



XV Seminario Nazionale di Gnomonica
MONCLASSICO 30 maggio - 1° giugno 2008

A SOFTWARE CODE FOR DESIGN AND SIMULATION OF SUN DIALS

Gianpiero Casalegno

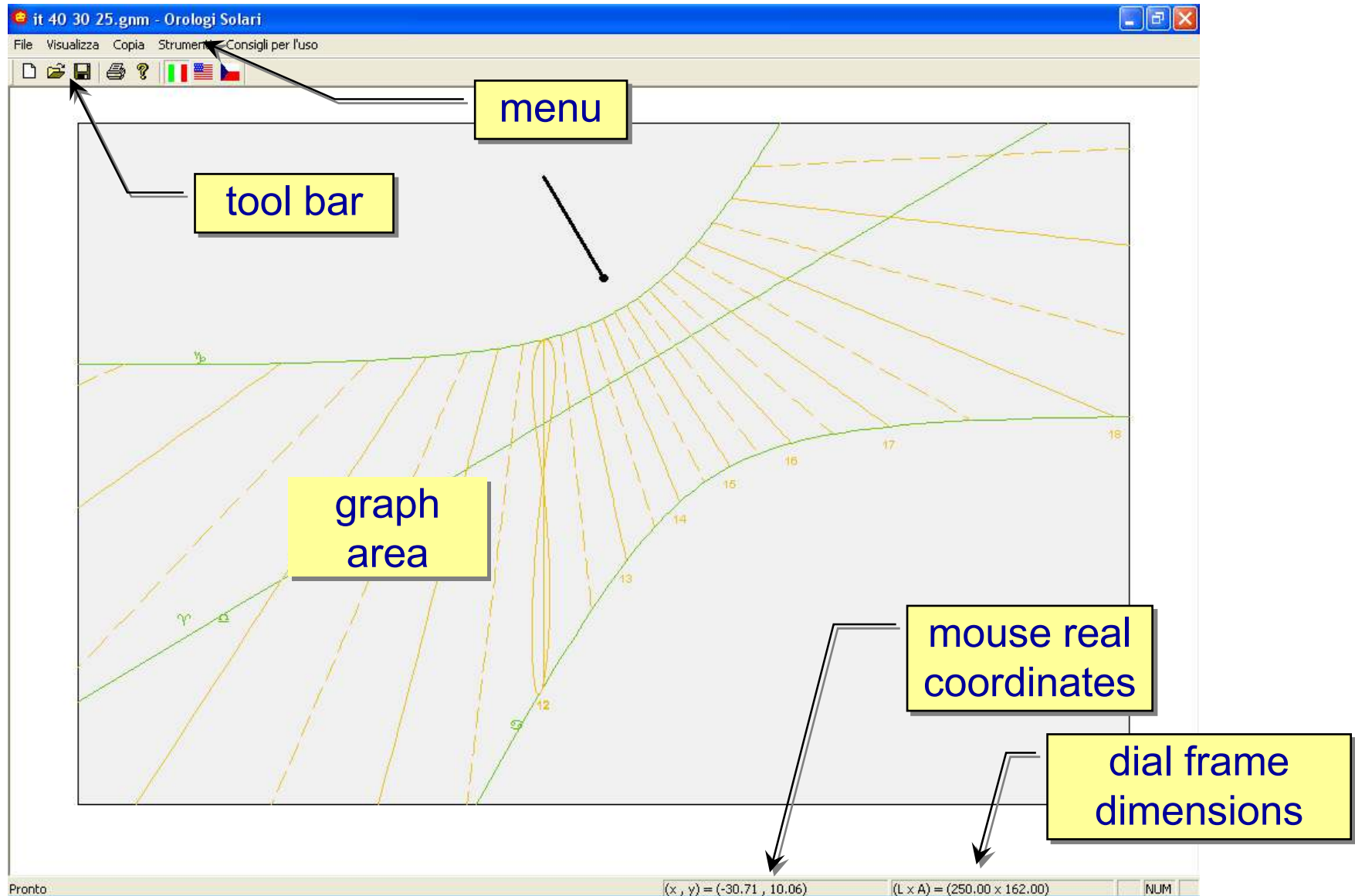
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anni di Seminari

Program features

- Operating System : XP / 2000 / Vista (WINE compatible)
- directional and azimuth dials
- hour lines and day lines design
- graph export to vector / raster file
- shadow simulation
- reverse engineering of existing dials
- freeware

