Differential Image Motion Monitor & RoboDome

Marinelle Peneda, San Diego Mesa College
Carlos Vargas-Alvarez, San Diego State University
Advisor: Dr. Paul Etzel, San Diego State University

With images of visual binaries, the plate scale of the 12" Meade telescope, in the ULTRA site was determined for use of taking seeing measurements using the DIMM. The plate scale was found to be 0.699 arcseconds per pixel with a standard deviation of 0.009. Seeing measurements from 2005 July 26 to 2005 July 29 were found to be 0.700 arcseconds per pixel.

We conducted preliminary tests on the 10" RoboDome at Mount Laguna Observatory. Initially our goal was to polar-align the telescopes to a precision suitable for observing and research; however, due to the monsoonal season and various unforeseen engineering problems, the telescope was not polar aligned.

Introduction

The Differential Image Motion Monitor was created by Armin Rest of the University of Washington that takes seeing measurements in a fully automated robotic telescope. It measured seeing in both longitudinal and transversal direction, which is the full width half maximum (FWHM) in arcseconds. Good seeing covers small pixel size thus smaller FWHM value. Good seeing is desired to obtain acceptable data. With "good" seeing, the image projected onto the CCD is a fine point with high contrast. In the case of observing a cluster of stars, with "bad" seeing the images are blurs of stars. The DIMM is located in the ULTRA site.

The RoboDome is a fully automated robotic telescope that can be maneuvered through a network. Its dome is synchronized with the telescope. The main interest for establishing the RoboDome is for increased access for persons with disabilities to comply with the US Forest Service Summer Visitors' Program, increased telescope access for SDSU Astronomy 109 Lab students and SDSU Astronomy Majors for use with their research projects, as well as access for SDSU's community college partnerships.

Set- Up of DIMM

The set-up entails placing a sub-aperture in place of the dust cap onto the telescope. The sub-aperture has four holes. Four of the holes are on an optical wedge, which is aligned to the viewfinder. The optical wedge is used to diffract incoming light to project two images on the CCD with one object in the sky. Two of the holes used for focusing remained shut while taking light images. The holes for focusing were opened for use of focusing. When focusing, four images appear on the CCD and when focused only two images appear.

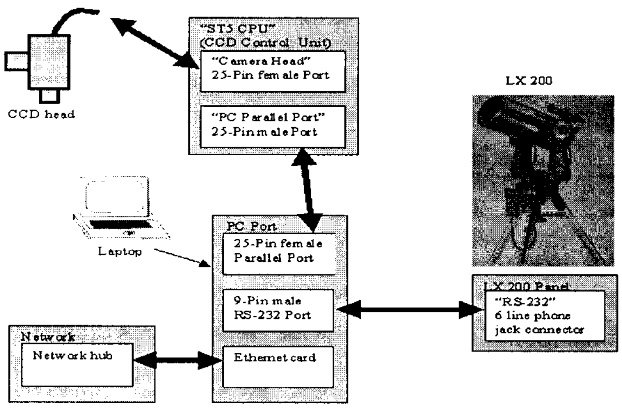


Figure 1: Basic diagram setup of the DIMM (Rest 1999).

The camera used for the DIMM was an SBIG ST-5C camera with a CCD size of 320X 240. The CCD camera was connected to the telescope in place of the eyepiece. The CCD and the telescope were connected to the laptop. The set-up is depicted in Figure 1.

Angular Diffraction Limits

By Fermat's principle, the minimum distance that a light travels is between the two apertures. Assuming perfect optical set-up and when two images are resolved, the optical path difference is approximately equal to the wavelength. Therefore, the angular resolution, $\theta_{min} \approx \lambda / D$ (Schroeder 2000), where D is the aperture diameter.

For 12" Meade (aperture separation), the aperture diameter (center to center) is 229mm and assuming the use of clear filter, we can assume λ equal to 5500 Å, thus yielding an angular resolution of 0.49" , which is a conservative measurement. Alternatively, using an aperture diameter of end to end, better angular resolution is approximately equal to 0.39 arcseconds,.

For the 1.0 meter ULTRA, the aperture diameter is 1000mm, which is the primary mirror diameter, the angular resolution was found to be 0.11 arcseconds which is not feasible on Earth.

