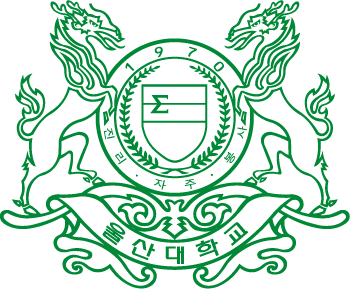
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| **R E P O R T** | |
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| **학 과** | **전기전자정보시스템공학전공** |
| **교수님 (Professor)** | **KANG, HEE-JUN 교수님** |
| **학 번 (Student ID)** | **20175308** |
| **이 름 (Name)** | **La Phuong Ha** |
| **제출일 (Times)** | **20190927** |



La Phuong Ha – ID: 20175308 – Assignment 5: Robot Manipulators

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1. Find the linear and angular velocities of the tool through velocity propagation

We have: 

Hence, the velocities of the tool are: 

Matlab code:

%Robot manipulator Assignment 5

theta1 = pi/4;

theta2 = pi/4;

theta3 = pi/4;

theta4 = pi/4;

theta5 = pi/4;

theta6 = pi/4;

a2 = 1; a3 = 0.3; d3 = 0.5; d4 = 1;

omega=[0;0;0.1]

R\_0\_1=[cos(theta1) -sin(theta1) 0;sin(theta1) cos(theta1) 0;0 0 1]

R\_1\_2=[cos(theta2) -sin(theta2) 0;0 0 1;-sin(theta2) -cos(theta2) 0]

R\_2\_3=[cos(theta3) -sin(theta3) 0;sin(theta3) cos(theta3) 0;0 0 1]

R\_3\_4=[cos(theta4) -sin(theta4) 0;0 0 1;-sin(theta4) -cos(theta4) 0]

R\_4\_5=[cos(theta5) -sin(theta5) 0;0 0 -1;sin(theta5) cos(theta5) 0]

R\_5\_6=[cos(theta6) -sin(theta6) 0; 0 0 1;-sin(theta6) -cos(theta6) 0]

R\_6\_t=[1 0 0;0 1 0;0 0 1]

P\_0\_1=[0;0;0]

P\_1\_2=[0;0;0]

P\_2\_3=[a2;0;d3]

P\_3\_4=[a3;d4;0]

P\_4\_5=[ 0;0;0]

P\_5\_6=[0;0;0]

P\_6\_t=[1;1;2]

% all joints verlocity

w\_0\_0=[0;0;0]

v\_0\_0=[0;0;0]

w\_1\_1=R\_0\_1'\*w\_0\_0+[0;0;0.1]

v\_1\_1=R\_0\_1'\*(v\_0\_0+cross(w\_0\_0,P\_0\_1))

w\_2\_2=R\_1\_2'\*w\_1\_1+[0;0;0.1]

v\_2\_2=R\_1\_2'\*(v\_1\_1+cross(w\_1\_1,P\_1\_2))

w\_3\_3=R\_2\_3'\*w\_2\_2+[0;0;0.1]

v\_3\_3=R\_2\_3'\*(v\_2\_2+cross(w\_2\_2,P\_2\_3))

w\_4\_4=R\_3\_4'\*w\_3\_3+[0;0;0.1]

v\_4\_4=R\_3\_4'\*(v\_3\_3+cross(w\_3\_3,P\_3\_4))

w\_5\_5=R\_4\_5'\*w\_4\_4+[0;0;0.1]

v\_5\_5=R\_4\_5'\*(v\_4\_4+cross(w\_4\_4,P\_4\_5))

w\_6\_6=R\_5\_6'\*w\_5\_5+[0;0;0.1]

v\_6\_6=R\_5\_6'\*(v\_5\_5+cross(w\_5\_5,P\_5\_6))

w\_t\_t=R\_6\_t'\*w\_6\_6+0

v\_t\_t=R\_6\_t'\*(v\_6\_6+cross(w\_6\_6,P\_6\_t))

w\_0\_t=R\_0\_1\*R\_1\_2\*R\_2\_3\*R\_3\_4\*R\_4\_5\*R\_5\_6\*R\_6\_t\*w\_6\_6

v\_0\_t=R\_0\_1\*R\_1\_2\*R\_2\_3\*R\_3\_4\*R\_4\_5\*R\_5\_6\*R\_6\_t\*v\_t\_t

V\_0=[v\_0\_t;w\_0\_t]

w\_1\_1=R\_0\_1'\*w\_0\_0+[0;0;0.1]

v\_1\_1=R\_0\_1'\*(v\_0\_0+cross(w\_0\_0,P\_0\_1))

w\_2\_2=R\_1\_2'\*w\_1\_1+[0;0;0.1]

v\_2\_2=R\_1\_2'\*(v\_1\_1+cross(w\_1\_1,P\_1\_2))