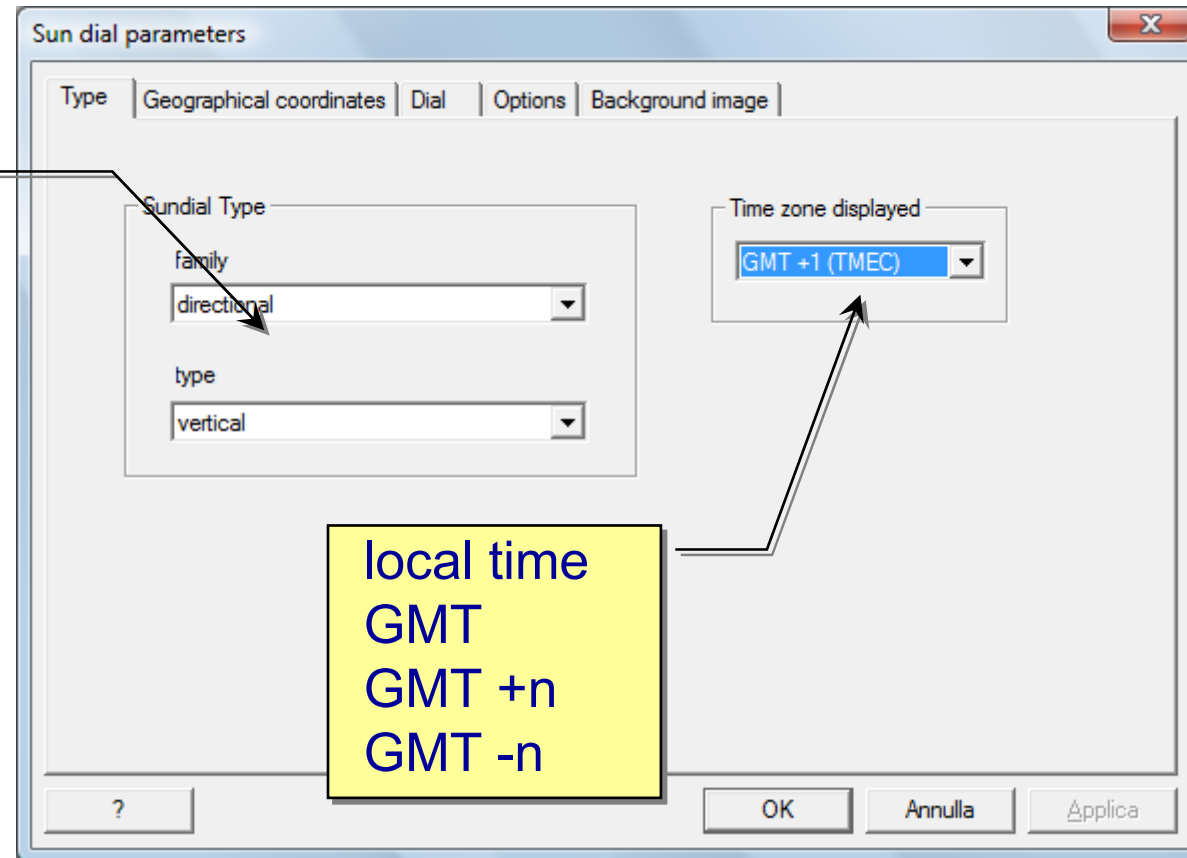
User interface



Definition of a new dial : type

family :