Image Reduction

The images were reduced using IRAF. The tasks zerocombine, flatcombine, and darkcombine were used to combine bias, flat, and dark frames, respectively. The task imarith was used to normalize the flat and reduce the images.

Plate Scale

Images of visual binaries such as 24 Com, κ Her AB, 16 Cyg Aa-B, and ζ UMa AB were taken and measured their separation in pixel using IRAF's task psfmeasure. The plate scale of the telescope was found through a ratio of separation of the visual binaries in arcseconds and pixel coverage. Thus, plate scale = separation in arcseconds / pixel coverage. The visual binaries were found to have an average plate scale of 0.699 arcseconds per pixel with a standard error of 0.009 as shown in Table 1.

Star	Mag. A	Mag. B	Separation (")	Separation (pixel)	"/pixel
24 Com	5.1	6.3	20.7	19.9	0.696
κ Her AB	5.1	6.2	27.3	27.3	0.718
16 Cyg Aa-B	6	6.2	39.8	39.6	0.701
ζ UMa AB	2.2	3.9	14.6	14.3	0.695

Table 1: Listed (left) were visual binaries used to determine the plate scale.

Seeing

From 2005 July 26 to 2005 July 29 seeing measurements were taken using the DIMM with a plate scale of 0.700 arcseconds per pixel. Furthermore, seeing measurements were taken using Vega and Arcturus. Figure 2 illustrates good seeing measurements at the ULTRA site with an average seeing of 0.68 arcseconds on 2005 July 28, 0.74 arcseconds on 2005 July 26, and 0.91 arcseconds on 2005 July 29 with a combined average of 0.78 arcseconds. Higher percentage of humidity contributes to greater value in FWHM, hence "bad" seeing. It was noted on the night of 2004 July 29 that the humidity was 69% that account for greater seeing of 0.91 arcseconds, which is comparatively greater compared to the previous nights with averages of 0.74 arcseconds and 0.68 arcseconds with

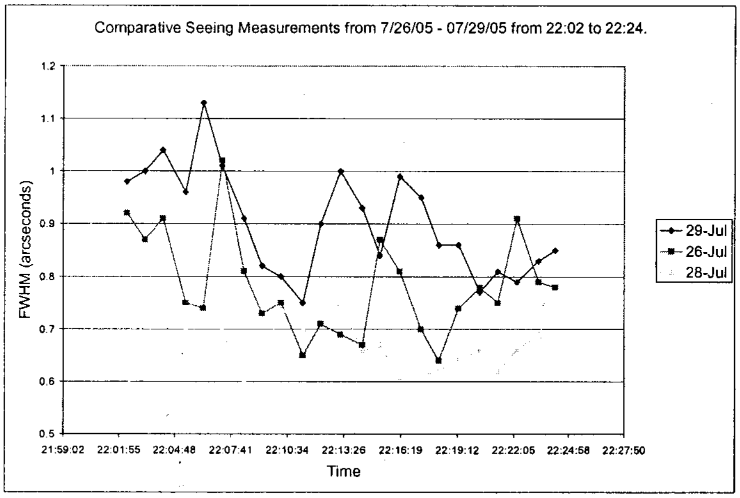
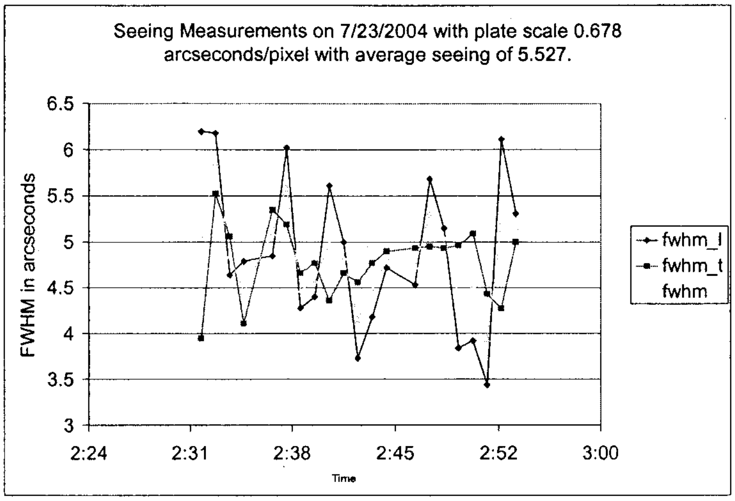


Fig. 2: Seeing measurements taken from 2005 July 26- 29 with plate scale of 0.700 arcseconds per pixel.

about 50% humidity. Although, seeing measurements obtained from 2005 July 26 to 2005 July 29 were relatively good seeing.

