The level of accuracy for digitizers dedicated to astrometry

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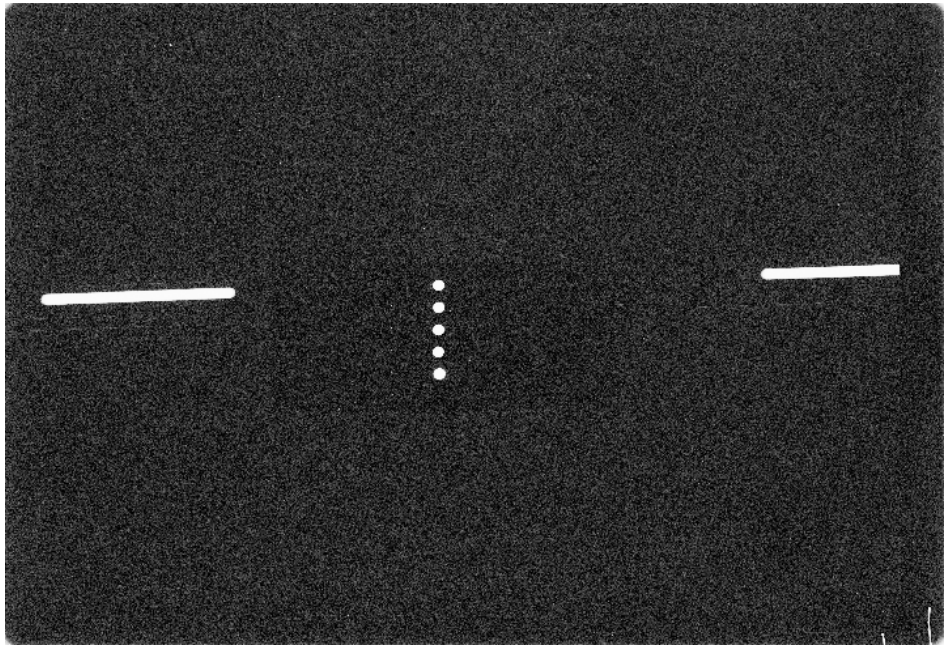
Introduction

- The study of the dynamics of the natural planetary satellite systems needs astrometric observations.
- The interval of time must be as long as possible in order to quantify long period terms and to analyse the evolution of the motion.

A new reduction of good photographic plates is a solution but needs a specific instrumentation to provide the best (?) accuracy.

- Problematic :
  - what are the main components of a digitizer ?
  - what is the influence on the final measurements ?
  - which accuracy could be obtained ?