- directional
- azimuth

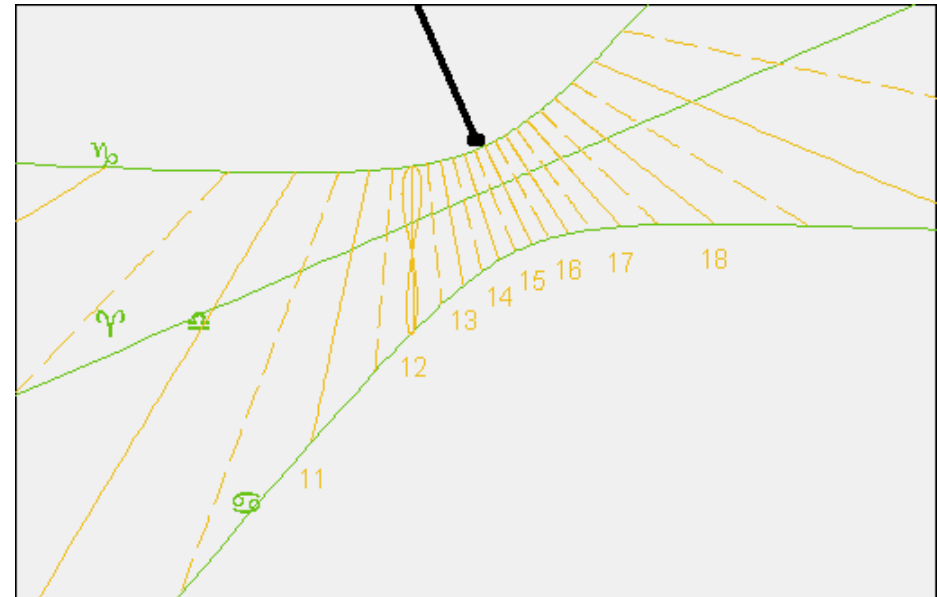


local time
GMT
GMT +n
GMT -n

Dial types

directional :

- **inclined declining**
- vertical declining
- horizontal
- polar
- equatorial



azimuth :

- horizontal analemmatic
- verticale declining analemmatic
- horizontal ortographic projective
- vertical declining ortographic projective
- horizontal stereographic projective
- vertical declining stereographic projective

