0; a8];
%Matriz de rotación de la junta 6 NO HAY ROTACIÓN
R(:,:,6)= [1 0 0;
           0 1 0;
           0 0 1];


%Creamos un vector de ceros
Vector_Zeros= zeros(1, 3);

%Inicializamos las matrices de transformación Homogénea locales
A(:,:,GDL)=simplify([R(:,:,GDL) P(:,:,GDL); Vector_Zeros 1]);
%Inicializamos las matrices de transformación Homogénea globales
T(:,:,GDL)=simplify([R(:,:,GDL) P(:,:,GDL); Vector_Zeros 1]);
%Inicializamos las posiciones vistas desde el marco de referencia inercial
PO(:,:,GDL)= P(:,:,GDL);
%Inicializamos las matrices de rotación vistas desde el marco de referencia
inercial
```

```
RO(:,:,GDL)= R(:,:,GDL);


for i = 1:GDL
    i_str= num2str(i);
   %disp(strcat('Matriz de Transformación local A', i_str));
    A(:,:,i)=simplify([R(:,:,i) P(:,:,i); Vector_Zeros 1]);
   %pretty (A(:,:,i));

   %Globales
    try
       T(:,:,i)= T(:,:,i-1)*A(:,:,i);
    catch
       T(:,:,i)= A(:,:,i);
    end
    disp(strcat('Matriz de Transformación global T', i_str));
    T(:,:,i)= simplify(T(:,:,i));
    pretty(T(:,:,i))

    RO(:,:,i)= T(1:3,1:3,i);
    PO(:,:,i)= T(1:3,4,i);
    %pretty(RO(:,:,i));
    %pretty(PO(:,:,i));
end
```

```
Matriz de Transformación global T1
/  cos(th1(t)) cos(th2(t)), -cos(th1(t)) sin(th2(t)), sin(th1(t)), a0 \
|                                                                     |
|        sin(th2(t)),              cos(th2(t)),            0,      a0 |
|                                                                     |
| -cos(th2(t)) sin(th1(t)),  sin(th1(t)) sin(th2(t)), cos(th1(t)), a0 |
|                                                                     |
\             0,                          0,                 0,       1 /
Matriz de Transformación global T2
/  cos(th1(t)) cos(th2(t)), -cos(th1(t)) sin(th2(t)), sin(th1(t)), a0 + a2 sin(th1(t)) + a1 cos(th1(t)) co
|
|        sin(th2(t)),              cos(th2(t)),            0,                    a0 + a1 sin(th2(t))
|
| -cos(th2(t)) sin(th1(t)),  sin(th1(t)) sin(th2(t)), cos(th1(t)), a0 + a2 cos(th1(t)) - a1 cos(th2(t)) si
|
\             0,                          0,                 0,                              1
Matriz de Transformación global T3
/  cos(th1(t)) cos(th2(t)) cos(th3(t)) - sin(th1(t)) sin(th3(t)),  cos(th3(t)) sin(th1(t)) sin(th4(t)) - c
|
|                     cos(th3(t)) sin(th2(t)),                                                     cos(th2(
|
| - cos(th1(t)) sin(th3(t)) - cos(th2(t)) cos(th3(t)) sin(th1(t)), cos(th1(t)) cos(th3(t)) sin(th4(t)) + c
|
\                                 0,
Matriz de Transformación global T4
/            sin(th5(t)) #2 - cos(th5(t)) #7,                       sin(th6(t)) #5 + cos(th5(t)) cos(th6(t)
|
| sin(th5(t)) #3 + cos(th3(t)) cos(th5(t)) sin(th2(t)), cos(th5(t)) cos(th6(t)) #3 - sin(th6(t)) #6 - cos(
|
|            sin(th5(t)) #1 - cos(th5(t)) #8,                       cos(th6(t)) sin(th5(t)) #8 - sin(th6(t)
|
\                            0,                                                                        0,
```

```
where

   #1 == cos(th1(t)) cos(th3(t)) sin(th4(t)) + cos(th4(t)) sin(th1(t)) sin(th2(t)) - cos(th2(t)) sin(th1(t

   #2 == cos(th3(t)) sin(th1(t)) sin(th4(t)) - cos(th1(t)) cos(th4(t)) sin(th2(t)) + cos(th1(t)) cos(th2(t

   #3 == cos(th2(t)) cos(th4(t)) + sin(th2(t)) sin(th3(t)) sin(th4(t))

   #4 == sin(th1(t)) sin(th2(t)) sin(th4(t)) - cos(th1(t)) cos(th3(t)) cos(th4(t)) + cos(th2(t)) cos(th4(t

   #5 == cos(th3(t)) cos(th4(t)) sin(th1(t)) + cos(th1(t)) sin(th2(t)) sin(th4(t)) + cos(th1(t)) cos(th2(t