USNO photographic plate

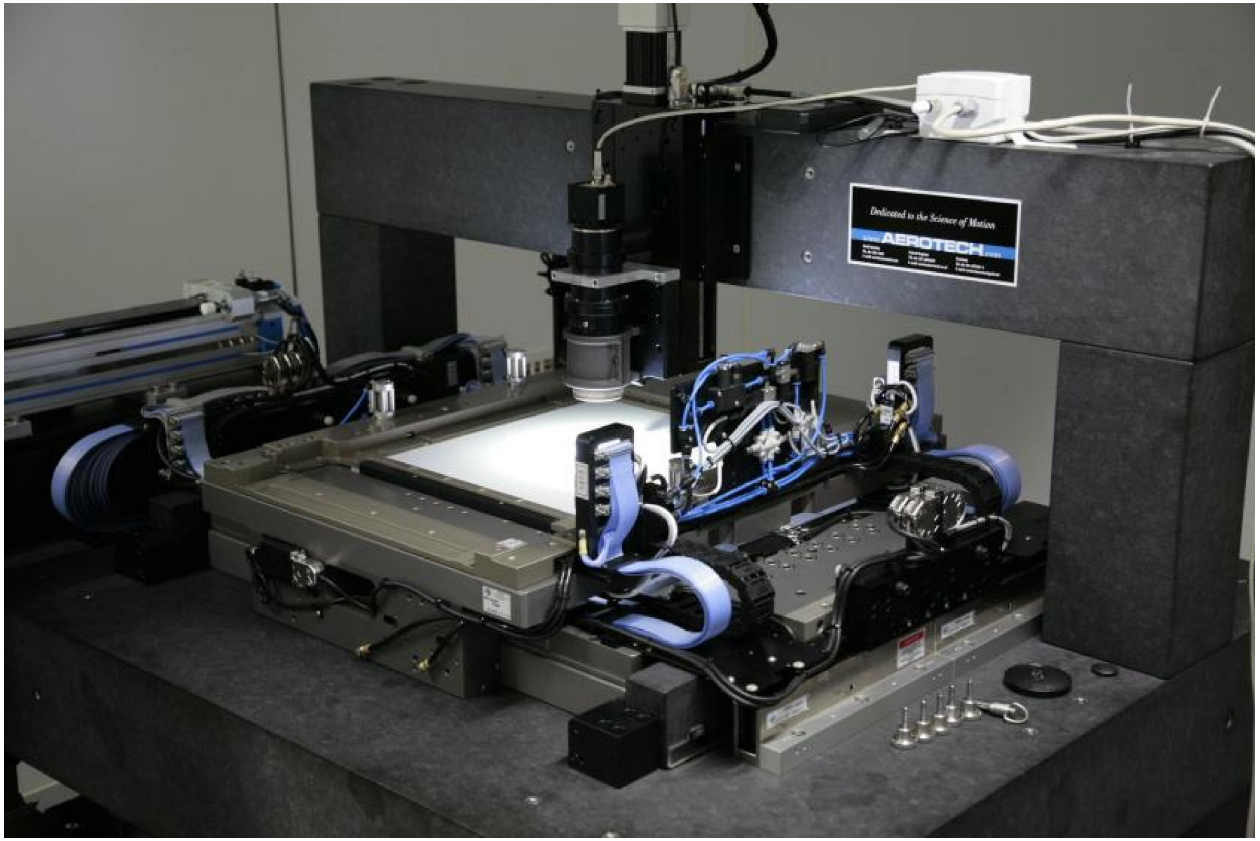
We use the USNO photographic plates for example to discuss the machine parameters that achieve a final astrometric accuracy of 1.5 mas ($\simeq 0.075\ \mu m$).

The digitization

	MAMA	StarScan	DAMIAN
Time	1 h	20 min	8 min
XY positioning	1 μm	0.1 μm	0.001 μm
XY repeatability	1.17 μm	0.50 μm	0.07 μm

Compared specifications of MAMA, StarScan and DAMIAN machines.

The DAMIAN specifications are better than the StarScan reference digitizer (Zacharias et al., 2008).



The DAMIAN scanner

1. Mechanical part : XY-table
2. Optical part : 2D camera optical unit
3. Environment

XY-table main terms :

1. Linear encoders (absolute/incremental)
   - devices that read the XY-table position
2. Positioning stability
   - deviation of a fixed position
   - error/difference between the real position and the measured position
3. Positioning repeatability
   - measuring dispersions
   - interval variation of several measurements

Optical unit main terms :

1. Unit quality
2. Reading accuracy
   - optical distortion
   - Dark, Flat and Offset

Environment main terms :

1. Environment stability : temperature, pressure and RH

	DAMIAN (man.)	DAMIAN (mes.)
XY positioning	1 nm	1 nm
XY stability	$<$ 10 nm	3 nm
XY repeatability	$<$ 10 nm	3 nm
Optical accuracy	70 nm	70 nm
Global accuracy	$<$ 90 nm	77 nm

Manufacturer and measured/estimated specifications of DAMIAN digitizer.

	DAMIAN (mes.)	Cost
XY positioning	1 nm	$$$$$$$$$$
XY stability	3 nm	
XY repeatability	3 nm	
Optical accuracy	70 nm	$
Global accuracy	77 nm	

Manufacturer and measured/estimated specifications of DAMIAN digitizer.

	DAMIAN (mes.)	Astrometric machine
XY positioning	1 nm	10 nm
XY stability	3 nm	30 nm
XY repeatability	3 nm	30 nm
Optical accuracy	70 nm	30 nm
Global accuracy	77 nm $\simeq$ 1.5 mas	100 nm $\simeq$ 2 mas

Estimated specifications of DAMIAN digitizer and an astrometric machine.