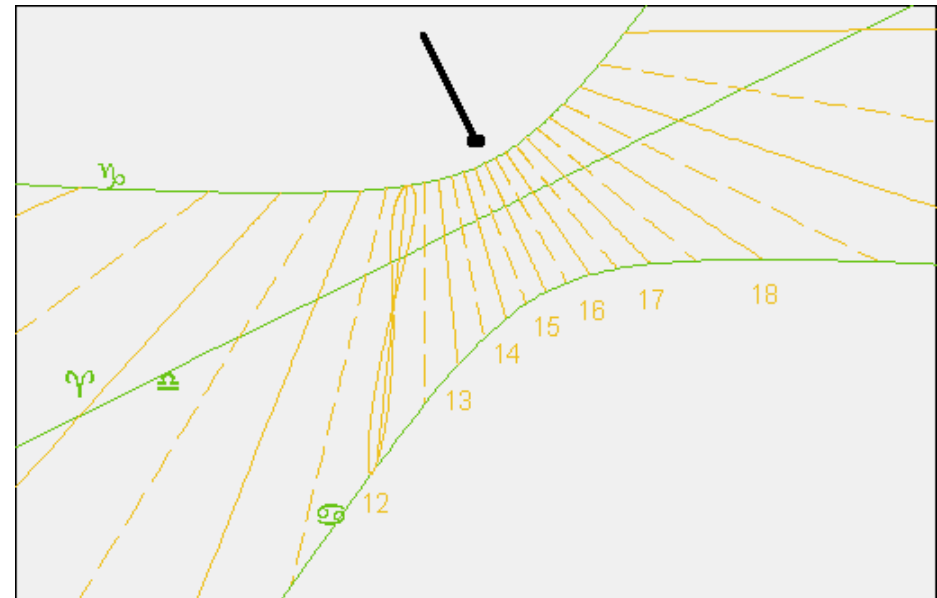
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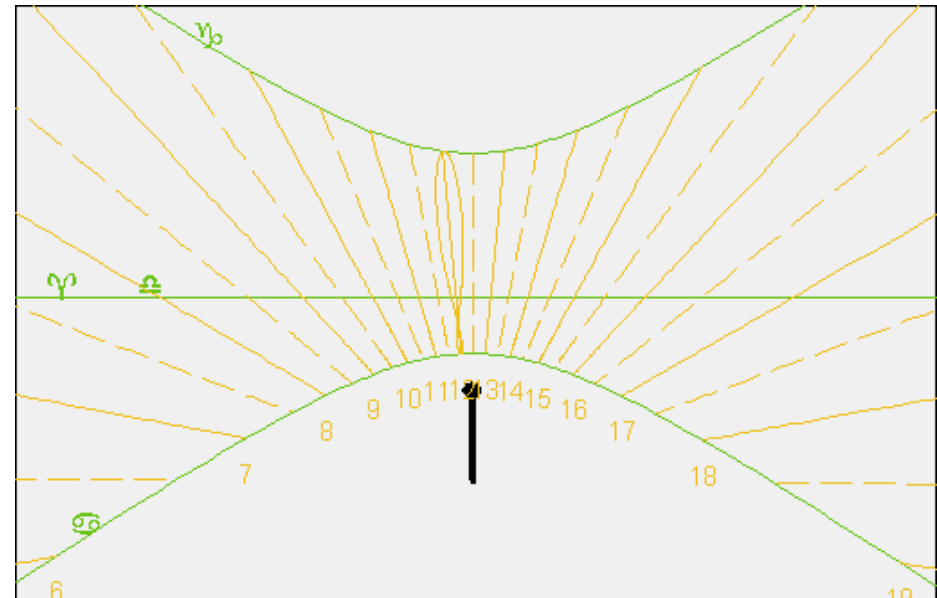
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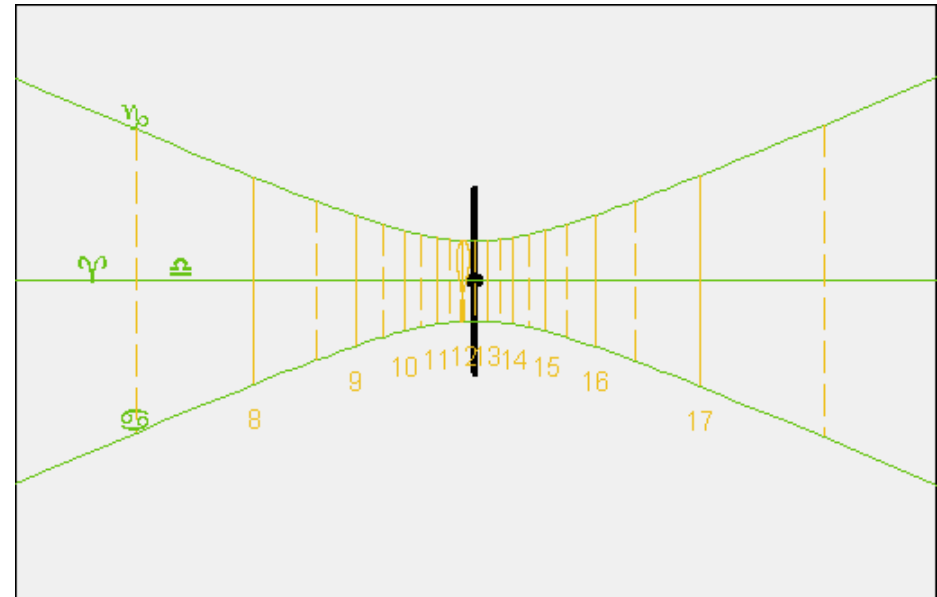
