Project Management HUMA 1001

Four Legged Robot : Control , Design and Fabrication

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Table of contents:

i. Introduction:

The uses of robots have increased throughout the years. From being used in Industries to medical fields. Robots have been used in exploring hazardous areas. However, wheeled or tracked robots are commonly used to cover the Earth's Landmass, although cannot access or cover the whole landmass due to the rough conditions that wheeled robots cannot access. Humans and animals having legs can go almost anywhere having the advantage over wheeled robots inspiring the motivation in creating legged robots. Legged robots have been introduced in the late 1960s with The Quadruped robots being the most famous. They have different types of actuations and joint configurations. Legged robots can be modelled dynamically or Kinematically. In this project, The Quadruped has had been modelled, and a full body modelling has been done for the robot. The proposed Quadruped in the thesis has 12 DOF. The full body model was inserted on MATLAB to simulate the different positions of the robot changing by changing the parameters of the equation. Using angles extracted from another quadruped robot and approximating them to the simulations the robot movement was controlled along the three axes and the rotation along them buy changing the values of the angles and the values of the equations of the full body model. This has been simulated on MATLAB and presented on hardware.

Figure 1 quadruped

Figure 2 quadruped

ii. WBS: (work breakdown structure)

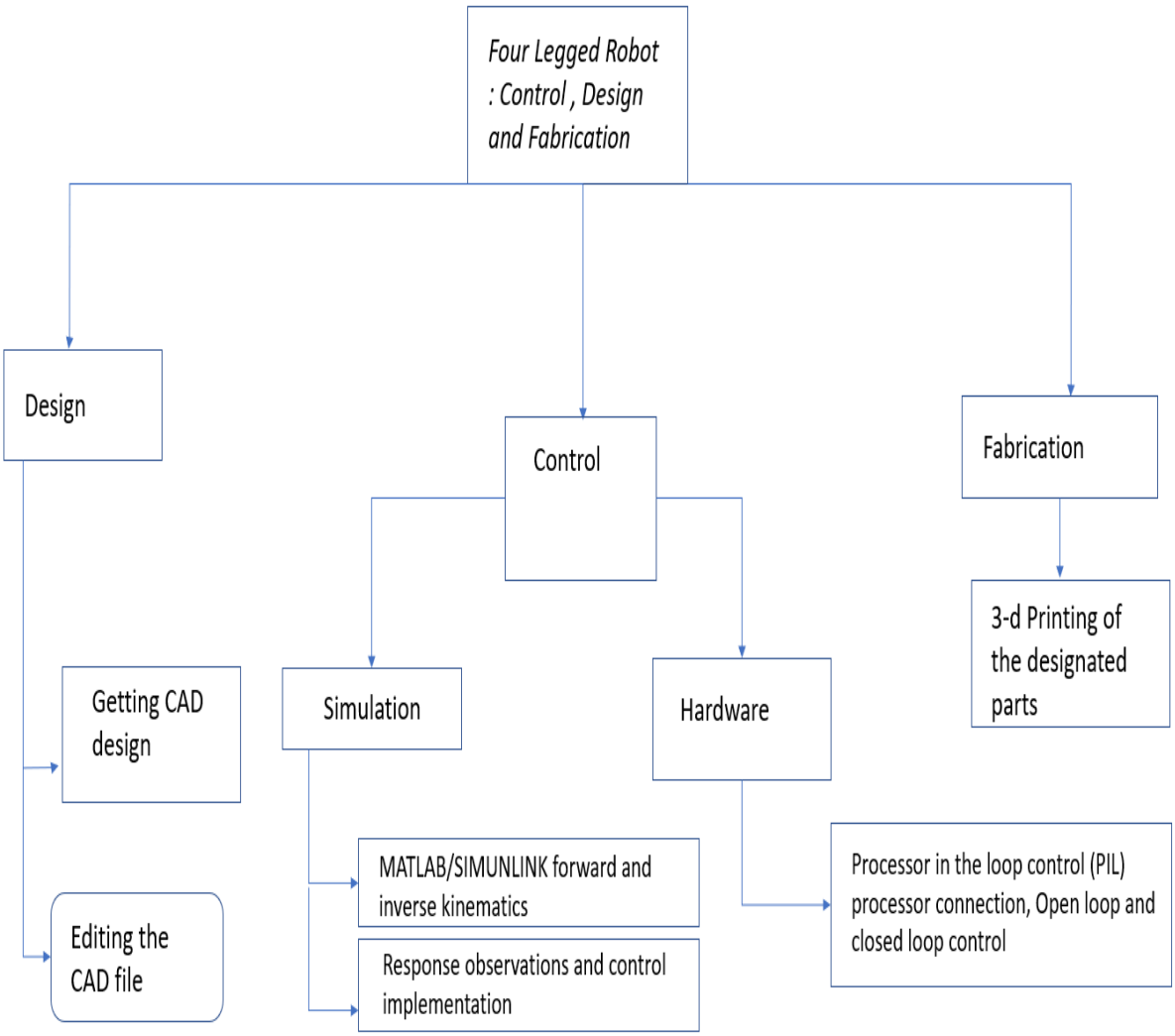

Figure 3 WBS

iii. LRC: (Linear responsibility chart)

Task	Team leader	Team member 2	Team member 3	Team member 4
Constructing the project plan	1	3	3	3
Regular reports to the supervisor	1	4	4	4
Literature review	2	1	1	1