w\_3\_3=R\_2\_3'\*w\_2\_2+[0;0;0.1]

v\_3\_3=R\_2\_3'\*(v\_2\_2+cross(w\_2\_2,P\_2\_3))

w\_4\_4=R\_3\_4'\*w\_3\_3+[0;0;0.1]

v\_4\_4=R\_3\_4'\*(v\_3\_3+cross(w\_3\_3,P\_3\_4))

w\_5\_5=R\_4\_5'\*w\_4\_4+[0;0;0.1]

v\_5\_5=R\_4\_5'\*(v\_4\_4+cross(w\_4\_4,P\_4\_5))

w\_6\_6=R\_5\_6'\*w\_5\_5+[0;0;0.1]

v\_6\_6=R\_5\_6'\*(v\_5\_5+cross(w\_5\_5,P\_5\_6))

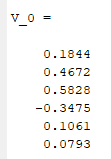
w\_t\_t=R\_6\_t'\*w\_6\_6+0

v\_t\_t=R\_6\_t'\*(v\_6\_6+cross(w\_6\_6,P\_6\_t))

w\_0\_t=R\_0\_1\*R\_1\_2\*R\_2\_3\*R\_3\_4\*R\_4\_5\*R\_5\_6\*R\_6\_t\*w\_6\_6

v\_0\_t=R\_0\_1\*R\_1\_2\*R\_2\_3\*R\_3\_4\*R\_4\_5\*R\_5\_6\*R\_6\_t\*v\_t\_t

V\_0=[v\_0\_t;w\_0\_t]

The output of Matlab: 

1. The matrix defining the frame {i} in reference to the base frame is calculated as below:

 where 

Then the Jacobian matrix is calculated as below:



Jacobian matrix is shown as below:



Matlab code:

%Code from assignment 3

th1 = pi/4;

th2 = pi/4;

th3 = pi/4;

th4 = pi/4;

th5 = pi/4;

th6 = pi/4;

a2 = 1; a3 = 0.3; d3 = 0.5; d4 = 1;

T6\_T = [1 0 0 0;0 1 0 0;0 0 1 0.2;0 0 0 1];

%D-H parameters

syms a1 a d th,

T = [cos(th) -sin(th) 0 a;

sin(th)\*cos(a1) cos(th)\*cos(a1) -sin(a1) -sin(a1)\*d;

sin(th)\*sin(a1) cos(th)\*sin(a1) cos(a1) cos(a1)\*d;

0 0 0 1];

T01 = vpa(subs(T,{a1,a,d,th},{[0,0,0,th1]}),2);

T12 = vpa(subs(T,{a1,a,d,th},{[-pi/2,0,0,th2]}),2);

T23 = vpa(subs(T,{a1,a,d,th},{[0,a2,d3,th3]}),2);

T34 = vpa(subs(T,{a1,a,d,th},{[-pi/2,a3,d4,th4]}),2);

T45 = vpa(subs(T,{a1,a,d,th},{[pi/2,0,0,th5]}),2);

T56 = vpa(subs(T,{a1,a,d,th},{[-pi/2,0,0,th6]}),2);

T06 = vpa(T01\*T12\*T23\*T34\*T45\*T56,2)

T0\_T = T06\*T6\_T

%Jacobian matrix calculation

P0\_t=T0\_T(1:3,4) ;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

k0\_1=T01(1:3,3) ;

P0\_1=T01(1:3,4) ;

J1=[cross(k0\_1,(P0\_t - P0\_1));k0\_1]

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

T02=T01\*T12

k0\_2=T02(1:3,3) ;

P0\_2=T02(1:3,4) ;

J2=[cross(k0\_2,(P0\_t - P0\_2));k0\_2]

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

T03=T01\*T12\*T23

k0\_3=T03(1:3,3) ;

P0\_3=T03(1:3,4) ;

J3=[cross(k0\_3,(P0\_t - P0\_3));k0\_3]

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

T04=T01\*T12\*T23\*T34

k0\_4=T04(1:3,3) ;

P0\_4=T04(1:3,4) ;

J4=[cross(k0\_4,(P0\_t - P0\_4));k0\_4]

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

T05=T01\*T12\*T23\*T34\*T45

k0\_5=T05(1:3,3) ;

P0\_5=T05(1:3,4) ;

J5=[cross(k0\_5,(P0\_t - P0\_5));k0\_5]

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

T06=T01\*T12\*T23\*T34\*T45\*T56

k0\_6=T06(1:3,3) ;

P0\_6=T06(1:3,4) ;

J6=[cross(k0\_6,(P0\_t - P0\_6));k0\_6]

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

J=[J1 J2 J3 J4 J5 J6]

1. The inverse velocity is calculated by:



Matlab Code:

TT\_dot=inv(J)\*V\_0