high dexterity and large workspace. The detail descriptions of the selected materials are presented in the subsection.

3.2.1 Description of planar 3-dof revolute manipulator

A planar robot manipulator is can be made of serial chains with revolute or prismatic joints. Planar 3-dof revolute manipulator is basically constructed by three revolute joints. All the links or rigid bodies of a serial chain are constrained to rotate in same plane or parallel to each other. A planar manipulator can only have revolute or prismatic joints. Indeed the axes of all revolute joints should be perpendicular to the planar chain while the axes of prismatic joint should always parallel to the planar chain. Joint variables and parameters of 3-dof planar manipulator are given in Table 3.2. Main aim of this chapter is to provide details study of selected manipulators for the kinematic analysis and position of the end effector at the desired point. This section deals with the different types of planar manipulator and selection of appropriate planar manipulator for the kinematic analysis.

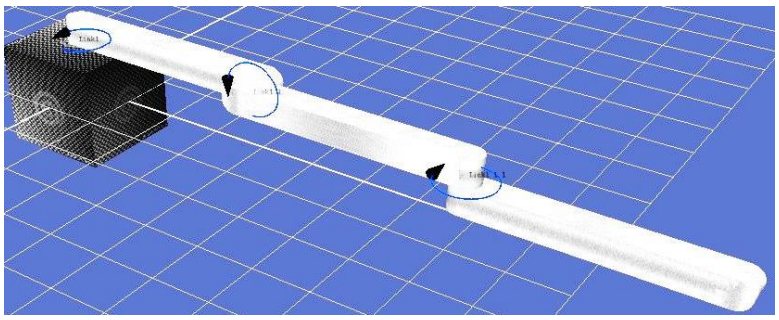

Figure 3.1 Model of 3-dof revolute manipulator

Table 3.2 Manipulator joint limits and kinematic parameters

Sl.	θ_i (degree)	d_i (mm)	a_i (mm)	α_i (degree)
1	$\theta_1 = \pm 180^0$	0	a_1= 100	0
2	$\theta_2 = \pm 180^0$	0	a_2= 70	0
3	$\theta_3 = \pm 180^0$	0	a_3= 50	0

The mathematical modelling of higher dof or spatial manipulators is quite lengthy and time consuming. Planar manipulators are simple to figure kinematic relationship as well as for mathematical modelling. The planar manipulators examples represent the foundation for designing, kinematic analysis and for controlling purpose without consumption of time in mathematical expressions. However, this deals with the kinematic analysis of planar manipulator but the spatial description can also be

prolonged. We will start with the example of the planar 3-dof revolute manipulator as shown in Figure 3.1. There are many industrial manipulators available which resembles 3-dof revolute planar configuration. For example, swivel of shoulder, extension of elbow and pitch of Cincinnati Milacron T3 manipulator can be treated as 3-dof planar manipulator. Similarly, in case of SCARA manipulator without considering of prismatic joint will resemble the 3-dof revolute manipulator just to move end effector in up or down position. Thus, it is useful to consider 3-dof revolute planar manipulator for the inverse kinematic analysis.

The 3-dof revolute planar manipulator can be geometrically specified with the link lengths a_1, a_2 and a_3. These links length are basically variables which depend on the configuration of robot manipulator. The links lengths can be define in many ways but the precise way is the most distal link from distal joint axis to the end effector point or tool point. Other important variables are coordinate points of the end effector which represents the position and orientation of the end effector. The positions are defined as the coordinates (X and Y) while orientation can be define as ϕ angle. The overall variables (X, Y and ϕ) defines the pose (position and orientation) of the end effector. The proper definition of these variables and parameters can be found in the next chapter. The other possible configuration of planar manipulator can be R-P, P-P, and P-P-P. In this thesis 3-dof revolute planar manipulator is considered for the further kinematic analysis and the detail mathematical modelling of the manipulator is presented in next chapter.

3.2.2 Description of 4-dof SCARA manipulator

The second selected configuration for forward and inverse kinematic analysis is Adept One SCARA manipulator. The SCARA (Selective Compliant Assembly Robot Arm or Selective Compliant Articulated Robot Arm) has an RRPR structure. This manipulator having 4 joint axes consisting three revolute and one prismatic joint which is unlike from the spherical robot manipulator with different applications. The joints first, second and fourth are revolute and their joint is prismatic see Figure 3.2 for overview. The joint variable and related kinematic parameters for inverse kinematic solution are presented in Table 3.3. The joint motions of Adept One SCARA manipulator can be described as:

(a) Joint 1 motion

Joint 1 which is also known as shoulder swivel gives the freedom for rotation of inner link and the column and the range of the rotation is 300^0.