On some nights, Santa Ana winds blowing from the northeast worsened the angular resolution. On 2004 July 23, one of the worst seeing measurements were obtained at the ULTRA site. The average seeing on that night was 5.53 arcseconds using a plate scale of 0.678 arcseconds per pixel, as shown in Figure 3.

Fig. 3: Seeing measurements obtained on 2004 July 23 with plate scale of 0.678.



RoboDome Components

The RoboDome has several devices such as the RoboFocus, SBIG ST-10XME, weather station, and digital dome works. The RoboFocus is a high precision focuser in both manual (hand controller) and automatic (computer). Digital dome works is the central control unit for all the devices within the dome.

Preliminary Methods for Polar Alignment

Preliminary procedures such as aligning the viewfinder with the eyepiece, balancing the telescope, and positioning wires to minimize dragging of the telescopes were performed prior to polar aligning the telescopes.

Aligning the viewfinder with the eyepiece or CCD camera entailed aligning the images in the viewfinder and centering the image in the CCD camera or eyepiece so that when polar aligning the telescope, the object visible in the viewfinder is also visible in the CCD. When the viewfinder and the CCD are aligned, the viewfinder may be used to search for objects in the sky and slew the telescope in the right position.

Additional devices attached to the telescope caused an imbalance in the telescope and counterweights were needed to balance it. The telescope was balanced using the zenith and the celestial equator as the primary axes. The telescope was first positioned to point to zenith and was balanced accordingly. Once weights are added and the telescope seems balanced with zenith, its stability is further checked with the celestial equator. A telescope is balanced when it remains stationary when positioned in a whole array of declination and right ascension. Since the telescope is linked to several electronic devices, wires may cause the telescope to be imbalanced. Before attempting to balance the telescope, wires were tethered and positioned to minimize additional dragging of the telescope that may cause additional imbalance the telescope.

Problems and Solutions

Some of the problems encountered were overheating of the telescope driver and the tempestuous weather, which prevented polar alignment of the telescope.

On initial examination of the telescope, the telescope was found wound twice with the hand control's wire and left powered ON by the previous user. As suspected, the telescope failed to initialize. The problem was suspected to be a malfunctioning hand control or a more complicated problem with the telescope driver. The hand control and the wire connecting to the telescope were replaced but the telescope still failed to initialize. Therefore, the problem was not a communication problem between the hand control and the telescope. Since the telescope was replaced as well, it was assessed that the problem truly was the driver. Thus, the driver was replaced. To minimize the reoccurrence of overheating, plans of adding a ventilation system is underway.

The RoboDome's diameter of 40 inches , housing a telescope with a diameter of 10 inches, left little clearance for an individual to fit in the dome to polar align. In order to polar align, the telescope's walls needed to be removed, leaving the electronic components within the dome vulnerable to heat and rain thus polar alignment of the RoboDome was delayed until after the monsoon season.

Conclusions

The plate scale was found to be 0.699 arcseconds per pixel, which has been consistent with Vargas' previous calculations. At the ULTRA site, the seeing has consistently been relatively "good" with an average seeing of 0.78 arcseconds using a plate scale of 0.700 arcseconds per pixel. Typical seeing at Mount Laguna Observatory 40 inch ranges from 1.5 to 2.5 arcseconds. Since $ 1.4 Million dollars is invested into the ULTRA project, good seeing is desired; ideally, seeing of less than 1 arcseconds is desired. Typically, good seeing at the ULTRA site is approximately 0.7 arcseconds. On best nights, seeing is as low as 0.5 arcseconds and on worst nights 10 arcseconds with Santa Ana Conditions.

The RoboDome was not polar aligned; however, preliminary procedures to polar alignment were accomplished. The viewfinder of the telescope was aligned with the CCD and balanced with counterweights. The RoboFocus and the CCD were tested to function individually and communication was established through the computer. The dome was maneuvered through the computer server, however, was unable to control the telescope through the network. The telescope was successfully controlled through the computer server as well as through the network. Polar alignment was not performed due to stormy weather.

Acknowledgements

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