Research for a suitable CAD model	2	1	3	3
Editing CAD model	2	1	3	3
Conducting a finite element analysis using ANSYS	2	2	1	3
Reviewing CAD model	1	3	2	1
Formulating a mathematical model	2	3	3	1
Simulating the model	2	3	1	2
Designing The open-loop circuit	2	3	1	1
Testing The open-loop circuit	1	3	1	1
Designing the closed-loop circuit	2	3	1	1
Resting the closed-loop circuit	1	3	1	1
Plotting the results	1	3	1	1
Documenting the results	1	1	1	1
Writing thesis	1	1	1	1
Submitting the thesis	1	4	4	4

1 > Actual Responsibility

2 > General Supervision

3 > Can be consulted

4 > Not needed

iv. 15 activities:

1- choose application for the robot accordingly choose the size (A)

2- study and choose best leg configuration (B)

3- study and choose best actuation for the given configuration (C)

4-get the dimensions of all components the motors and electronic components as well as the wires. (D)

5-Design the parts and the mathematical model(E)

6- do stress analysis simulations (F)

7-design control law (G)

8-build a simulation for the project (H)

9-manufacture the designed part (I)

10-design the circuit (J)

11-buy the motors and electronic components (K)

12- test the components individually (L)

13- print and assemble the circuit (M)

14- assemble the project (N)

15- get dimensions for the robot after assembly for kinematics (O)

16- Open loop control implementation and Arduino implementation (P)

17- obtain kinematic model (Q)

18-test the feasibility of the kinematic model on hardware and modify its constants if needed (R)

19- apply the designed closed loop control. Modify the gains if required. (S)

20- test the control model on several cases (T)

v. ***Table with predecessors:***

Activity	Predecessor	Time(days)
A	-	2
B	A	2
C	A,B	2
D	C	1
E	D	7
F	E	3
G	E	5
H	G	2
I	E,F	4
J	D,E	3
K	J	1
L	K	1
M	K,L	3
N	M,I	2
O	N	1
P	N	10
Q	O	3
R	Q	2
S	R	2
T	S	2

vi. AON:

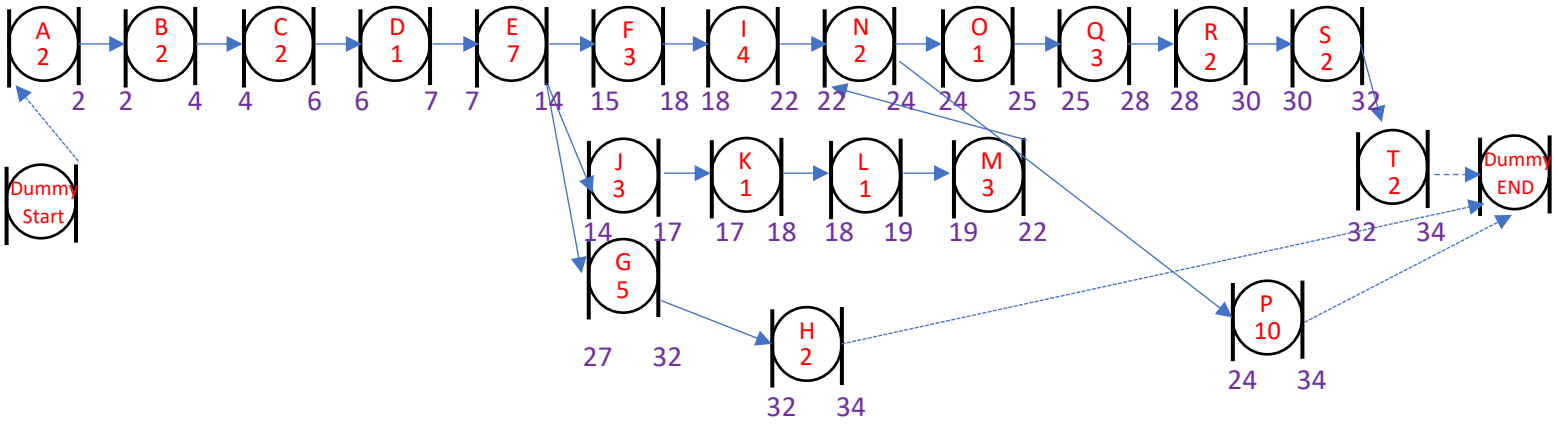

Figure 4 AON

vii. AOA:

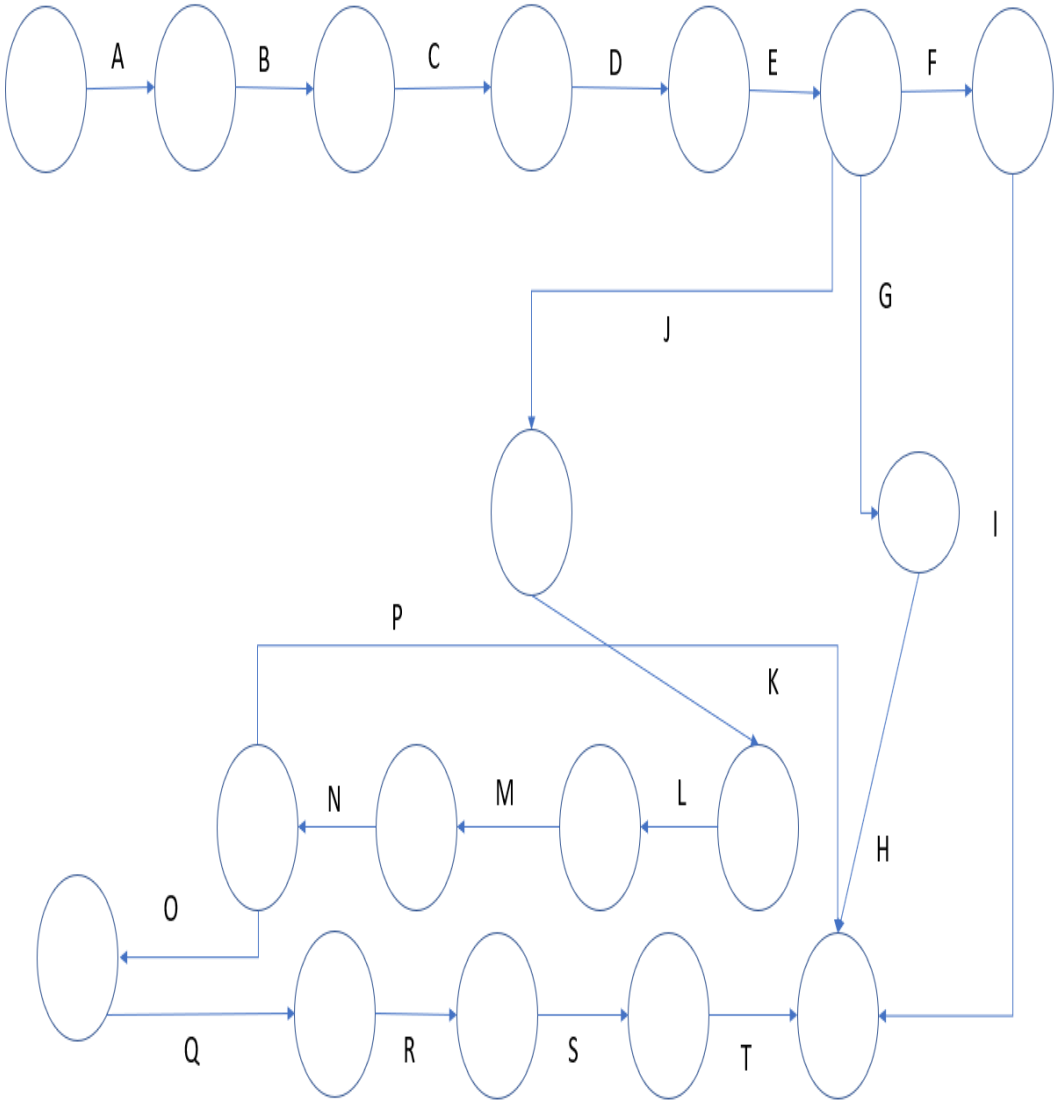

Figure 5 AOA

Activity	ES	EF	LS	LF	Slack
A	0	2	0	2	0
B	2	4	2	4	0
C	4	6	4	6	0
D	6	7	6	7	0
E	7	14	7	14	0
F	14	17	15	18	1
G	14	19	27	32	13
H	19	21	32	34	13
I	17	21	18	22	1
J	14	17	14	17	0
K	17	18	17	18	0
L	18	19	18	19	0
M	19	22	19	22	0
N	22	24	22	24	0
O	24	25	24	25	0
P	24	34	24	34	0
Q	25	28	25	28	0
R	28	30	28	30	0
S	30	32	30	32	0
T	32	34	32	34	0

viii. Critical paths:

There are 2 critical paths which are:

A-B-C-D-E-J-K-L-M-N-O-Q-R-S-T

A-B-C-D-E-J-K-L-M-N-P

ix. Crashing

	Crash time	crash cost	normal time	normal cost
A	1	150	2	100
B	1	200	2	150
C	1	300	2	200
D	1	250	1	175
E	3	400	7	300
F	1	300	3	250
G	2	300	5	225
H	1	150	2	125
I	2	250	4	175
J	1	300	3	200
K	1	300	1	250
L	1	275	1	225
M	2	300	3	200
N	1	200	2	150
O	1	200	1	100
P	6	400	10	350
Q	2	300	3	250
R	1	350	2	250
S	1	200	2	100
T	1	175	2	125

	Allowable crash time=NT-CT	crash cost/unit time=CC-NC/NT-CT
A	1	50
B	1	50
C	1	100
D	0	0
E	4	25
F	2	25
G	3	25
H	1	25
I	2	37.5
J	2	50
K	0	0
L	0	0
M	1	100
N	1	50
O	0	0
P	4	12.5
Q	1	50
R	1	100
S	1	100
T	1	50

1. To be crashed

P+Q	62.5
P+R	112.5
P+S	112.5
P+T	62.5
A	50
B	50
C	100
E	25
J	50
M	100
N	50

*****Crash E by 4***

2. To be crashed

P+Q	62.5
P+R	112.5
P+S	112.5
P+T	62.5
A	50
B	50
C	100
~~E~~	~~25~~

J 50

M 100

N 50

***Crash A by 1**

P+Q 62.5

P+R 112.5

P+S 112.5

P+T 62.5

~~A 50~~

~~B 50~~

C 100

~~E 25~~

J 50

M 100

N 50

***Crash B by 1**

P+Q 62.5

P+R 112.5

P+S 112.5

P+T 62.5

~~A 50~~

~~B 50~~

C 100

~~E 25~~

J 50

M 100

~~N 50~~

***Crash N by 1**

P+Q 62.5

P+R 112.5

P+S 112.5

P+T 62.5

~~A 50~~

~~B 50~~

C 100

~~E 25~~

~~J 50~~

M 100

~~N 50~~

***Crash J by 1**

Because of new critical paths introduced the new crashing possibilities are:

C 100

F+M 125

I+M 137.5

P+Q 62.5

P+R 112.5

P+S 112.5

P+T 62.5

P+T

P+Q

Crash P+T by 1

C 100

F+M 125

I+M 137.5

P+Q 62.5

P+R 112.5

P+S 112.5

P+T 62.5

P+T

P+Q

Crash P+Q by 1

New possibilities are:

C 100

F+M 125

I+M 137.5

~~P+Q 62.5~~ (Q cannot be crashed)

P+R 112.5

P+S 112.5

~~P+T 62.5~~

*****Crash C by 1***

New Possibilities are:

~~C 100~~

F+M 125

I+M 137.5

~~P+Q 62.5~~ (Q cannot be crashed)

P+R 112.5

P+S 112.5

~~P+T 62.5~~

P+R

P+S

*****Crash P+R by 1***

New Possibilities are:

~~C 100~~

F+M 125

I+M 137.5

~~P+Q 62.5~~ (Q cannot be crashed)

~~P+R 112.5~~

P+S 112.5

~~P+T 62.5~~

P+R

P+S

*****Crash P+S by 1***

New Possibilities are:

~~C 100~~

F+M 125

I+M 137.5

~~P+Q 62.5~~ (Q cannot be crashed)

~~P+R 112.5~~

~~P+S 112.5~~

~~P+T 62.5~~

*****Crash F+M by 1***

The project cannot be crashed again due to no more possibilities.

Path	Duration	crash E by 4	crash A by 1	crash B by 1	crash N by 1	crash J by 1	crash P+T by 1	crash P+Q by 1	crash C by 1	crash P+R by 1	crash P+S by 1	crash F+M by 1
ABCDEJKLMNP	34	30	29	28	27	26	25	24	23	22	21	20
ABCDEFINP	33	29	28	27	26	26	25	24	23	22	21	20
ABCDEFINOQRST	33	29	28	27	26	26	25	24	23	22	21	20
ABCDEJKLMNOQRST	34	30	29	28	27	26	25	24	23	22	21	20
ABCDEGH	24	20	19	18	18	18	18	18	17	17	17	17

Crashing cost:

1. 3900+25(4)=4000
2. 4000+50=4050
3. 4050+50=4100
4. 4100+50=4150
5. 4150+50=4200
6. 4200+62.5=4262.5
7. 4262.5+62.5=4325
8. 4325+100=4425
9. 4425+112.5=4537.5
10. 4537.5+112.5=4650
11. 4650+125=4775

x. PERT

Task	optimistic	most likely	pessimistic	mean	Variance	standard deviation	critical path :		P	Z	X
A	1	2	3	2	0.111111	0.333333	38	38	0.6	0.25	38.35355
B	1	2	3	2	0.111111	0.333333	ABCDEJKLMNOQRST	ABCDEJKLMNP	0.9	1.28	39.81019
C	1	2	3	2	0.111111	0.333333	variance:		0.99	3.7	43.23259
D	1	2	3	2	0.111111	0.333333	2	1.888889			
E	5	7	9	7	0.444444	0.666667	standard deviation				
F	2	3	4	3	0.111111	0.333333	1.414214	1.374369			
G	3	5	4	4.5	0.027778	0.166667					
H	1	2	3	2	0.111111	0.333333					
I	2	4	6	4	0.444444	0.666667					
J	2	3	4	3	0.111111	0.333333					
K	1	2	3	2	0.111111	0.333333					
L	1	2	3	2	0.111111	0.333333					
M	2	3	4	3	0.111111	0.333333					
N	1	2	3	2	0.111111	0.333333					
O	1	2	3	2	0.111111	0.333333					
P	9	11	13	11	0.444444	0.666667					
Q	2	3	4	3	0.111111	0.333333					
R	1	2	3	2	0.111111	0.333333					
S	1	2	3	2	0.111111	0.333333					
T	1	2	3	2	0.111111	0.333333					