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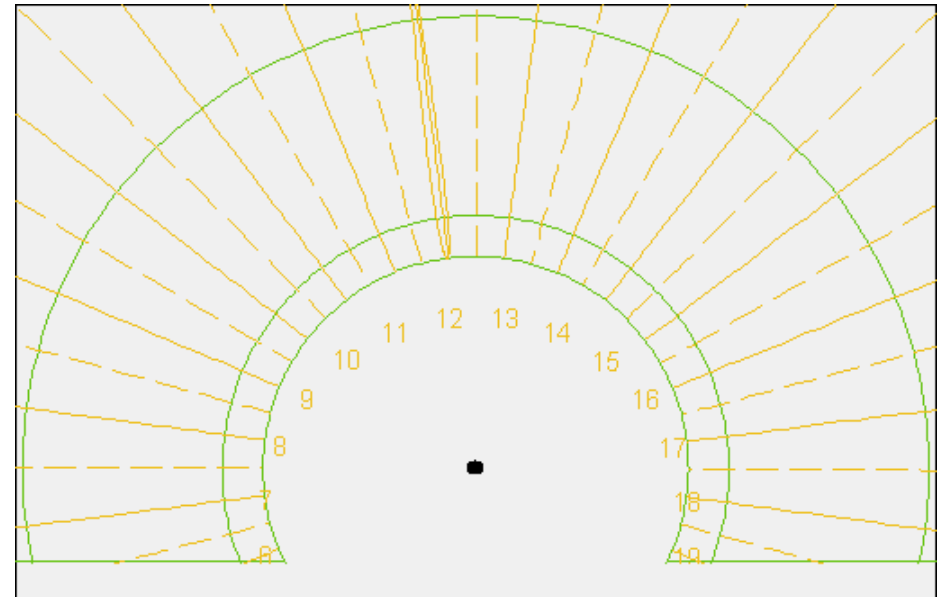
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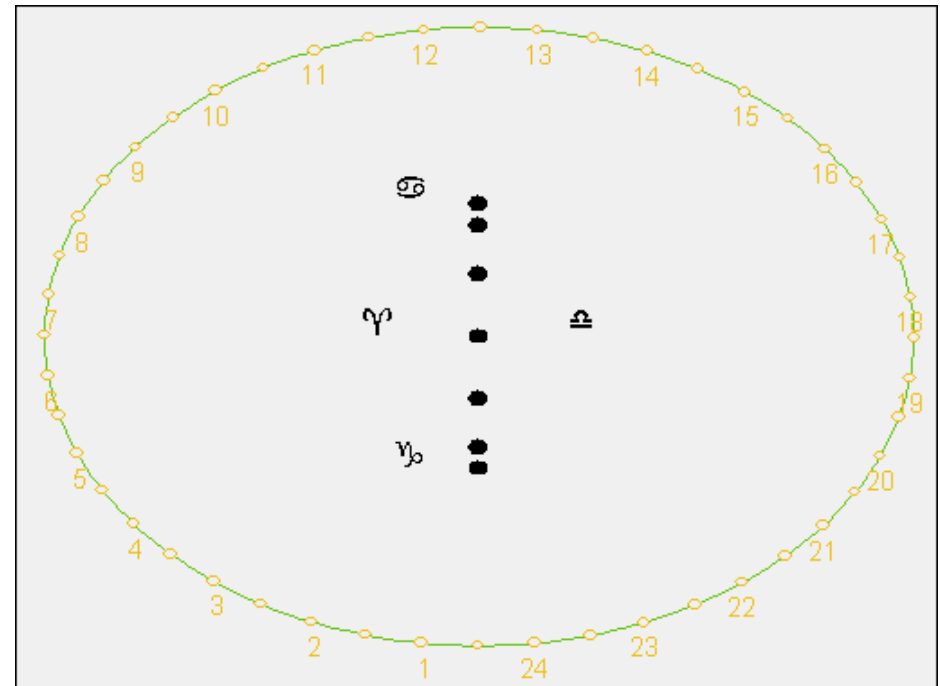
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