

Towards a fully automatic and robust DIMM (DIMMA)

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Abstract. Quantitative seeing measurements have been provided at the Canarian Observatories since 1990 by differential image motion monitors (DIMMs). Image quality needs to be studied in long term (routine) measurements. This is important, for instance, in deciding on the siting of large telescopes or in the development of adaptive optics programmes, not to mention the development and design of new instruments. On the other hand, the continuous real time monitoring is essential in the day-to-day operation of telescopes.

These routine measurements have to be carried out by standard, easy-to-operate and cross-calibrated instruments that required to be operational with minimum intervention over many years. The DIMMA (Automatic Differential Image Motion Monitor) is the next step, a fully automated seeing monitor that is capable of providing data without manual operation and in remote locations. Currently, the IAC has two DIMMs working at Roque de los Muchachos Observatory (ORM) and Teide Observatory (OT). They are robotic and require an operator to start and initialize the program, focus the telescope, change the star when needed and turn off at the end of the night, all of which is done remotely. With a view to automation, we have designed a code for monitoring image quality (avoiding spurious data) and a program for autofocus, which is presented here. The data quality control protocol is also given.

1. Introduction

The optical conditions are crucial both for site characterization and selection, and for feasibility studies for adaptive optics. The DIMM provides the full atmospheric seeing with an accuracy better than 0.1, with a sampling rate better than 1 datum/minute, and produces accurate, absolute and reproducible data [1]. Control tests are important and have to be implemented routinely (e.g. [2], [3]). The DIMM is the ideal instrument for long term monitoring of image quality and has been adopted at the Canarian Observatories [4].

The basis of the DIMM is to separate two light beams coming from the same star but received in two separate zones of the primary mirror (telescope aperture). This task is accomplished by completely covering the telescope aperture except for two small apertures. The light going through one of the apertures will be slightly deflected by a prism, thus obtaining two images of the same star in the focal plane. Seeing data can be computed from the variance of the distance between the two images, in both the horizontal and vertical axes (more details in [5] and [1]).

Routine measurements require instruments to be working with minimum operational life-span of many years. In this sense, for the optimum performance of the DIMM, we have designed and



implemented new applications towards obtaining a fully automated DIMM (hereafter DIMMA).

A number of systems based on this scheme are at present installed in most astrophysical observatories and are being routinely used for site surveys. There are two DIMMs installed at the Canary Islands Observatories (Roque de los Muchachos Observatory - La Palma - and Teide Observatory - Tenerife; see Figs 1 and 2); however, nowadays operators (IAC Telescopic Operation Technicians at Teide Observatory or TOTs) are needed.

The DIMMA system (Differential Image Motion Monitor *Automático*) is a step forward in telescope-based equipment used for site evaluation in astrophysics. Using the experience and know-how of the DIMM systems [1] regularly operated since 1995 at the IAC by the Sky Quality Team, the DIMM provides a comprehensive set of data without the need for manned operation, in close linkage with the rest of the world using internet.



Figure 1. Image of the DIMMA station at the ORM (Las Moradas site), 300 m east of the Gran Telescopio Canarias (GTC).



Figure 2. Image of the DIMMA station at Teide Observatory, close to the ESA Optical Ground Station (OGS).

Currently, the IAC DIMMs are robotic and require an operator to start and initialize the program, focus the telescope, change the star when needed and turn off at the end of the night or in bad weather conditions, all remotely. With a view to complete automation, we have designed a code for monitoring the image quality (avoiding spurious data) and a program for autofocus, including software and web cameras for surveillance, alerts and protection.

The second phase for full automation will incorporate automatic scheduling for observations and appropriate response in bad weather conditions. Figure 3 shows the configuration of the DIMMA. The dome control is completely independent. All components and sensor status are controlled with a common interface. The system is designed and implemented in LabVIEW.

2. Autofocus algorithm

The autofocus algorithm is summarized in Figure 4. The cluster focus configuration, i.e. the input parameters used, is based on the hardware (CCD, mechanics of the focus motor, etc.) of our DIMM system.