Do the machine differences decrease the cost significantly ? A small part of this economy should be used to improve the optical unit.

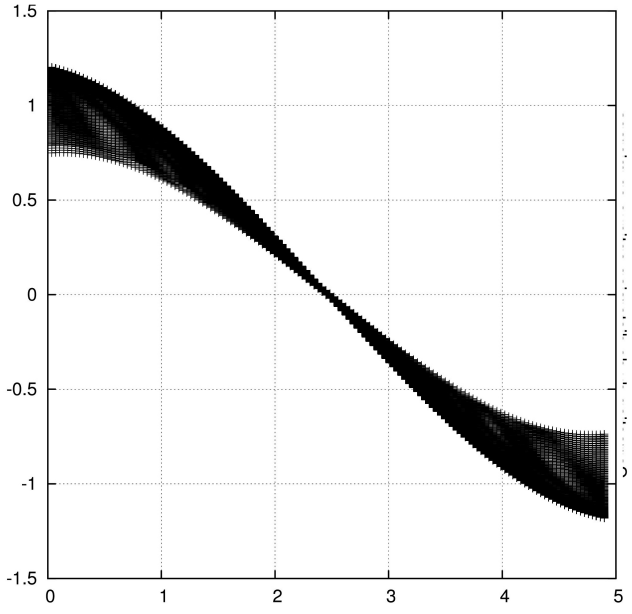
New specifications

1. Increasing the positioning reading, stability and repeatability values permits to build a fast digitizer.
2. Improving the optical unit (pixel size, dynamics, resolution) permits to digitize more extended areas in the same time and thus to reduce the scan delay.
3. Performing several digitizations permits to decrease the global accuracy by a $1/\sqrt{n}$ factor.

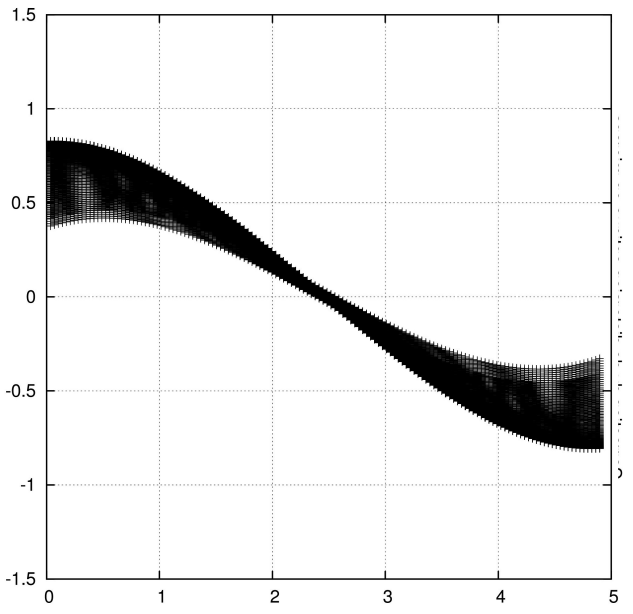
Don't forget !

Much work remains to do because some parts of the process are then dominating :

- the object fitting accuracy is up to 15 mas ;
- the reference star catalog accuracy is up to 15 mas.



x subimage distortion corrections in μm related to initial x position in mm.



y subimage distortion corrections in μm related to initial y position in mm.

The environment conditions influence the optical unit response :

- the common correction is up to 1.26 μm on the x-axis and 0.78 μm on the y-axis ;
- a Δt variation of 1°C introduces a Δc distortion correction up to 0.2 μm ($\simeq$ 4 mas) on both axes.

The machine should be placed in an air-conditioned clear room with at least fixed temperature with $\pm$0.25°C.

Conclusion

The DAMIAN digitizer

- the best current machine dedicated to digitization ;
- already reaches an accuracy of 1.5 mas but sized to provide better results.

What about a new machine ?

- the best way is to balance the mechanical and optical precisions to reach an accuracy of 1.5 mas ;
- it is possible to custom catalog products ;
- is the economy significant ?

Much work remains

It is important to improve the next steps of the process (image analysis, use of star catalogs, ...) not to decrease the accuracy at this point.

Questions