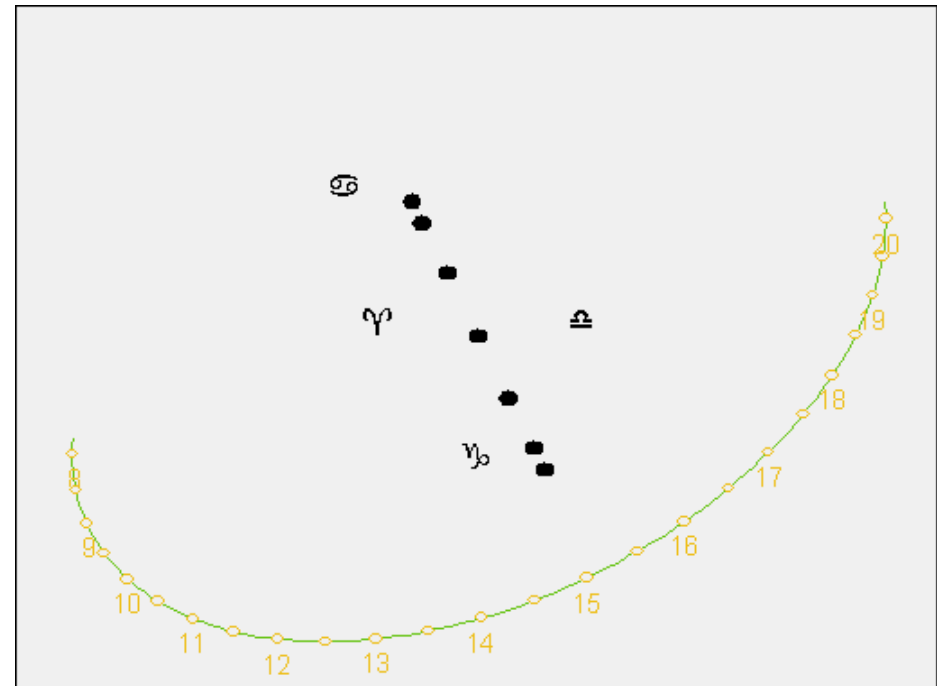
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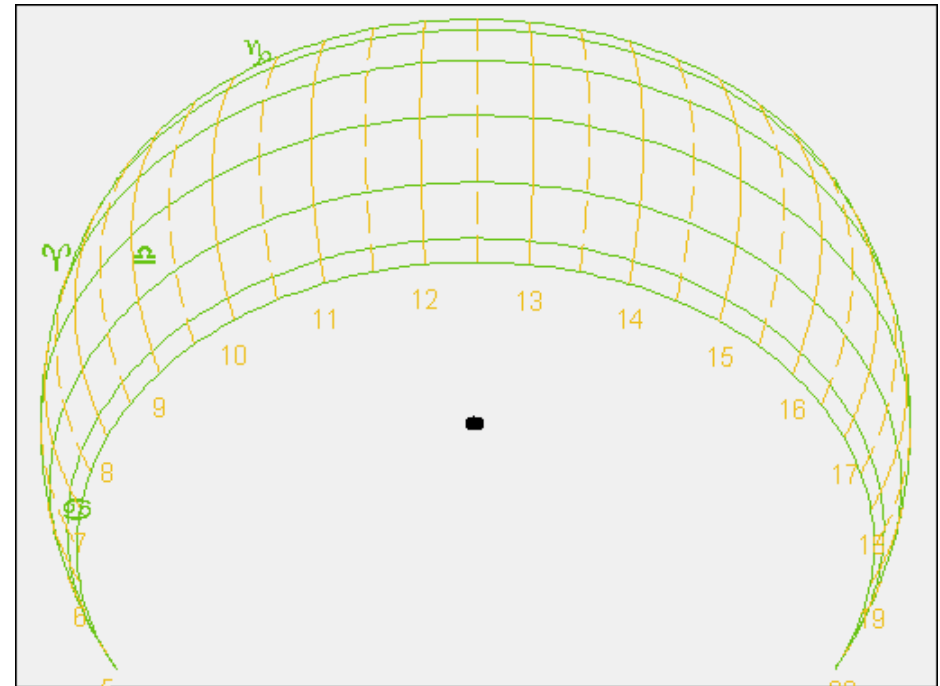
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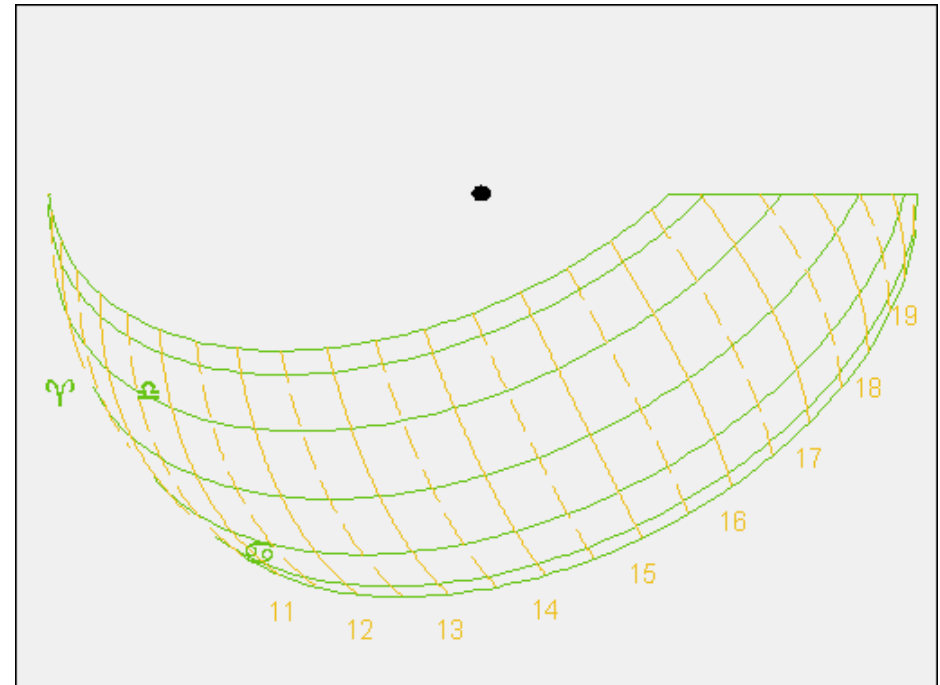