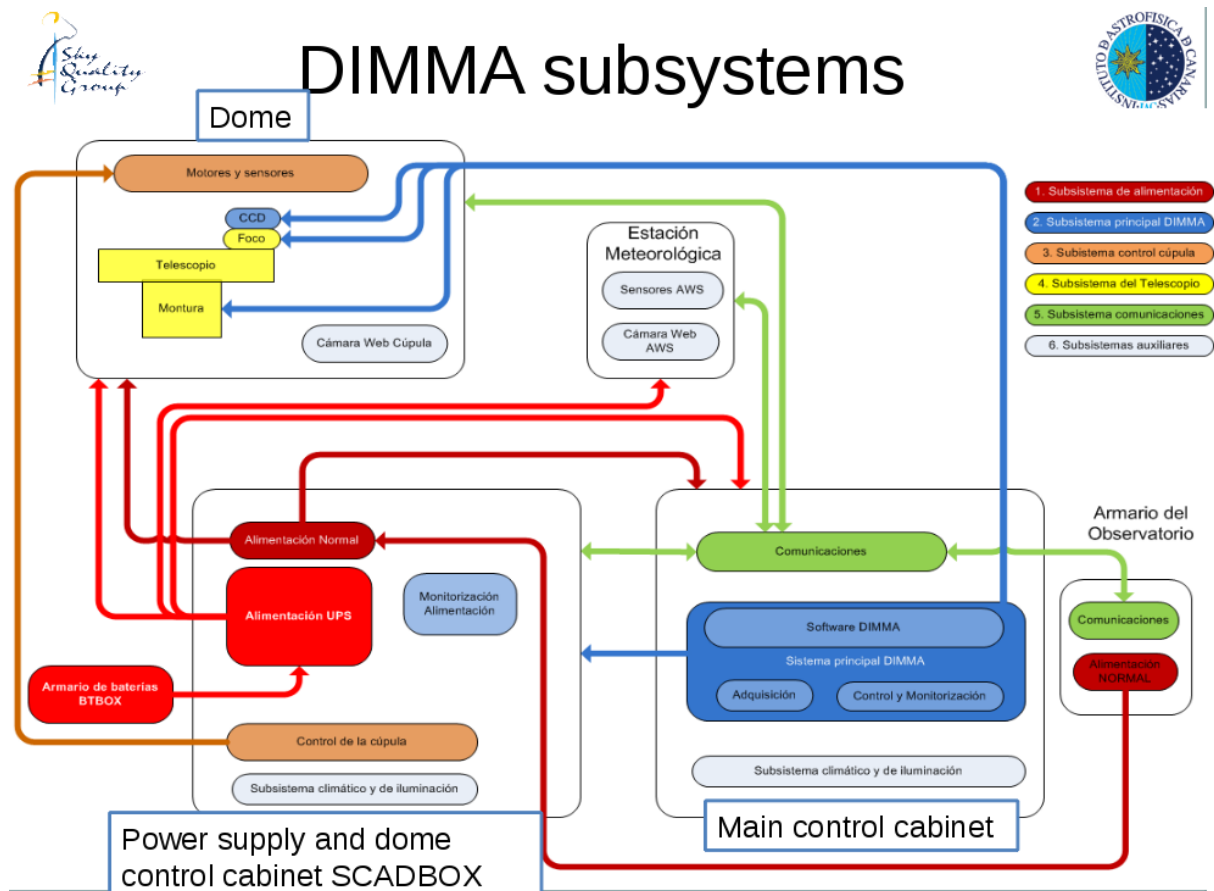


Figure 3. Configuration of the DIMMA: power supply (red); main DIMMA subsystem - software for acquisition and control of data - (blue); dome control (orange); telescope subsystem (yellow); communication (green) and auxiliary subsystems - web cameras and automatic weather station sensors - (white).

The initial sampling position ($PosIni$) or distance between the centroids of spots is suggested to be 25 pixels (corresponding in our case with 18180 counts, using a focus change or $Step = 10$ counts). The final position $PosEnd = PosIni + (Step \times Nsample)$, must be set up at 40 pixels. N images (20) are scanned, stored and processed, the mean and the standard deviation (σ) of the mean of the distance of the centroids are calculated. The σ threshold is 3 pixels and the maximum allowed σ is 10 pixels. This process is repeated 30 times ($Nsample$), and finally we plot the relationship between the distance in pixels and the focus position to obtain the best linear regression (see Fig. 5). We want to obtain a focus position precision better than 1 pixel, therefore, the scan must be smaller than the counts per pixel ratio, but it is limited by the mechanics of the motor. The focus position from 25 to 40 pixels is summarized in Table 1. The theoretical focus values for DIMMA-ORM and DIMMA-OT are 35 and 33 pixels respectively.

3. Quality control of the data

The first control routine concerns the number of accepted and rejected data. Reasons of rejection are mainly associated with a discrepancy greater than 20% between the fwmh longitudinal (fwhml) and the fwmh transversal (fwhmt). This could be an indication of focus problems and/or conditions where the technique cannot be employed (see [1] for further details). Other

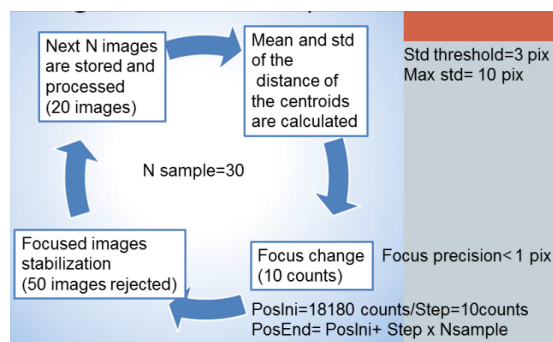


Figure 4. Autofocus algorithm for the DIMMA.

