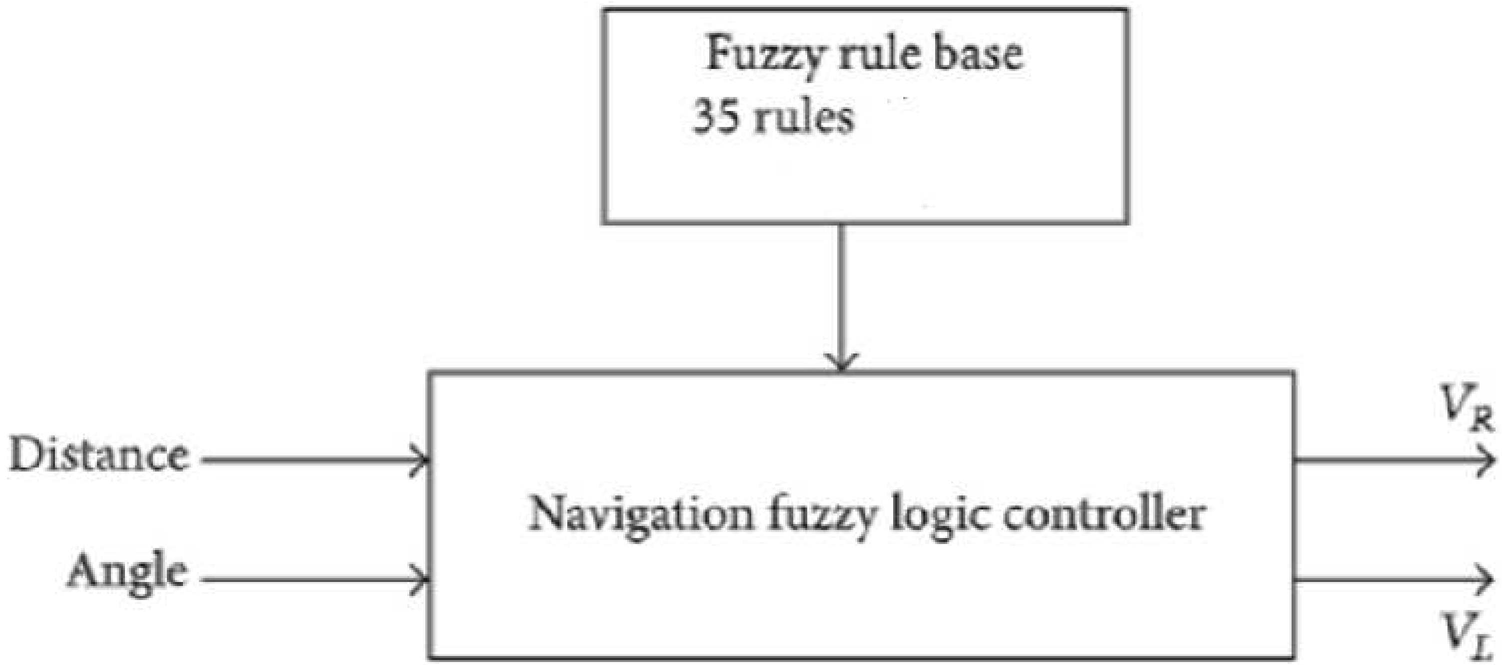

Fuzzy rule base
35 rules
Distance
Angle
Navigation fuzzy logic controller
V_R
V_L

ω_r = The speed of right wheel.

ω_l = The speed of left wheel

L = distance between wheels

R = Radius of each wheel is 6 cm.