   #6 == cos(th2(t)) sin(th4(t)) - cos(th4(t)) sin(th2(t)) sin(th3(t))

   #7 == sin(th1(t)) sin(th3(t)) - cos(th1(t)) cos(th2(t)) cos(th3(t))

   #8 == cos(th1(t)) sin(th3(t)) + cos(th2(t)) cos(th3(t)) sin(th1(t))
Matriz de Transformación global T5
/ sin(th7(t)) #2 - cos(th7(t)) #5,  cos(th7(t)) cos(th8(t)) #2 - sin(th8(t)) #7 + cos(th8(t)) sin(th7(t))
|
| cos(th7(t)) #8 - sin(th7(t)) #3, - sin(th8(t)) #9 - cos(th8(t)) sin(th7(t)) #8 - cos(th7(t)) cos(th8(t))
|
| sin(th7(t)) #1 - cos(th7(t)) #4,  cos(th8(t)) sin(th7(t)) #4 - sin(th8(t)) #6 + cos(th7(t)) cos(th8(t))
|
\                0,                                                      0,

where

   #1 == cos(th6(t)) sin(th5(t)) #12 - sin(th6(t)) #11 + cos(th5(t)) cos(th6(t)) #10

   #2 == sin(th6(t)) #14 + cos(th5(t)) cos(th6(t)) #13 + cos(th6(t)) sin(th5(t)) #15

   #3 == sin(th6(t)) #17 - cos(th5(t)) cos(th6(t)) #16 + cos(th3(t)) cos(th6(t)) sin(th2(t)) sin(th5(t))

   #4 == cos(th5(t)) #12 - sin(th5(t)) #10

   #5 == cos(th5(t)) #15 - sin(th5(t)) #13

   #6 == cos(th6(t)) #11 + sin(th5(t)) sin(th6(t)) #12 + cos(th5(t)) sin(th6(t)) #10

   #7 == cos(th5(t)) sin(th6(t)) #13 - cos(th6(t)) #14 + sin(th5(t)) sin(th6(t)) #15

   #8 == sin(th5(t)) #16 + cos(th3(t)) cos(th5(t)) sin(th2(t))

   #9 == cos(th6(t)) #17 + cos(th5(t)) sin(th6(t)) #16 - cos(th3(t)) sin(th2(t)) sin(th5(t)) sin(th6(t))

   #10 == cos(th1(t)) cos(th3(t)) sin(th4(t)) + cos(th4(t)) sin(th1(t)) sin(th2(t)) - cos(th2(t)) sin(th1(

   #11 == sin(th1(t)) sin(th2(t)) sin(th4(t)) - cos(th1(t)) cos(th3(t)) cos(th4(t)) + cos(th2(t)) cos(th4(

   #12 == cos(th1(t)) sin(th3(t)) + cos(th2(t)) cos(th3(t)) sin(th1(t))

   #13 == cos(th3(t)) sin(th1(t)) sin(th4(t)) - cos(th1(t)) cos(th4(t)) sin(th2(t)) + cos(th1(t)) cos(th2(

   #14 == cos(th3(t)) cos(th4(t)) sin(th1(t)) + cos(th1(t)) sin(th2(t)) sin(th4(t)) + cos(th1(t)) cos(th2(

   #15 == sin(th1(t)) sin(th3(t)) - cos(th1(t)) cos(th2(t)) cos(th3(t))

   #16 == cos(th2(t)) cos(th4(t)) + sin(th2(t)) sin(th3(t)) sin(th4(t))

   #17 == cos(th2(t)) sin(th4(t)) - cos(th4(t)) sin(th2(t)) sin(th3(t))
Matriz de Transformación global T6
```

```
/ sin(th7(t)) #2 - cos(th7(t)) #5,    cos(th7(t)) cos(th8(t)) #2 - sin(th8(t)) #7 + cos(th8(t)) sin(th7(t)
|
|             #9 - #8,             - sin(th8(t)) #10 - cos(th8(t)) sin(th7(t)) #18 - cos(th7(t)) cos(th8(t
|
| sin(th7(t)) #1 - cos(th7(t)) #4,    cos(th8(t)) sin(th7(t)) #4 - sin(th8(t)) #6 + cos(th7(t)) cos(th8(t)
|
\                0,                                                        0,

where

   #1 == cos(th6(t)) sin(th5(t)) #13 - sin(th6(t)) #12 + cos(th5(t)) cos(th6(t)) #11

   #2 == sin(th6(t)) #15 + cos(th5(t)) cos(th6(t)) #14 + cos(th6(t)) sin(th5(t)) #16

   #3 == sin(th7(t)) sin(th8(t)) #18 - cos(th8(t)) #10 + cos(th7(t)) sin(th8(t)) #17