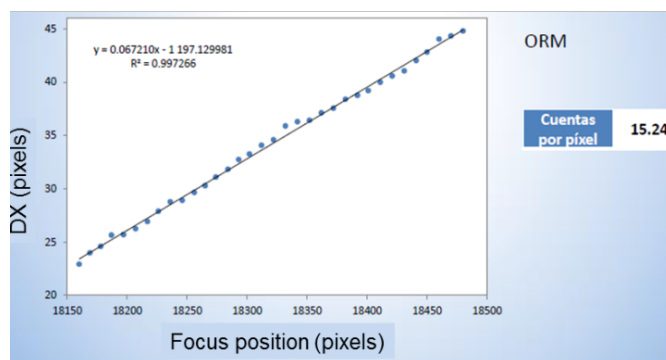


Figure 5. Relationship between the distance in pixels and the focus position.

reasons for the rejection of data (automatically identified with an error code) and the percentages of occurrence are indicated in Table 2, corresponding to 551 observing nights with the DIMM at Teide Observatory. The statistics of the rejected measurements in a given time-lapse is an indicator of the robustness of the accepted data. The percentages of rejected data are represented in Fig. 6, the total number of rejected data being 13% and 11.9% for the DIMMA-OT and DIMMA-ORM respectively. The main cause of lost data is the discrepancy between the fwhml and the fwhmt, being 66.4% and 62.3% of the total rejected data for the DIMMA-OT and DIMM-ORM respectively, followed by the low signal to noise ratio of the images and unfocused images (this study was performed without autofocus implementation).

Besides the IAC equipment, there are two more DIMMs installed at the ORM summit

Table 1. Focus position results for DIMMA-ORM and DIMMA-OT.

	DIMMA ORM	DIMMA OT
pixels	(counts)	(counts)
25	18181	12815
33	—	12646
35	18344	—
25 – 40	229	-273

Table 2. Causes and percentajes of rejected data for a sample of 551 and 304 observing nights at the OT and ORM respectively.

Code #	Diagnostic	Rel. Freq	Abs. Freq
0	No errors	86.98 %	377661
9	Full discrepancy	0.00 %	9
11	Distorted spots	0.16 %	696
12	Unfocused images	1.04 %	4517
13	Low SNR	2.32 %	10084
14	No maximum	0.01 %	48
16	Lost images	0.00 %	18
17	Offset image	0.34 %	1494
31	Wrong airmasses	0.23 %	995
50	fwhml/fwhmt > 20 %	8.64 %	37520
99	User's stopping	0.25 %	1103
1001	Source of images disconnected	0.00 %	6
-10	Negative codes	0.01 %	22
Total:		100.00 %	434173

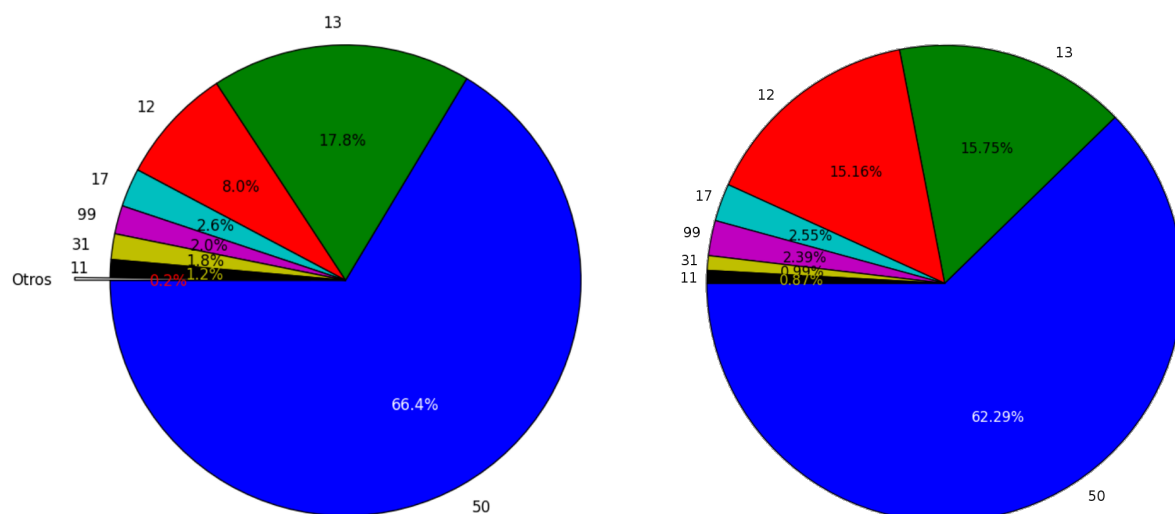


Figure 6. Diagram of the causes and percentages of rejected data for the DIMMA-OT (left) and the DIMMA-ORM (right). The total rejected data are 13.0% and 11.9% for OT (551 nights) and ORM (304 nights), respectively. See rejection codes in Table 2.

operated by the Isaac Newton Group (ING) and Telescopio Nazionale Galileo (TNG) teams. We perform routine comparisons (the most recent was published in Canarian Observatories Updates (CUpS) [6] The statistical results are consistent to within the errors. The difference in the median seeing is less than 0.1 arcsec.

4. Remarks

- Two cross-calibrated DIMMs have been in operation at the OT and ORM since March 2011 and April 2012 respectively.
- A robust and reliable automated DIMMA capable of providing data without manual operation and in remote locations is being developed at the IAC.
- Automatic focus and data quality control has been satisfactorily implemented.

The future is the implementation of the automatic scheduling and weather monitoring.

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