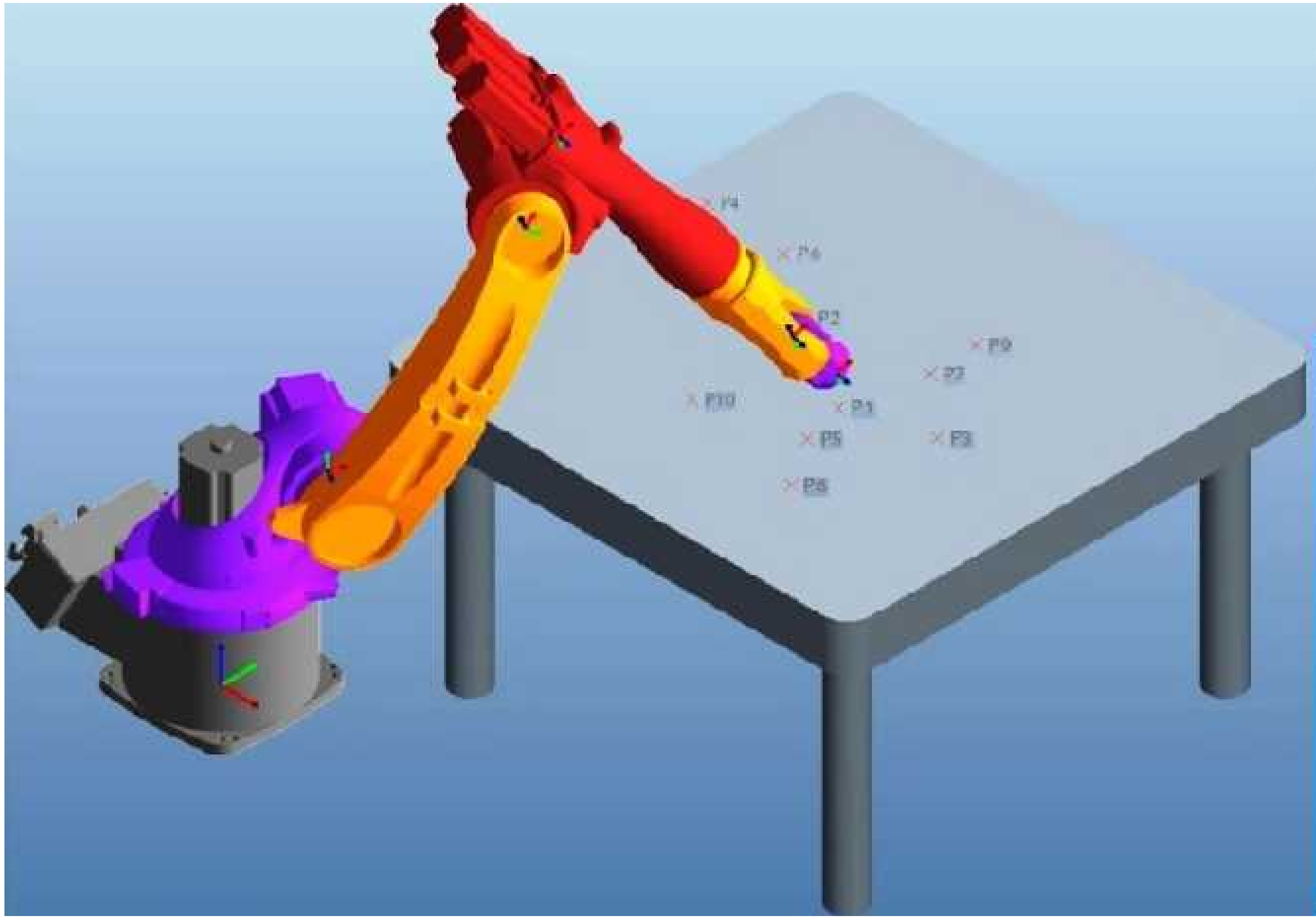
$$Angular\ velocity\ of\ the\ robot = \omega = \frac{R}{L}(\omega_r - \omega_l)$$

Angle of rotation of the robot = $\theta = \omega \times \Delta T$

Since the time interval is 1 sec. $\theta = \omega = \frac{R}{L}(\omega_r - \omega_l)$

$$Linear\ speed\ of\ the\ robot = v = \frac{R}{2}(\omega_r + \omega_l)$$

		Angle (φ)													
		NB		NM		NS		Z		PS		PM		PB	
		V_R	V_L	V_R	V_L	V_R	V_L	V_R	V_L	V_R	V_L	V_R	V_L	V_R	V_L
	VS	B	Z	M	Z	F	Z	S	F	Z	F	Z	F	Z	M
	S	VB	Z	B	Z	M	Z	S	F	Z	M	Z	B	Z	VB
Distance (D)	M	VB	Z	VB	Z	B	Z	M	M	Z	B	Z	VB	Z	VB
	B	VB	Z	VB	Z	VB	Z	B	B	Z	VB	Z	VB	Z	VB
	VB	VB	Z	VB	Z	VB	Z	VB	VB	Z	VB	Z	VB	Z	VB



Points	X_a	Y_a	Z_a
P_1	0.08	0.1	1.2
P_2	0.09	0.11	0.2
P_3	0.02	0.11	1.25
P_4	0.4	0.125	1.2
P_5	-0.5	-0.127	0.127
P_6	0.2	0.115	0.127
P_7	0.25	0.115	0.2
P_8	0.125	0.5	0.105
P_9	0.18	0.3	0.105
P_{10}	0.19	0.12	0.207

Motors	Axis rotation (°)			Rotation velocity (°/s)	Rated output of motor (W)	Energy consumption of motor (W.s/°)
	ϑ_i	$\theta_{i, min}$	$\theta_{i, max}$	v_i		EP_i
θ_1	310	−155	155	90	280	3.1111
θ_2	245	−65	180	90	190	2.1111
θ_3	173	−68	105	90	240	2.6666
θ_4	700	−350	350	120	100	0.8333
θ_5	360	50	310	120	60	0.5
θ_6	700	−530	170	190	50	0.2631

$$R_{\mathrm{PTP}} = \sum_{i=1}^{n} \left| \theta_{i,j} - \theta_{i,j-1} \right|$$

Points (j)	θ_1 (°)	θ_2 (°)	θ_3 (°)	θ_4 (°)	θ_5 (°)	θ_6 (°)
1	82.96	50.39	−165.65	−305.56	−134.13	−54.44
2	82.88	−7.84	90.08	−139.00	84.70	55.62
3	−7.82	150.31	11.73	82.95	79.09	−297.32
4	15.42	109.37	−0.78	−3.84	179.00	−298.37
5	−153.10	32.55	62.70	259.50	96.55	−118.21
6	12.49	−17.63	74.53	262.34	216.91	−375.83
7	14.66	−5.46	79.98	249.74	206.47	−375.86
8	78.66	17.58	60.21	219.04	162.09	−375.74
9	63.07	6.77	75.65	199.34	142.18	−371.24
10	34.38	8.27	92.79	184.11	114.27	−371.34

Task Planning of Robot using Clustering Algorithm

Problem Definition:

	[30-70] Reach	[0.2-0.9] Accuracy	[10-35] Gripper force
1	36	0.80	26.00
2	67	0.90	32.00
3	34	0.30	35.00
4	69	0.40	23.00
5	34	0.20	27.00
6	49	0.80	25.00
7	53	0.60	11.00
8	66	0.88	18.00
9	62	0.51	23.00
10	54	0.29	20.00

	1	4	C1	C2	C11	C22
1	0	1.01	0.4	0.729	0.546	0.667
2	0.82379	0.8	0.906	0.624	1.056	0.592
3	0.80144	1.01	0.438	0.985	0.294	0.961
4	1.01072	0	0.820	0.347	0.896	0.404
5	0.85953	0.93	0.485	0.928	0.342	0.917
6	0.32096	0.77	0.485	0.459	0.658	0.392
7	0.78275	0.69	0.784	0.467	0.892	0.468
8	0.83147	0.72	0.956	0.435	1.116	0.419
9	0.7754	0.24	0.627	0.148	0.732	0.185
10	0.88435	0.43	0.612	0.489	0.635	0.515

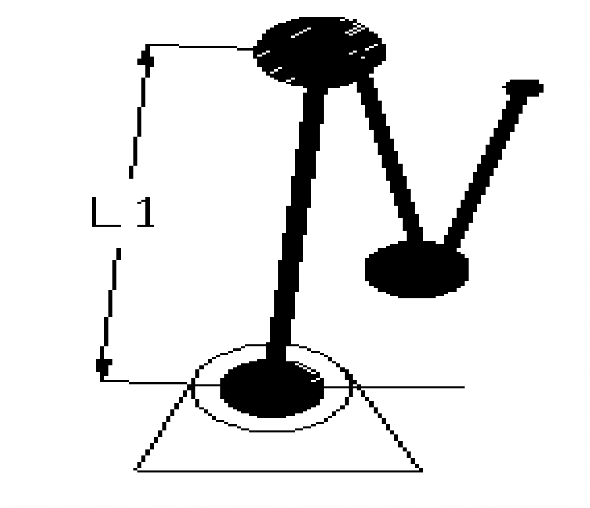
C1	38.18	0.53	28.25
C2	61.71	0.60	21.17
C11	34.67	0.43	29.33
C22	59.86	0.63	21.71

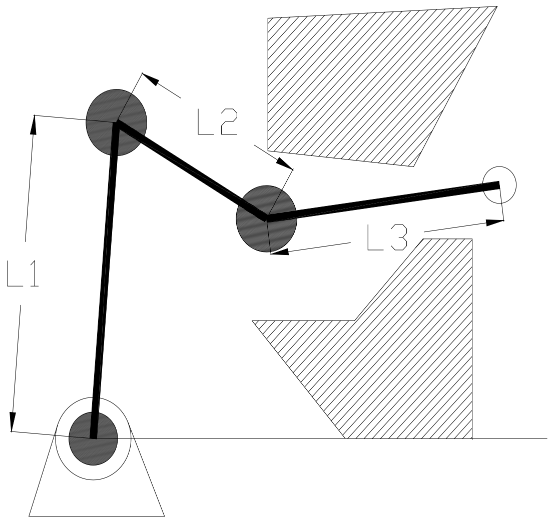
Obstacle Avoidance Robot Manipulator

- The applications of industrial robots in the field of manufacturing are increasing due to their autonomy, flexibility, and self governing work in different environments.
- In most of manufacturing applications such as material handling, assembly, spraying, spot welding, riveting, molding, etc., these robots has to perform the tasks under the conditions of restrictions. Therefore motion control of manipulator movements in an environment with obstacles is of increasing importance.

- The non-redundant manipulators are not sufficiently effective as they cannot perform complex movements under the conditions of the restrictions.

- To overcome this difficulty, robots should possess at least one degree of-freedom more than the number required for the general free positioning, i.e. they should be redundant.

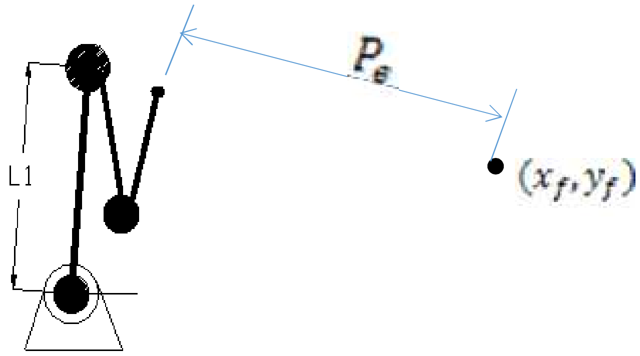

L 1

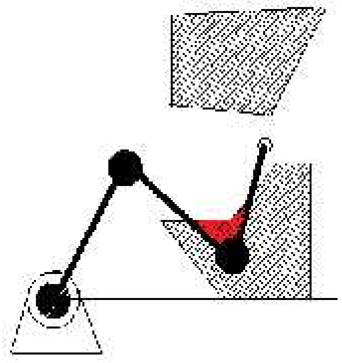

L2
L1
L3

Definition of problem

- The inverse kinematic problem of a redundant manipulator is highly nonlinear. Hence number of inverse kinematic solutions may become infinite and closed form solutions are impossible to find in general.
- Secondly, the conventional linear PID controllers are not adequate for precise control of redundant robot manipulators.