   #4 == cos(th5(t)) #13 - sin(th5(t)) #11

   #5 == cos(th5(t)) #16 - sin(th5(t)) #14

   #6 == cos(th6(t)) #12 + sin(th5(t)) sin(th6(t)) #13 + cos(th5(t)) sin(th6(t)) #11

   #7 == cos(th5(t)) sin(th6(t)) #14 - cos(th6(t)) #15 + sin(th5(t)) sin(th6(t)) #16

   #8 == sin(th7(t)) #17

   #9 == cos(th7(t)) #18

   #10 == cos(th6(t)) #19 + cos(th5(t)) sin(th6(t)) #20 - cos(th3(t)) sin(th2(t)) sin(th5(t)) sin(th6(t))

   #11 == cos(th1(t)) cos(th3(t)) sin(th4(t)) + cos(th4(t)) sin(th1(t)) sin(th2(t)) - cos(th2(t)) sin(th1(

   #12 == sin(th1(t)) sin(th2(t)) sin(th4(t)) - cos(th1(t)) cos(th3(t)) cos(th4(t)) + cos(th2(t)) cos(th4(

   #13 == cos(th1(t)) sin(th3(t)) + cos(th2(t)) cos(th3(t)) sin(th1(t))

   #14 == cos(th3(t)) sin(th1(t)) sin(th4(t)) - cos(th1(t)) cos(th4(t)) sin(th2(t)) + cos(th1(t)) cos(th2(

   #15 == cos(th3(t)) cos(th4(t)) sin(th1(t)) + cos(th1(t)) sin(th2(t)) sin(th4(t)) + cos(th1(t)) cos(th2(

   #16 == sin(th1(t)) sin(th3(t)) - cos(th1(t)) cos(th2(t)) cos(th3(t))

   #17 == sin(th6(t)) #19 - cos(th5(t)) cos(th6(t)) #20 + cos(th3(t)) cos(th6(t)) sin(th2(t)) sin(th5(t))

   #18 == sin(th5(t)) #20 + cos(th3(t)) cos(th5(t)) sin(th2(t))

   #19 == cos(th2(t)) sin(th4(t)) - cos(th4(t)) sin(th2(t)) sin(th3(t))

   #20 == cos(th2(t)) cos(th4(t)) + sin(th2(t)) sin(th3(t)) sin(th4(t))
```

```
% %Calculamos el jacobiano lineal de forma diferencial
% %disp('Jacobiano lineal obtenido de forma diferencial');
% %Derivadas parciales de x respecto a th1 y th2
% Jv11= functionalDerivative(PO(1,1,GDL), th1);
% Jv12= functionalDerivative(PO(1,1,GDL), th2);
% Jv13= functionalDerivative(PO(1,1,GDL), th3);
% %Derivadas parciales de y respecto a th1 y th2
% Jv21= functionalDerivative(PO(2,1,GDL), th1);
% Jv22= functionalDerivative(PO(2,1,GDL), th2);
% Jv23= functionalDerivative(PO(2,1,GDL), th3);
% %Derivadas parciales de z respecto a th1 y th2
```

```
% Jv31= functionalDerivative(PO(3,1,GDL), th1);
% Jv32= functionalDerivative(PO(3,1,GDL), th2);
% Jv33= functionalDerivative(PO(3,1,GDL), th3);
%
% %Creamos la matríz del Jacobiano lineal
% jv_d=simplify([Jv11 Jv12 Jv13;
%               Jv21 Jv22 Jv23;
%               Jv31 Jv32 Jv33]);
% %pretty(jv_d);

%Calculamos el jacobiano lineal de forma analítica
Jv_a(:,GDL)=PO(:,:,GDL);
Jw_a(:,GDL)=PO(:,:,GDL);

for k= 1:GDL
    if RP(k)==0
       %Para las juntas de revolución
        try
            Jv_a(:,k)= cross(RO(:,3,k-1), PO(:,:,GDL)-PO(:,:,k-1));
            Jw_a(:,k)= RO(:,3,k-1);
        catch
            Jv_a(:,k)= cross([0,0,1], PO(:,:,GDL));%Matriz de rotación de 0
            % con respecto a 0 es la Matriz Identidad, la posición previa
tambien será 0
            Jw_a(:,k)=[0,0,1];%Si no hay matriz de rotación previa se
obtiene la Matriz identidad
         end
     else
%         %Para las juntas prismáticas
        try
            Jv_a(:,k)= RO(:,3,k-1);
        catch
            Jv_a(:,k)=[0,0,1];
        end
            Jw_a(:,k)=[0,0,0];
     end
 end

Jv_a= simplify (Jv_a);
Jw_a= simplify (Jw_a);
%disp('Jacobiano lineal obtenido de forma analítica');
%pretty (Jv_a);
%disp('Jacobiano ángular obtenido de forma analítica');
%pretty (Jw_a);

