10. CONCLUSIONS AND SCOPE FOR FURTHER WORK

10.1 CONCLUSIONS
The analysis, design and experimental verification of three robot manipulators namely a new mechanical manipulator, a swing motion manipulator and a new biped robot are presented in the thesis. Section A illustrates the detailed discussion about the proposed manipulation robot and a swing motion manipulator. The major problems like work volume and work envelope, structural stability, accuracy and repeatability of the existing configurations are identified and resolved in proposed manipulator configuration. The key problem such as the cantilever action of existing configuration is avoided in the proposed manipulator configuration by bringing the fulcrum in between the load and applied force, which almost simulates the human arm in a real way. The robot manipulator operates with three rotational degrees of movements and it has a unique position of the end-effector for particular angles of rotation. The work volume is simulated using computer graphics and a partial spherical work volume is obtained. The work volume of the proposed model is having a normalized volume index of 0.808, which is greater than any other existing configurations.

The direct and inverse kinematic problems are analyzed for the proposed configuration. The relevant kinematic equations are formulated from the geometry of configuration as well as Denavit and Hartenberg conventions. The formulated equations are used to verify the results with computer simulation. Similarly the relevant inverse kinematic equations are formulated and verified. The equations for velocity and acceleration of links are also
developed as a part of kinematic analysis. The determination of velocity and acceleration helps to design velocity/acceleration compensations.

An experimental model is fabricated in the laboratory to test the validity of the proposed configuration. The maximum error found in the experimental results is about 3.66mm, which is equivalent to 6% of the analytical value. The error of 3.66mm is found in one direction only. In the other two directions, the error ranges from 1.19mm to 2.86mm. The error is attributed to mechanical inaccuracies such as backlash error, joint error of precision fabrication. These errors can be minimized by appropriate manufacturing methods. The work volume and work envelope of the experimental model are verified with the analytically obtained results (Refer Fig 4.10 to Fig 4.14).

If a robot requires a large workspace in the order of meters, it is difficult to achieve with a conventional manipulator due to mechanical limitations such as the link length. Hence, a new swing motion manipulator is analyzed and fabricated. The configuration of swing motion manipulator is almost the same as the proposed mechanical manipulator except the forearm is replaced by a string. The elbow of the manipulator can be thrown out so that the string stretches outwards to reach the distant object. Simultaneously, it can be rotated so that a wide range of objects can be reached in three-dimensional workspace. This has greater applications for collecting objects such as garbage floating on the sea, removing rubbles in disaster-stricken areas or collecting various kinds of fruit in agriculture etc. The relevant equations to reach the three-dimensional trajectory point are analyzed for the
present configuration The torque required for particular movement is also derived from the fundamental principle. To validate the analytical results, an experimental model is fabricated in the laboratory. The test results are also included.

An investigation on pneumatically operated new biped robot is carried out and presented in section B. The stability of the biped robot is more complex compared to any other walking machines. The existing biped robots have six degrees of freedom and six degrees of movement for each leg. Many researchers have attempted to visualize two-legged walking machines for a stable movement. A simple four degrees of freedom, two-legged walking machine has been analyzed from the fundamental principles. A moving weight is used to bring stability to the robot on one-legged footing. The weight is moved from left to right and vice versa to bring down the center of gravity of the footing leg. The robot is operated by lifting one leg and rotating about the axis of the other footing leg for a forward motion and then bringing down the leg. The alternate movement of right leg and left leg makes the robot to move forward.

The static and kinematic analysis of the proposed robot is carried out for determining the stability and coordination of the legs. The moving weight is an important factor to be considered for stability of the biped robot. The optimum weight for the stability of the biped robot is determined from the static analysis and then stroke length for the weight to be moved is determined. The angular displacement and lift of the leg are also important for smooth walking. In view of the smooth walking, direct and inverse kinematic equations for the proposed robot are formulated.
A sequential pneumatic control system is designed and included. A full working model of the system is fabricated in the laboratory and tested. A simple six-port control valve is designed and fabricated in the laboratory for the manual operation of the robot. The fabricated robot is allowed to walk through smooth surface effectively. The biped robot is expected to walk on a rough terrain and climb the staircases. The robot is tested for walking on a surface with an angle of slope 8°. It is also tested to walk on a step of rise 10mm. The proposed model is an experimental one to demonstrate the functional feasibility.

10.2 SCOPE FOR FURTHER WORK

In the thesis, analysis, design and fabrication of three robot configurations are presented in two sections A and B. The section A demonstrated the feasibility study of a new configuration of mechanical manipulator. The direct and inverse kinematic analysis are carried out and validated through experimental verification. A simple model is fabricated in the laboratory for the experimental purpose. The fabrication of a full size mechanical manipulator and its feasibility study for multipurpose applications are to be investigated. The joints such as higher pair, sliding pair are to be modeled and analyzed properly so that the accuracy of the end-effector position can be improved. The proper manufacturing techniques are to be investigated for developing the accurate joints. The development of control strategy with appropriate sensors is most important. An investigation in this area is also required.

An investigation is required for the fabrication of full size biped robot with sensors. The walking can be performed automatically.
by providing limit switches. The force sensors can also be mounted on the joints of biped robot in order to balance it during walking on a rough terrain.