Obstacle avoidance Model





Minimize $P_e = \sqrt{(x_c - x_f)^2 + (y_c - y_f)^2}$

Where $x_c = \sum_{i=1}^{N} L_i \cos\theta_i$ **and** $y_c = \sum_{i=1}^{N} L_i \sin\theta_i$

Subjected to $A_{overlap} = 0$

With penalty
Objective function $Z = \sqrt{(x_c - x_f)^2 + (y_c - y_f)^2} + p * A_{overlap}$

Determination of Overlap area

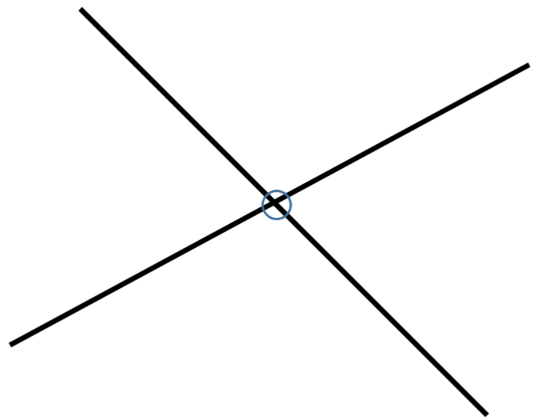
1. Identification of the point of intersection

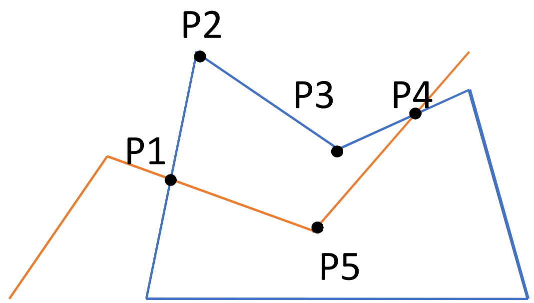
2. Identification of boundary line segment