Q_p = sym('Qp', [1, length(Q)]);
%disp('Velocidad lineal obtenida mediante el Jacobiano lineal');
V=simplify (Jv_a*Q_p');

pretty(V);
```

```
/
|
|
| ___
| Qp1 (a0 + a2 sin(th1(t)) + a1 cos(th1(t)) cos(th2(t)) - #129 + #128 + #125 + #124 - #74 + #115 - #79 + #
|
|
\

where

   #1 == a8 cos(th1(t)) cos(th2(t)) cos(th5(t)) cos(th6(t)) cos(th7(t)) sin(th3(t)) sin(th4(t)) sin(th8(t)

   #2 == a8 cos(th1(t)) cos(th2(t)) sin(th3(t)) sin(th4(t)) sin(th5(t)) sin(th7(t)) sin(th8(t))

   #3 == a8 cos(th3(t)) cos(th5(t)) cos(th6(t)) cos(th7(t)) sin(th1(t)) sin(th4(t)) sin(th8(t))

   #4 == a8 cos(th1(t)) cos(th2(t)) cos(th4(t)) cos(th7(t)) sin(th3(t)) sin(th6(t)) sin(th8(t))

   #5 == a8 cos(th1(t)) cos(th2(t)) cos(th5(t)) cos(th8(t)) sin(th3(t)) sin(th4(t)) sin(th6(t))

   #6 == a7 cos(th1(t)) cos(th2(t)) cos(th5(t)) cos(th6(t)) sin(th3(t)) sin(th4(t)) sin(th7(t))

   #7 == a8 cos(th1(t)) cos(th4(t)) cos(th5(t)) cos(th6(t)) cos(th7(t)) sin(th2(t)) sin(th8(t))

   #8 == a8 cos(th1(t)) cos(th2(t)) cos(th3(t)) cos(th6(t)) cos(th7(t)) sin(th5(t)) sin(th8(t))

   #9 == a8 cos(th2(t)) sin(th1(t)) sin(th3(t)) sin(th4(t)) sin(th5(t)) sin(th7(t)) sin(th8(t))

   #10 == a8 cos(th2(t)) cos(th4(t)) cos(th7(t)) sin(th1(t)) sin(th3(t)) sin(th6(t)) sin(th8(t))

   #11 == a8 cos(th2(t)) cos(th5(t)) cos(th8(t)) sin(th1(t)) sin(th3(t)) sin(th4(t)) sin(th6(t))

   #12 == a7 cos(th2(t)) cos(th5(t)) cos(th6(t)) sin(th1(t)) sin(th3(t)) sin(th4(t)) sin(th7(t))

   #13 == a8 cos(th4(t)) cos(th5(t)) cos(th6(t)) cos(th7(t)) sin(th1(t)) sin(th2(t)) sin(th8(t))

   #14 == a8 cos(th2(t)) cos(th3(t)) cos(th6(t)) cos(th7(t)) sin(th1(t)) sin(th5(t)) sin(th8(t))

   #15 == a8 cos(th1(t)) cos(th3(t)) cos(th5(t)) cos(th6(t)) cos(th7(t)) sin(th4(t)) sin(th8(t))

   #16 == a8 cos(th2(t)) cos(th5(t)) cos(th6(t)) cos(th7(t)) sin(th1(t)) sin(th3(t)) sin(th4(t)) sin(th8(t

   #17 == a8 cos(th3(t)) sin(th1(t)) sin(th4(t)) sin(th5(t)) sin(th7(t)) sin(th8(t))

   #18 == a8 cos(th6(t)) cos(th7(t)) sin(th1(t)) sin(th3(t)) sin(th5(t)) sin(th8(t))

   #19 == a8 cos(th1(t)) cos(th7(t)) sin(th2(t)) sin(th4(t)) sin(th6(t)) sin(th8(t))

   #20 == a8 cos(th1(t)) cos(th4(t)) sin(th2(t)) sin(th5(t)) sin(th7(t)) sin(th8(t))

   #21 == a8 cos(th3(t)) cos(th4(t)) cos(th7(t)) sin(th1(t)) sin(th6(t)) sin(th8(t))

   #22 == a8 cos(th3(t)) cos(th5(t)) cos(th8(t)) sin(th1(t)) sin(th4(t)) sin(th6(t))

   #23 == a7 cos(th3(t)) cos(th5(t)) cos(th6(t)) sin(th1(t)) sin(th4(t)) sin(th7(t))

   #24 == a7 cos(th1(t)) cos(th2(t)) cos(th4(t)) sin(th3(t)) sin(th6(t)) sin(th7(t))

   #25 == a7 cos(th1(t)) cos(th2(t)) cos(th7(t)) sin(th3(t)) sin(th4(t)) sin(th5(t))

