Chapter 9  CONCLUSIONS

9.1 Introduction

For the presented work, rate of development and newer findings are very rapid during last few years. The various work planned by every researcher and scientists are as per the specific application. Most of the time those are for prosthetic, military, and humanoid projects and some times for industrial application. Therefore it is observed that application is a parameter which forces the direction and depth in the area of MRG system’s research.

Accordingly, the experimentation was planned for the sorting operation of the grasped objects with an objective of application oriented programming. It has been found that the repeatability is satisfactory for all the measurements.

9.2 Summary

Design, development, analysis of system and experimentations of the fabricated MRG is of considerable high work volume. Integration of the MRG system which includes several sensors and electronic components with online monitoring of the total grasping cycle is very tough task. It is achieved satisfactorily and experimentations are conducted as per the requirement. Though normal robotic gripping is observed by the many researchers, scientist and industries, the dexterous grasping with biomimetic approach is observed for few cases, as per the literature survey completed before and during this work.

This total work contributes to major sectors of robotics such as

1. Efficient material handling,
2. Development of sensors for online controlling action,
3. Biomimetic approach during designing of the robotic systems
   (Sequence of finger actuation and hand – eye coordinated type of action at dexterous grasping by multifingered grippers)
4. Online monitoring of grasping force for the control on the applied force,
5. Online monitoring of the contact deformation of the objects being grasped,
6. Image processing using vision sensors and use of its feedback at grasping,
7. Design, Development, Analysis and Fabrication with the help of easily available sources and economical set-up.

8. Multi-sensor systems with effective use of each at different decision making major stages with logical decisions due to appropriate programming.

The refined stages for the grasping action by MRG fingers at final experimentation are as below:

I. Actuation of Middle Finger before Thumb at the start of grasping

II. Grasping completes with the help of only two exactly apposite fingers. (i.e. Middle Finger and Thumb of MRG)

III. First finger of MRG gets actuated and completes the grasp. It considers the total deformation observed by camera and decides the grasping position i.e. force for gripping. This completes a normal and safe grasping. This is exactly as per the human action observed for grasping the object. (for all moderate conditions of size, shape and weight) Also for delicate object like foam this stage takes concern of vision sensor similar to that of hand-eye coordinated movements in case of human hand grasping.

IV. Third finger which is at the bottom side of the gripper at grasping condition [ref fig 8.2 c of chapter 8] gets actuated only when the slipping is observed during the lifting and carrying of the object by the MRG. It ensures additional reserved force application and attempts to avoid slip. This is again as per the biomimetic action embedded in the programme as per the objectives of this work. This stage is for perfect and safe grasping. This action is expected for two reasons, first a slippery surface and second is excess weight.

V. Though the grasping action is stage wise; release of object at the time of placing it in the appropriate bin is comparatively less serious. Once the object is placed in the proper bin further action is without any sensor. The distance measured and
the placing of object at suitable height is taken care at robot main programming. All the fingers gets actuated for retaining their original position before grasping.

The planned trials were conducted, errors were observed and necessary corrections in the settings are incorporated accordingly. Therefore this MRG system can be termed as a gripping system with biomimetic action.

After summarizing the discussions on the basis of experimentations and the results obtained from the last chapter, following conclusions are drawn:

9.3 Conclusions

- The objectives decided in this presented work are completed satisfactorily. The total work was planned for the improvements in the grasping modality. The findings and the suitable decision for the objectives focuses a light on the work completed. The improvements expected in effective and dexterous grasping by Robot gripper were obtained.

- Several crucial decisions and selections are carried out during this work. Those were proper selection of mechanism for gripping with biomimetic approach, selection of appropriate sensors for feedback, various essential analysis of the developed system before manufacturing and after manufacturing the complete system, integration of the systems (Actuators & sensors on MRG, Controller for MRG, Robot arm and Robot controller) and most important amongst this was an effective programming at MRG controller and Robot arm controller.

- Mechanism is selected carefully for MRG. It is so selected that it is most updated, combining the advantages of all existing grippers, economical and can support biomimetic approach with simpler actuation and control possibilities.

- Sensors selected are appropriate and gives online and real time feedback for better control. They are economical, easy for installations and easy for obtaining the required response. Advanced sensors such as PZT, IPMC, and CNT are also studied and few of
them were tested and calibrated as well. Since the results obtained were not satisfactory, the conventional sensors such as ultrasound sensors and infra red sensors were selected along with force sensor of pressure sensing gel type which caters all types of needs. The vision sensor selected is simple webcam for easy focusing, user friendly mounting and operations.

- The task decided in the objective about size and deforming surface are the only criterion, which are found to be more relevant for the experimentation. Hence three different object (i.e. Wood, Plastic, and Foam) with these varying parameters (i.e. diameter & Weight) are considered for experimentation. Foam being used as a term resembling a sponge in elasticity, absorbency, or porousness, it is referred for more deformable object. Hence three different types of foam are selected for understanding its effect of change of shape at Image processing.

- Results of various analysis were of confirmative and supportive types. Those are discussed in the chapter 7 in detail.

- The total experimentations lead to the conclusions that the system thus designed manufactured, analyzed and tested, works effectively and with satisfactory level of performance.

- The performance indicator required for grasping are achieved above satisfactory level. (ref. graph of fig. 8.13) Performance of the system is similar to human hand grasping. The way, human hand responds for bigger and slippery objects, similar response is observed during the experimentations of MRG. This observation supports the implementation of biomimetic approach as well.

- Overall it can be noted that the presented work can be useful in various allied fields of robotics such as effective material handling with active grippers, prosthesis hand, humanoid robot designs, and economical grippers with biomimetic approach.
9.4 Suggestions for Future Work

The multifingered gripping in robotics is a complex phenomenon. There are always possibilities of developments due to continuous advancements in the areas of sensors, actuators, electronic components, controllers and various related softwares.

Some of the possibilities of future work in the areas covered by the presented work are mentioned below:

1. Multifingered gripper having more DOF with fewer design improvements and better actuators can offer flexibility in the grasp operation. Following two possibilities can elevate the performance of MRG
   A) Abduction and adduction movements if embedded in the action of gripper it can offer better MRG action as that of NAIST [31] and LARM hand [36].
   B) Presented work has been experimented only for planar grasping and in single posture. Testing at different position and various orientations can explore the possibilities of same MRG for a various applications. It can surely add more relevant inputs for development of universal gripper system using MRG.

2. If the MRG is tested with humanoid setup, relevant experimentations can be planned and carried out.

3. Presented work was planned for precision grasp only. Thus limitations such as slow and steady grasping become inherent part of precision grasping action. For faster action, high speed, compact and real time controlled actuators can offer more versatility in the grasping action.

   The observation from literature survey has indicated that application is a drive behind more perfection at the grasping action. Hence designing the MRG for specific task can surely improve its effective use than making it a generalized solution similar to human hand.