3. Identification of overlap region

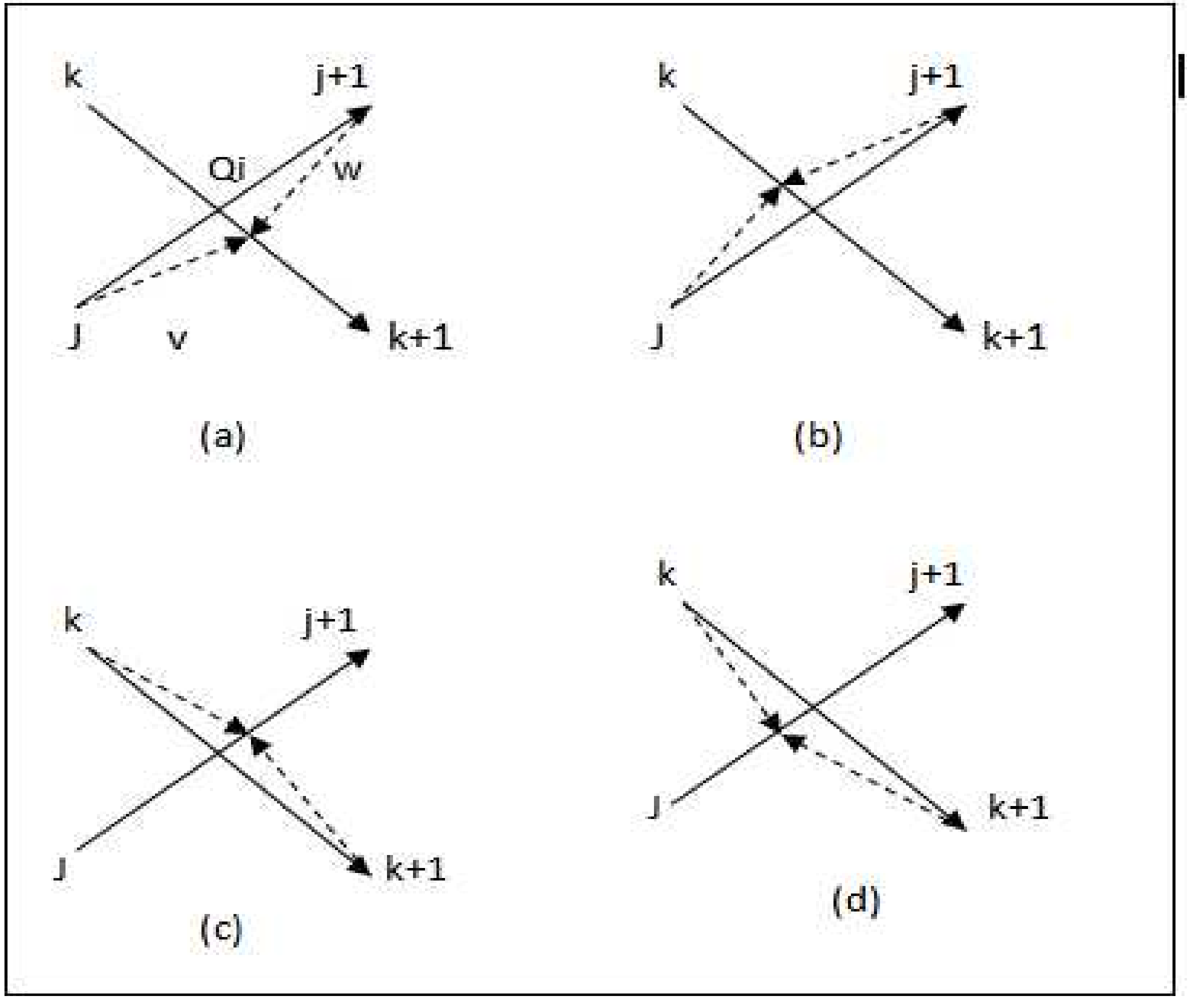
4. Calculation of overlap area

1. Identification of the point of intersection



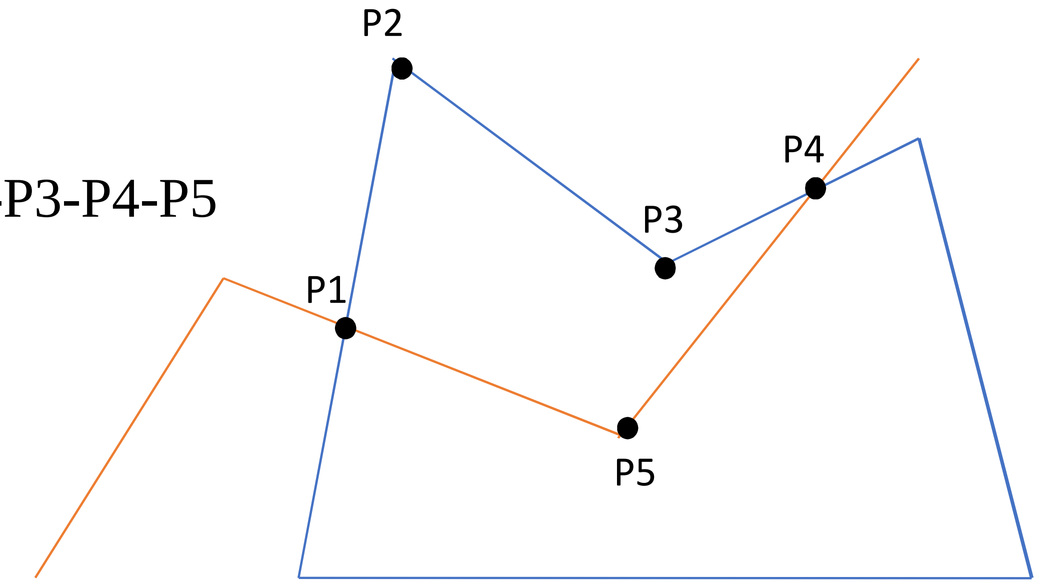


Identification of boundary line segment (Jain et al., 1992)