   #26 == a8 cos(th1(t)) cos(th4(t)) cos(th5(t)) cos(th8(t)) sin(th2(t)) sin(th6(t))

   #27 == a8 cos(th1(t)) cos(th2(t)) cos(th3(t)) cos(th5(t)) sin(th7(t)) sin(th8(t))
```

```
#28 == a8 cos(th1(t)) cos(th2(t)) cos(th3(t)) cos(th8(t)) sin(th5(t)) sin(th6(t))

#29 == a7 cos(th1(t)) cos(th4(t)) cos(th5(t)) cos(th6(t)) sin(th2(t)) sin(th7(t))

#30 == a7 cos(th1(t)) cos(th2(t)) cos(th3(t)) cos(th6(t)) sin(th5(t)) sin(th7(t))

#31 == a8 cos(th1(t)) cos(th2(t)) cos(th4(t)) cos(th6(t)) cos(th8(t)) sin(th3(t))

#32 == a8 cos(th5(t)) sin(th1(t)) sin(th3(t)) sin(th7(t)) sin(th8(t))

#33 == a8 cos(th8(t)) sin(th1(t)) sin(th3(t)) sin(th5(t)) sin(th6(t))

#34 == a7 cos(th6(t)) sin(th1(t)) sin(th3(t)) sin(th5(t)) sin(th7(t))

#35 == a7 cos(th1(t)) sin(th2(t)) sin(th4(t)) sin(th6(t)) sin(th7(t))

#36 == a7 cos(th3(t)) cos(th4(t)) sin(th1(t)) sin(th6(t)) sin(th7(t))

#37 == a7 cos(th3(t)) cos(th7(t)) sin(th1(t)) sin(th4(t)) sin(th5(t))

#38 == a8 cos(th1(t)) cos(th6(t)) cos(th8(t)) sin(th2(t)) sin(th4(t))

#39 == a7 cos(th1(t)) cos(th4(t)) cos(th7(t)) sin(th2(t)) sin(th5(t))

#40 == a8 cos(th3(t)) cos(th4(t)) cos(th6(t)) cos(th8(t)) sin(th1(t))

#41 == a7 cos(th1(t)) cos(th2(t)) cos(th3(t)) cos(th5(t)) cos(th7(t))

#42 == a8 cos(th7(t)) sin(th1(t)) sin(th2(t)) sin(th4(t)) sin(th6(t)) sin(th8(t))

#43 == a8 cos(th4(t)) sin(th1(t)) sin(th2(t)) sin(th5(t)) sin(th7(t)) sin(th8(t))

#44 == a8 cos(th1(t)) cos(th3(t)) sin(th4(t)) sin(th5(t)) sin(th7(t)) sin(th8(t))

#45 == a7 cos(th2(t)) cos(th4(t)) sin(th1(t)) sin(th3(t)) sin(th6(t)) sin(th7(t))

#46 == a7 cos(th2(t)) cos(th7(t)) sin(th1(t)) sin(th3(t)) sin(th4(t)) sin(th5(t))

#47 == a8 cos(th1(t)) cos(th6(t)) cos(th7(t)) sin(th3(t)) sin(th5(t)) sin(th8(t))

#48 == a8 cos(th4(t)) cos(th5(t)) cos(th8(t)) sin(th1(t)) sin(th2(t)) sin(th6(t))

#49 == a8 cos(th2(t)) cos(th3(t)) cos(th5(t)) sin(th1(t)) sin(th7(t)) sin(th8(t))

#50 == a8 cos(th2(t)) cos(th3(t)) cos(th8(t)) sin(th1(t)) sin(th5(t)) sin(th6(t))

#51 == a7 cos(th4(t)) cos(th5(t)) cos(th6(t)) sin(th1(t)) sin(th2(t)) sin(th7(t))

#52 == a7 cos(th2(t)) cos(th3(t)) cos(th6(t)) sin(th1(t)) sin(th5(t)) sin(th7(t))

#53 == a8 cos(th1(t)) cos(th3(t)) cos(th4(t)) cos(th7(t)) sin(th6(t)) sin(th8(t))

#54 == a8 cos(th1(t)) cos(th3(t)) cos(th5(t)) cos(th8(t)) sin(th4(t)) sin(th6(t))

#55 == a7 cos(th1(t)) cos(th3(t)) cos(th5(t)) cos(th6(t)) sin(th4(t)) sin(th7(t))

#56 == a8 cos(th2(t)) cos(th4(t)) cos(th6(t)) cos(th8(t)) sin(th1(t)) sin(th3(t))

#57 == a6 cos(th1(t)) cos(th2(t)) cos(th5(t)) cos(th6(t)) sin(th3(t)) sin(th4(t))

