Preface

The twinkling of stars is no more fascinating to the astronomers. It blurs the celestial images taken with an astronomical telescope and stopes the detailed study of the celestial objects. The resolution of an ideal diffraction-limited telescope is inversely proportional to the diameter of the primary mirror of the telescope, which defines the size of the telescope. The same statement can be reframed, the performance of the telescope increases with the telescope size. But the twinkling of the stars caused by the Earth's turbulence restricts the quality of the optical ground-based telescopes. The image quality saturates at the performance of a telescope equal to the size of the atmospheric coherence length scale (r_0) irrespective of the large sizes of the telescope (D). I want to mention here the importance of the large telescope though it produces the image quality equal to r_0 sized telescope. The bigger telescope collects a large number of photons, which enables us to observe fainter stars and the deep universe. Let us understand how stars twinkle and light propagates in the homogeneous medium (identical speed of light in all direction in the medium). Any tiny/point-like source emits light, and it spreads equally in all direction (4π steradian) leads spherical wavefront (Huygens principle). Light from the celestial objects reaches all most freely up to the upper layer of our Earth's atmosphere, and the spherical wavefront converges to plane wavefront due to a small portion of the large sphere. Now, due to solar heating, the atmosphere becomes turbulent and inhomogeneous in density and leads to the different speed of the light. Thus the different points of the plane wavefront move at a different speed, direction and become distorted wavefront. The quantity of the distortion/wrinkle on the wavefront depends on the degree of atmospheric turbulence. This zig-zag path and aberrated wavefront produce twinkling of satrs.

As a solution to this problem, ironing the wavefront can be done to remove the wrinkles from the wavefront like washed clothes. The technology associated with the ironing the wavefront is called Adaptive Optics(AO). Babcock invented AO in 1953 and started implementation around three decades later after the advancement of the technology. The adaptive optics technology is an interdisciplinary subject with optical engineering, mechanical engineering, computer-software, servo system, detector, laser etc. The AO technology at first measures the distortion of the wavefront by the wavefront sensor (Shack Hartmann, Pyramid Wavefront sensor etc.) and corrects the wavefront by the deformable mirror (DM, a very thin mirror *membrane attached to an array of actuators) in a servo closed-loop control system which produces flat plane wavefront. The plane wavefront enables the maximum capability of the telescope. The sensitivity of the telescope for sources fainter than the sky background grows as the fourth power of the diameter in a turbulence-free/compensated environment instead of a square of diameter in seeing limited condition. This technology is very costly and complex to handle by small and medium-sized professional telescopes. But AO has great potential in upgrading the performance of moderate-sized telescopes (1 to 3m).*

Thus to provide the AO capabilities to the moderate-sized telescope at an affordable price robotic AO system called Robo-AO was built which was the joint venture between California Institute of Technology, USA and Inter-University Centre for Astronomy and Astrophysics, Pune, India. It is a fairly robust, laser-guided AO system; works with minimal overheads and produces moderate sky coverage, which will significantly enhance the scientific capabilities of moderate (1 to 3m class) telescopes. For the first time in India, we are going to use this sophisticated AO technology for 2m telescope of Inter-University Centre for Astronomy and Astrophysics at Girawali in Pune. It is the second version of Robo-AO called iRobo-AO keeping the predecessor's name waiting for first light.

This work presented in this thesis is completely based on the design and development of iRobo-AO telescope followed by installation and commissioning of it on the 2m telescope at the IUCAA Girawali Observatory (IGO). The thesis is organised as below. ***Chapter 1*** *contains the basic foundation and the building blocks of the AO system with description a few adaptive systems as examples. The iRobo-AO has three units: Cassegrain AO facility, laser guide star facility and near-infrared camera facility. A description of the Cassegrain AO facility is given in* ***Chapter 2****. Laser Guide Star facility for probing the wavefront which is installed at the side of the telescope tube is given in* ***Chapter 3*** *to overcome the scarcity of the guide stars. The atmosphere not only introduce aberration in the wavefront. It also introduce the dispersion which elongates the image along the normal direction to the horizon and deteriorates the resolution. To nullify the dispersion effect an atmospheric dispersion corrector is placed in AO corrected light beam path and explained in* ***Chapter 4****. The effect of atmospheric turbulence is less in the higher wavelength region. Thus in the near-infrared band, AO corrected larger field of view is found. To accommodate higher AO corrected field of view, a near-infrared camera facility for mounting at the NIR focus of the Cassegrain AO facility is* *developed and given in* ***Chapter 5****. All the work related to the commissioning is mentioned in* ***Chapter 6****. In the end, the thesis is concluded with the summary, conclusion and future scope of work in* ***Chapter 7.***