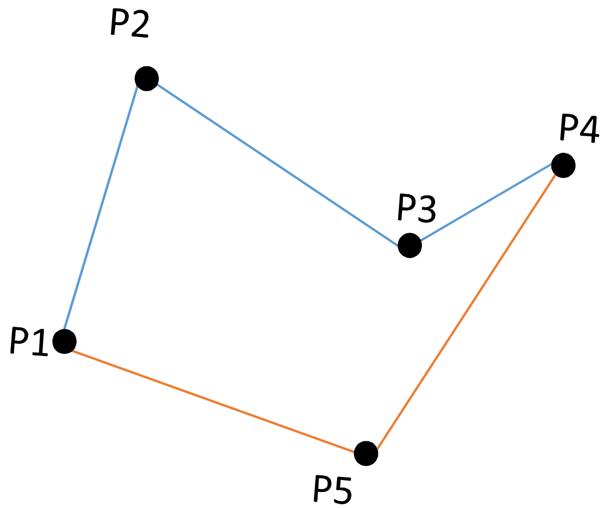


3. Identification of overlap region

Overlap region - P1-P2-P3-P4-P5



4. Calculation of overlap area

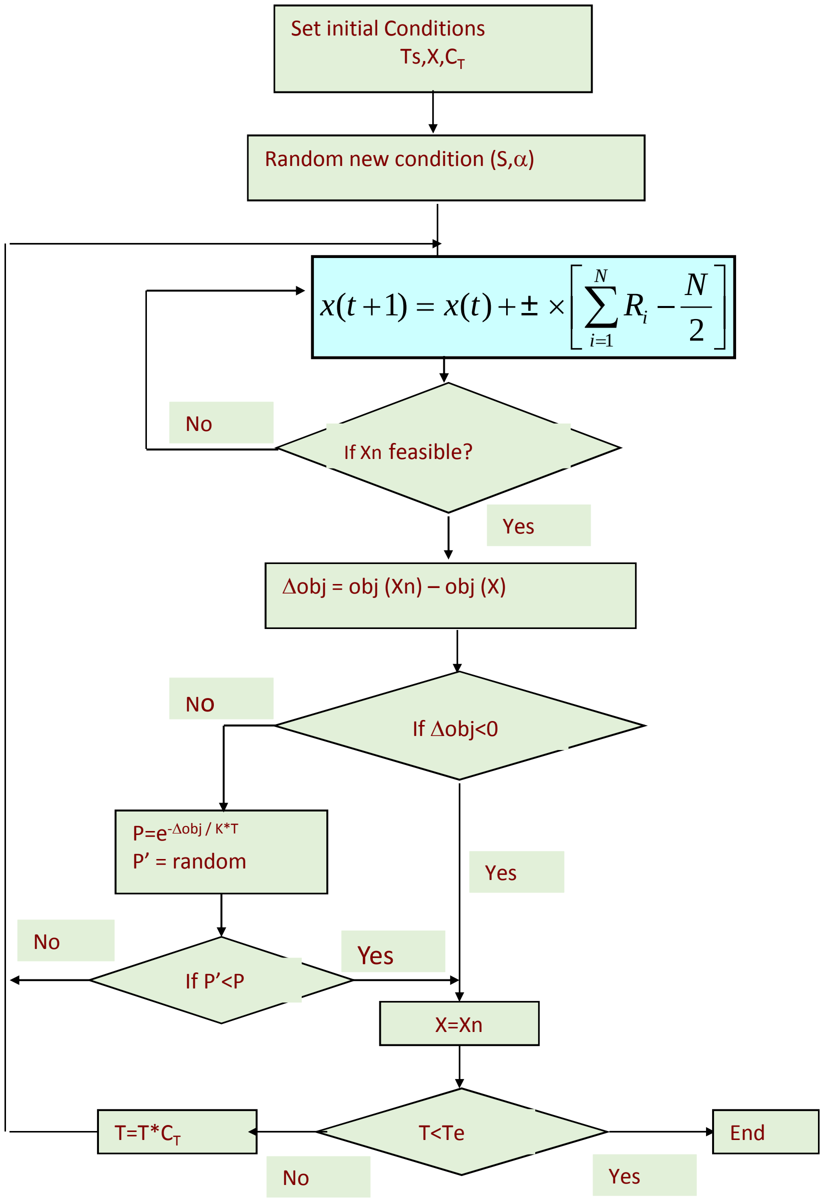


$$A_{overlap} = \frac{1}{2}\sum x_i(y_{i+1} - y_i) - y_i(x_{i+1} - x_i)$$

Simulated Annealing (SA)

- The simulated annealing algorithm developed by Kirkpatrick *et al.* (1983) resembles the cooling process of molten metals through annealing.
- The cooling phenomenon is simulated by controlling a temperature like parameter introduced with the concept of Boltzman probability distribution.
- If ‘i’ is the current configuration with cost C(i) then probability of accepting ‘j’ as next configuration with is:

$$\Pr\{new = j \mid current = i\} = \begin{cases} 1 & if \quad \Delta C \le 0 \\ e^{-\Delta C/T} & otherwise \end{cases}$$


Set initial Conditions
Ts,X,C_T
Random new condition (S,α)
$x(t+1) = x(t) + \pm \times \left[\sum_{i=1}^{N} R_i - \frac{N}{2} \right]$
No
If Xn feasible?
Yes
Δobj = obj (Xn) – obj (X)
No
If Δobj<0
$P=e^{-\Delta obj / K*T}$
P' = random
Yes
No
Yes
If P'<P
X=Xn
T=T*C_T
T<Te
End
No
Yes

The specifications of manipulator considered in this example are given in the Table 1.