#58 == a7 cos(th5(t)) cos(th7(t)) sin(th1(t)) sin(th3(t))

#59 == a7 sin(th1(t)) sin(th2(t)) sin(th4(t)) sin(th6(t)) sin(th7(t))
```

```
#60 == a8 cos(th1(t)) cos(th5(t)) sin(th3(t)) sin(th7(t)) sin(th8(t))

#61 == a8 cos(th1(t)) cos(th8(t)) sin(th3(t)) sin(th5(t)) sin(th6(t))

#62 == a8 cos(th6(t)) cos(th8(t)) sin(th1(t)) sin(th2(t)) sin(th4(t))

#63 == a7 cos(th1(t)) cos(th6(t)) sin(th3(t)) sin(th5(t)) sin(th7(t))

#64 == a7 cos(th4(t)) cos(th7(t)) sin(th1(t)) sin(th2(t)) sin(th5(t))

#65 == a5 cos(th1(t)) cos(th2(t)) sin(th3(t)) sin(th4(t)) sin(th5(t))

#66 == a7 cos(th1(t)) cos(th3(t)) cos(th4(t)) sin(th6(t)) sin(th7(t))

#67 == a7 cos(th1(t)) cos(th3(t)) cos(th7(t)) sin(th4(t)) sin(th5(t))

#68 == a6 cos(th3(t)) cos(th5(t)) cos(th6(t)) sin(th1(t)) sin(th4(t))

#69 == a6 cos(th1(t)) cos(th2(t)) cos(th4(t)) sin(th3(t)) sin(th6(t))

#70 == a7 cos(th2(t)) cos(th3(t)) cos(th5(t)) cos(th7(t)) sin(th1(t))

#71 == a6 cos(th1(t)) cos(th4(t)) cos(th5(t)) cos(th6(t)) sin(th2(t))

#72 == a6 cos(th1(t)) cos(th2(t)) cos(th3(t)) cos(th6(t)) sin(th5(t))

#73 == a8 cos(th1(t)) cos(th3(t)) cos(th4(t)) cos(th6(t)) cos(th8(t))

#74 == a5 cos(th5(t)) sin(th1(t)) sin(th3(t))

#75 == a6 cos(th6(t)) sin(th1(t)) sin(th3(t)) sin(th5(t))

#76 == a6 cos(th1(t)) sin(th2(t)) sin(th4(t)) sin(th6(t))

#77 == a5 cos(th3(t)) sin(th1(t)) sin(th4(t)) sin(th5(t))

#78 == a6 cos(th3(t)) cos(th4(t)) sin(th1(t)) sin(th6(t))

#79 == a5 cos(th1(t)) cos(th4(t)) sin(th2(t)) sin(th5(t))

#80 == a7 cos(th1(t)) cos(th5(t)) cos(th7(t)) sin(th3(t))

#81 == a5 cos(th1(t)) cos(th2(t)) cos(th3(t)) cos(th5(t))

#82 == a8 cos(th2(t)) cos(th5(t)) cos(th6(t)) cos(th7(t)) sin(th3(t)) sin(th4(t)) sin(th8(t))

#83 == a8 cos(th2(t)) sin(th3(t)) sin(th4(t)) sin(th5(t)) sin(th7(t)) sin(th8(t))

#84 == a8 cos(th2(t)) cos(th4(t)) cos(th7(t)) sin(th3(t)) sin(th6(t)) sin(th8(t))

#85 == a8 cos(th2(t)) cos(th5(t)) cos(th8(t)) sin(th3(t)) sin(th4(t)) sin(th6(t))

#86 == a7 cos(th2(t)) cos(th5(t)) cos(th6(t)) sin(th3(t)) sin(th4(t)) sin(th7(t))

#87 == a6 cos(th2(t)) cos(th5(t)) cos(th6(t)) sin(th1(t)) sin(th3(t)) sin(th4(t))

#88 == a8 cos(th4(t)) cos(th5(t)) cos(th6(t)) cos(th7(t)) sin(th2(t)) sin(th8(t))

#89 == a8 cos(th2(t)) cos(th3(t)) cos(th6(t)) cos(th7(t)) sin(th5(t)) sin(th8(t))

#90 == a8 cos(th7(t)) sin(th2(t)) sin(th4(t)) sin(th6(t)) sin(th8(t))

#91 == a8 cos(th4(t)) sin(th2(t)) sin(th5(t)) sin(th7(t)) sin(th8(t))
```

#92 == a5 cos(th2(t)) sin(th1(t)) sin(th3(t)) sin(th4(t)) sin(th5(t))

#93 == a7 cos(th2(t)) cos(th4(t)) sin(th3(t)) sin(th6(t)) sin(th7(t))

#94 == a7 cos(th2(t)) cos(th7(t)) sin(th3(t)) sin(th4(t)) sin(th5(t))

#95 == a6 cos(th2(t)) cos(th4(t)) sin(th1(t)) sin(th3(t)) sin(th6(t))

#96 == a8 cos(th4(t)) cos(th5(t)) cos(th8(t)) sin(th2(t)) sin(th6(t))

#97 == a8 cos(th2(t)) cos(th3(t)) cos(th5(t)) sin(th7(t)) sin(th8(t))

#98 == a8 cos(th2(t)) cos(th3(t)) cos(th8(t)) sin(th5(t)) sin(th6(t))

#99 == a7 cos(th4(t)) cos(th5(t)) cos(th6(t)) sin(th2(t)) sin(th7(t))

#100 == a7 cos(th2(t)) cos(th3(t)) cos(th6(t)) sin(th5(t)) sin(th7(t))

#101 == a6 cos(th2(t)) cos(th5(t)) cos(th6(t)) sin(th3(t)) sin(th4(t))

#102 == a6 cos(th4(t)) cos(th5(t)) cos(th6(t)) sin(th1(t)) sin(th2(t))

#103 == a6 cos(th2(t)) cos(th3(t)) cos(th6(t)) sin(th1(t)) sin(th5(t))

#104 == a8 cos(th2(t)) cos(th4(t)) cos(th6(t)) cos(th8(t)) sin(th3(t))

#105 == a6 cos(th1(t)) cos(th3(t)) cos(th5(t)) cos(th6(t)) sin(th4(t))

#106 == a7 sin(th2(t)) sin(th4(t)) sin(th6(t)) sin(th7(t))

#107 == a6 sin(th1(t)) sin(th2(t)) sin(th4(t)) sin(th6(t))

#108 == a5 cos(th2(t)) sin(th3(t)) sin(th4(t)) sin(th5(t))

#109 == a5 cos(th4(t)) sin(th1(t)) sin(th2(t)) sin(th5(t))

#110 == a8 cos(th6(t)) cos(th8(t)) sin(th2(t)) sin(th4(t))

#111 == a7 cos(th4(t)) cos(th7(t)) sin(th2(t)) sin(th5(t))

#112 == a6 cos(th2(t)) cos(th4(t)) sin(th3(t)) sin(th6(t))

#113 == a6 cos(th1(t)) cos(th6(t)) sin(th3(t)) sin(th5(t))

#114 == a5 cos(th1(t)) cos(th3(t)) sin(th4(t)) sin(th5(t))

#115 == a3 cos(th1(t)) cos(th2(t)) sin(th3(t)) sin(th4(t))

#116 == a6 cos(th4(t)) cos(th5(t)) cos(th6(t)) sin(th2(t))

#117 == a6 cos(th2(t)) cos(th3(t)) cos(th6(t)) sin(th5(t))

#118 == a6 cos(th1(t)) cos(th3(t)) cos(th4(t)) sin(th6(t))

#119 == a5 cos(th2(t)) cos(th3(t)) cos(th5(t)) sin(th1(t))

#120 == a4 cos(th1(t)) cos(th2(t)) cos(th4(t)) sin(th3(t))

#121 == a7 cos(th2(t)) cos(th3(t)) cos(th5(t)) cos(th7(t))

#122 == a5 cos(th4(t)) sin(th2(t)) sin(th5(t))

#123 == a3 cos(th2(t)) sin(th3(t)) sin(th4(t))

```
#124 == a4 cos(th1(t)) sin(th2(t)) sin(th4(t))

#125 == a3 cos(th3(t)) sin(th1(t)) sin(th4(t))

#126 == a5 cos(th1(t)) cos(th5(t)) sin(th3(t))

#127 == a4 cos(th2(t)) cos(th4(t)) sin(th3(t))

#128 == a4 cos(th3(t)) cos(th4(t)) sin(th1(t))

#129 == a3 cos(th1(t)) cos(th4(t)) sin(th2(t))

#130 == a5 cos(th2(t)) cos(th3(t)) cos(th5(t))

#131 == a6 sin(th2(t)) sin(th4(t)) sin(th6(t))

#132 == a4 sin(th2(t)) sin(th4(t))

#133 == a3 cos(th4(t)) sin(th2(t))

#134 == #147 + a6 #149 - a3 #152 + a4 #151 - a8 #146 - a5 #150

#135 == #139 - a6 #149 - #147 + a3 #152 - a4 #151 + a8 #146 + a5 #150

#136 == cos(th6(t)) #141 + sin(th5(t)) sin(th6(t)) #142 + cos(th5(t)) sin(th6(t)) #140

#137 == cos(th5(t)) sin(th6(t)) #143 - cos(th6(t)) #144 + sin(th5(t)) sin(th6(t)) #145

#138 == #147 + a6 #149 - a8 #146 - a5 #150

#139 == a1 sin(th2(t))