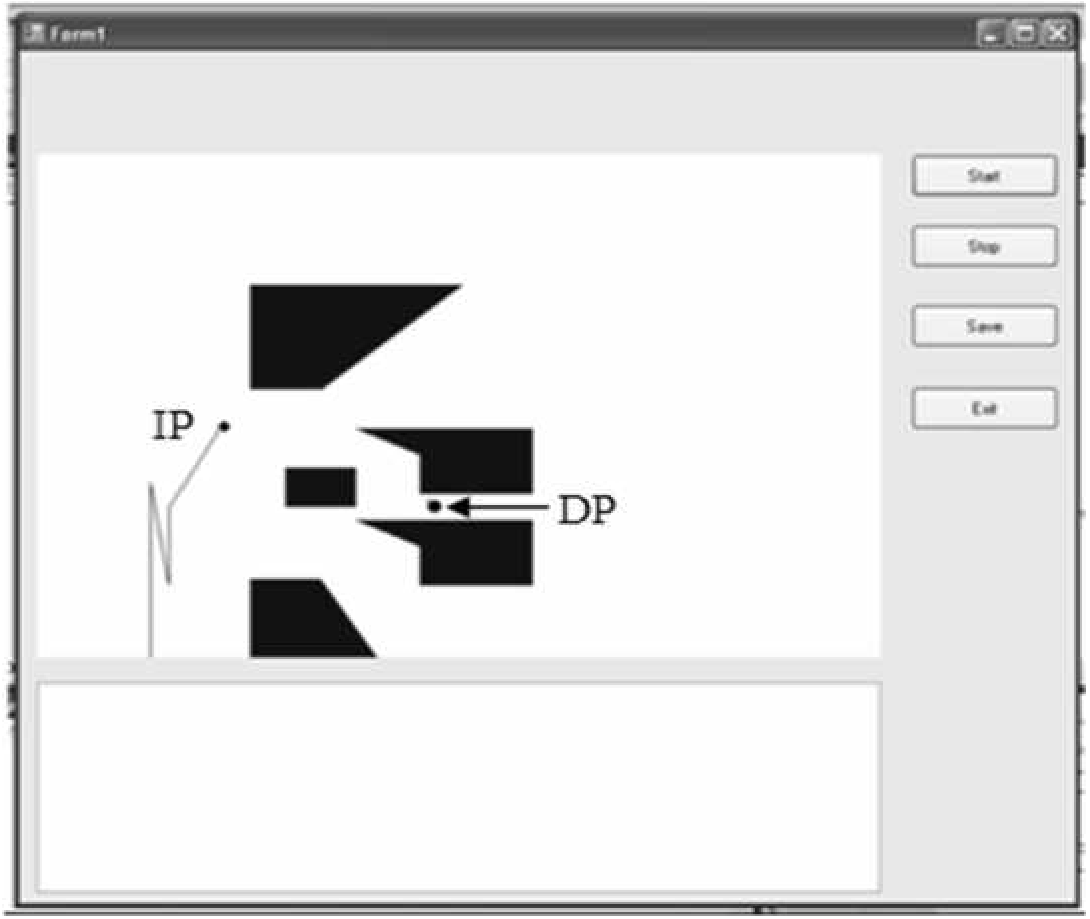
Number of manipulator links = 4

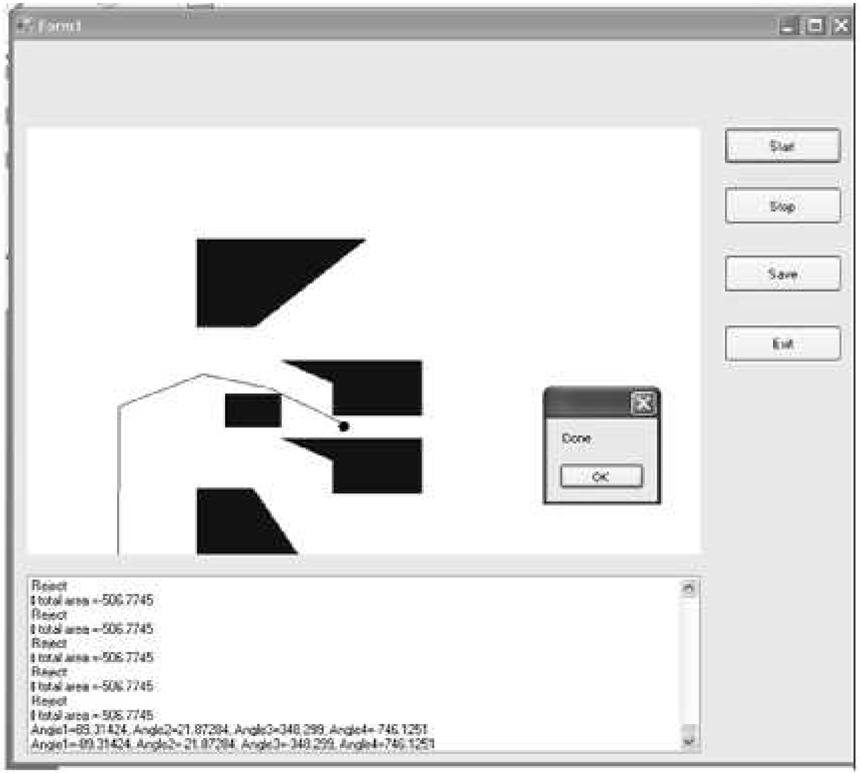
Initial position defined [X_c, Y_c] = [48.892, 191.335]

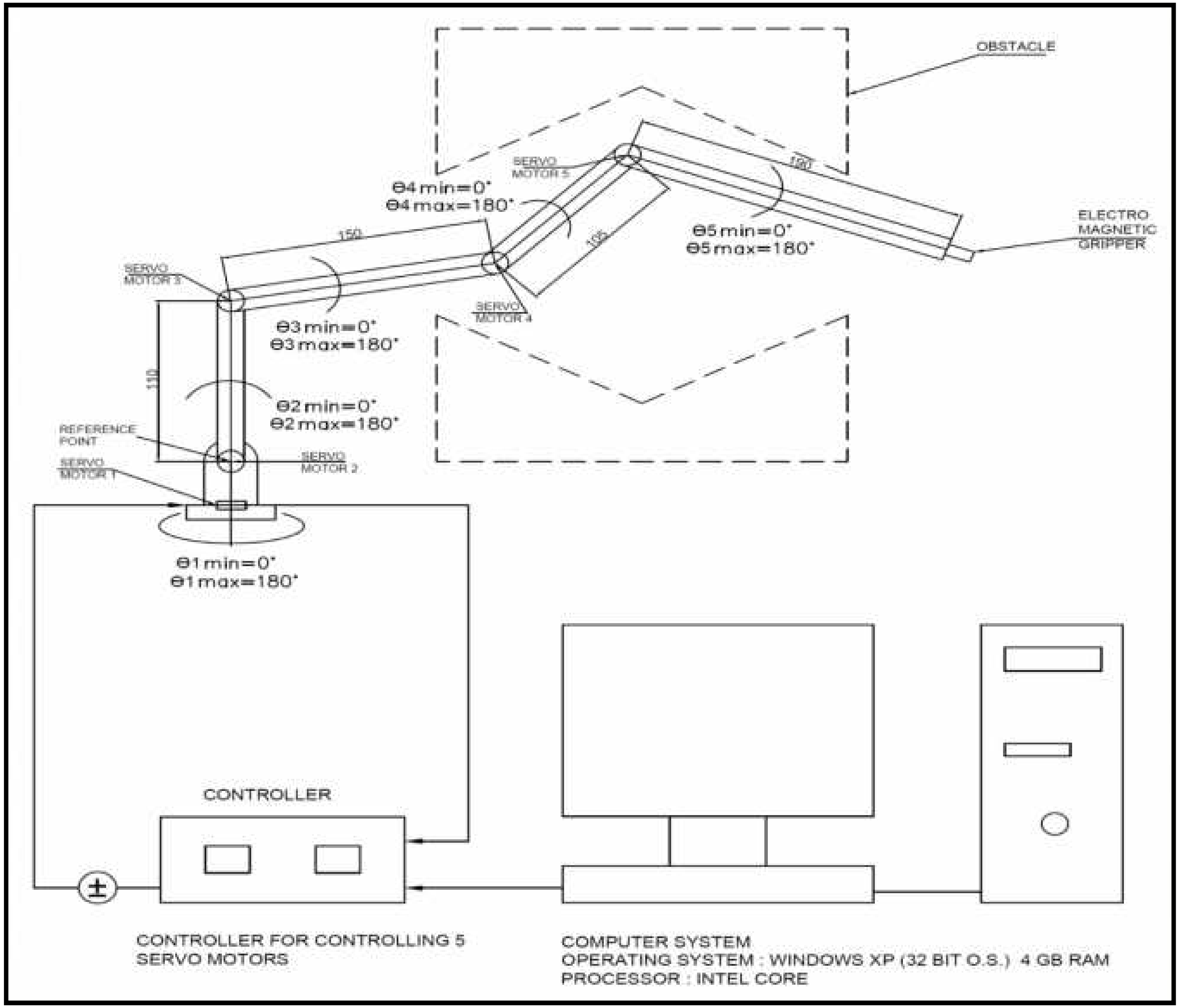
Desired position (DP) [X_f, Y_f] = [195, 136]

TABLE 1 Manipulator link specifications considered in example

Link number (i)	*Length of the link (L_i)*	*Initial angle (¯$_i$)*
1	150	90
2	80	280
3	60	90
4	70	60


Form1
Start
Stop
Save
Exit
IP
DP


Start
Stop
Save
Exit
Done
OK
Reject
total area =-506.7745
Reject
total area =-506.7745
Reject
total area =-506.7745
Reject
total area =-506.7745
Reject
total area =-506.7745


OBSTACLE
SERVO MOTOR 5
Θ4 min=0°
Θ4 max=180°
150
190
105
Θ5 min=0°
Θ5 max=180°
ELECTRO MAGNETIC GRIPPER
SERVO MOTOR 3
SERVO MOTOR 4
Θ3 min=0°
Θ3 max=180°
110
Θ2 min=0°
Θ2 max=180°
REFERENCE POINT
SERVO MOTOR 1
SERVO MOTOR 2
Θ1 min=0°
Θ1 max=180°
CONTROLLER
CONTROLLER FOR CONTROLLING 5 SERVO MOTORS
COMPUTER SYSTEM
OPERATING SYSTEM : WINDOWS XP (32 BIT O.S.) 4 GB RAM
PROCESSOR : INTEL CORE

Servo motors

Servo motors are generally an assembly of four things: a DC motor, a gearing set, a control circuit and a position-sensor. The position of servo motors can be controlled more precisely than those of standard DC motors, and they usually have three wires (power, ground & control). Power to servo motors is constantly applied, with the servo control circuit regulating the draw to drive the motor. However, due to servo motor angle of rotation of manipulator links is restricted to 180°.

The specifications of the servo motor selected are as below:

- Torque capacity: 16 Kg-cm
- Operating temperature: 10-60°C
- Operating features: Double ball bearing, metal gears,

Controller

The controller specifications for 5 axis robot manipulator developed are as follows:

Reach:	550 mm in any direction; 180 degree rotation fourth and back
Repeatability error:	0.20 mm
Maximum speed	15°/sec for link1, 90°/sec for other links
Max torque	16 kg-cm
Power:	110/240v ac 420VA (standard controller)
Temperature range:	10 - 60°C (wider range optional)
MTBF:	5000 hours
Drives	Servo motors
Gripper	High power electro-magnet

Use A* algorithm to determine the shortest path for an automated guided vehicle while moving from work station at (4, 6) to workstation at (1, 1) shown in Fig. below. The obstacles are in the form of tool storage racks at locations (3, 3), (1, 4) and (4, 2).

(1,1)	(2,1)	(3,1)	(4,1)
(1,2)	(2,2)	(3,2)	(4,2)
(1,3)	(2, 3)	(3,3)	(4,3)
(1,4)	(2, 4)	(3,4)	(4,4)
(1, 5)	(2,5)	(3, 5)	(4,5)
(1,6)	(2,6)	(3,6)	(4,6)

	1	2	3	4
1	(1,1)	(2,1)	(3,1)	(4,1)
2	(1,2)	(2,2)	(3,2)	(4,2)
3	(1,3)	(2, 3)	(3,3)	(4,3)
4	(1,4)	(2, 4)	(3,4)	(4,4)
5	(1, 5)	(2,5)	(3, 5)	(4,5)
6	(1,6)	(2,6)	(3,6)	(4,6)

	g	h	Total
4,5	1	7	8
3, 6	1	7	8
3, 5	2	6	8
4, 4	2	6	8
3,4	3	5	8
3,6	0	7	7
2,5	3	5	8