#140 == cos(th1(t)) cos(th3(t)) sin(th4(t)) + cos(th4(t)) sin(th1(t)) sin(th2(t)) - cos(th2(t)) sin(th1

#141 == sin(th1(t)) sin(th2(t)) sin(th4(t)) - cos(th1(t)) cos(th3(t)) cos(th4(t)) + cos(th2(t)) cos(th4

#142 == cos(th1(t)) sin(th3(t)) + cos(th2(t)) cos(th3(t)) sin(th1(t))

#143 == cos(th3(t)) sin(th1(t)) sin(th4(t)) - cos(th1(t)) cos(th4(t)) sin(th2(t)) + cos(th1(t)) cos(th2

#144 == cos(th3(t)) cos(th4(t)) sin(th1(t)) + cos(th1(t)) sin(th2(t)) sin(th4(t)) + cos(th1(t)) cos(th2

#145 == sin(th1(t)) sin(th3(t)) - cos(th1(t)) cos(th2(t)) cos(th3(t))

#146 == sin(th7(t)) sin(th8(t)) #150 - cos(th8(t)) #148 + cos(th7(t)) sin(th8(t)) #149

#147 == a7 (sin(th7(t)) #149 - cos(th7(t)) #150)

#148 == cos(th6(t)) #151 + cos(th5(t)) sin(th6(t)) #152 - cos(th3(t)) sin(th2(t)) sin(th5(t)) sin(th6(t

#149 == sin(th6(t)) #151 - cos(th5(t)) cos(th6(t)) #152 + cos(th3(t)) cos(th6(t)) sin(th2(t)) sin(th5(t

#150 == sin(th5(t)) #152 + cos(th3(t)) cos(th5(t)) sin(th2(t))

#151 == cos(th2(t)) sin(th4(t)) - cos(th4(t)) sin(th2(t)) sin(th3(t))

#152 == cos(th2(t)) cos(th4(t)) + sin(th2(t)) sin(th3(t)) sin(th4(t))
```

```
%disp('Velocidad angular obtenida mediante el Jacobiano angular');
W=simplify (Jw_a*Q_p');
    pretty(W);
```

```
/               ___         ___                           ___
|  0,  #1, #1,  Qp1 #10,  - Qp1 #4,                     - Qp1 (cos(th8(t)) #4 + cos(th7(t)) sin(th8(t)) (s
|
|                ___         ___     ___
|  0,   0,  0, - Qp1 #12, - Qp1 #5, Qp1 (sin(th7(t)) sin(th8(t)) (sin(th5(t)) #13 + cos(th3(t)) cos(th5(t)
|
| ___             ___         ___                             ___
\ Qp1, #2, #2,  - Qp1 #7, - Qp1 #3,                       - Qp1 (cos(th8(t)) #3 + sin(th7(t)) sin(th8(t))

where

                     ___
   #1 == sin(th1(t)) Qp1

                     ___
   #2 == cos(th1(t)) Qp1

   #3 == cos(th6(t)) #7 + sin(th5(t)) sin(th6(t)) #8 + cos(th5(t)) sin(th6(t)) #6

   #4 == cos(th5(t)) sin(th6(t)) #9 - cos(th6(t)) #10 + sin(th5(t)) sin(th6(t)) #11

   #5 == cos(th6(t)) #12 + cos(th5(t)) sin(th6(t)) #13 - cos(th3(t)) sin(th2(t)) sin(th5(t)) sin(th6(t))

   #6 == cos(th1(t)) cos(th3(t)) sin(th4(t)) + cos(th4(t)) sin(th1(t)) sin(th2(t)) - cos(th2(t)) sin(th1(t

   #7 == sin(th1(t)) sin(th2(t)) sin(th4(t)) - cos(th1(t)) cos(th3(t)) cos(th4(t)) + cos(th2(t)) cos(th4(t

   #8 == cos(th1(t)) sin(th3(t)) + cos(th2(t)) cos(th3(t)) sin(th1(t))

   #9 == cos(th3(t)) sin(th1(t)) sin(th4(t)) - cos(th1(t)) cos(th4(t)) sin(th2(t)) + cos(th1(t)) cos(th2(t

   #10 == cos(th3(t)) cos(th4(t)) sin(th1(t)) + cos(th1(t)) sin(th2(t)) sin(th4(t)) + cos(th1(t)) cos(th2(

   #11 == sin(th1(t)) sin(th3(t)) - cos(th1(t)) cos(th2(t)) cos(th3(t))

   #12 == cos(th2(t)) sin(th4(t)) - cos(th4(t)) sin(th2(t)) sin(th3(t))

   #13 == cos(th2(t)) cos(th4(t)) + sin(th2(t)) sin(th3(t)) sin(th4(t))
```