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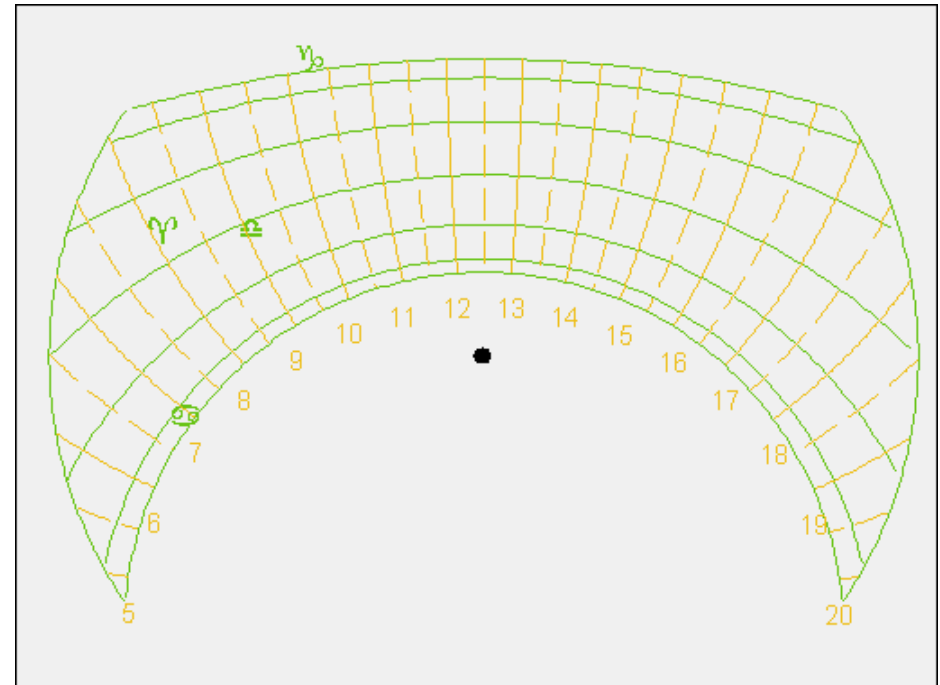
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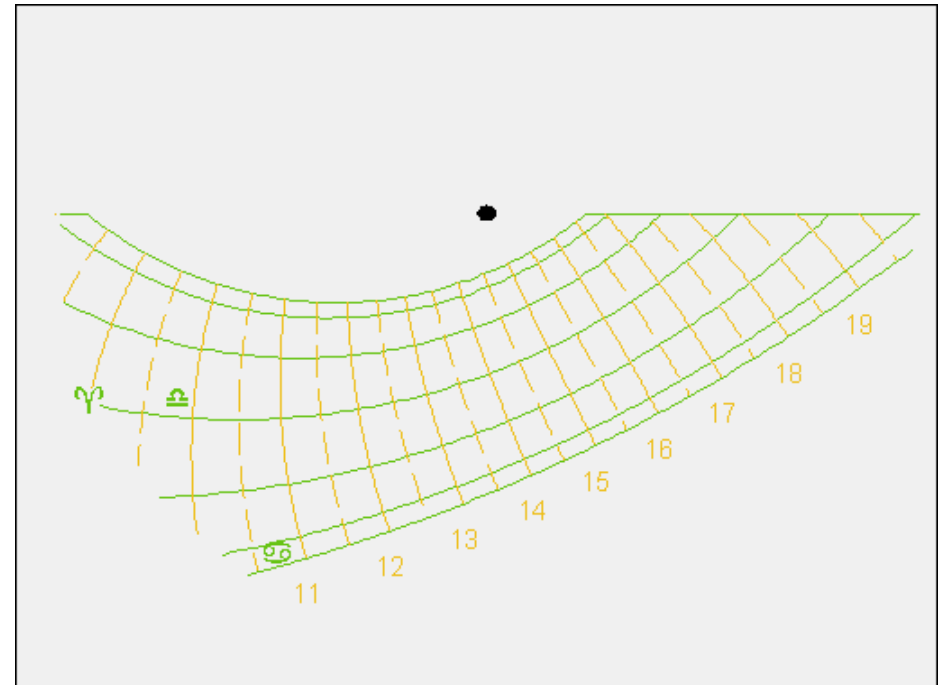
Dial types

directional :

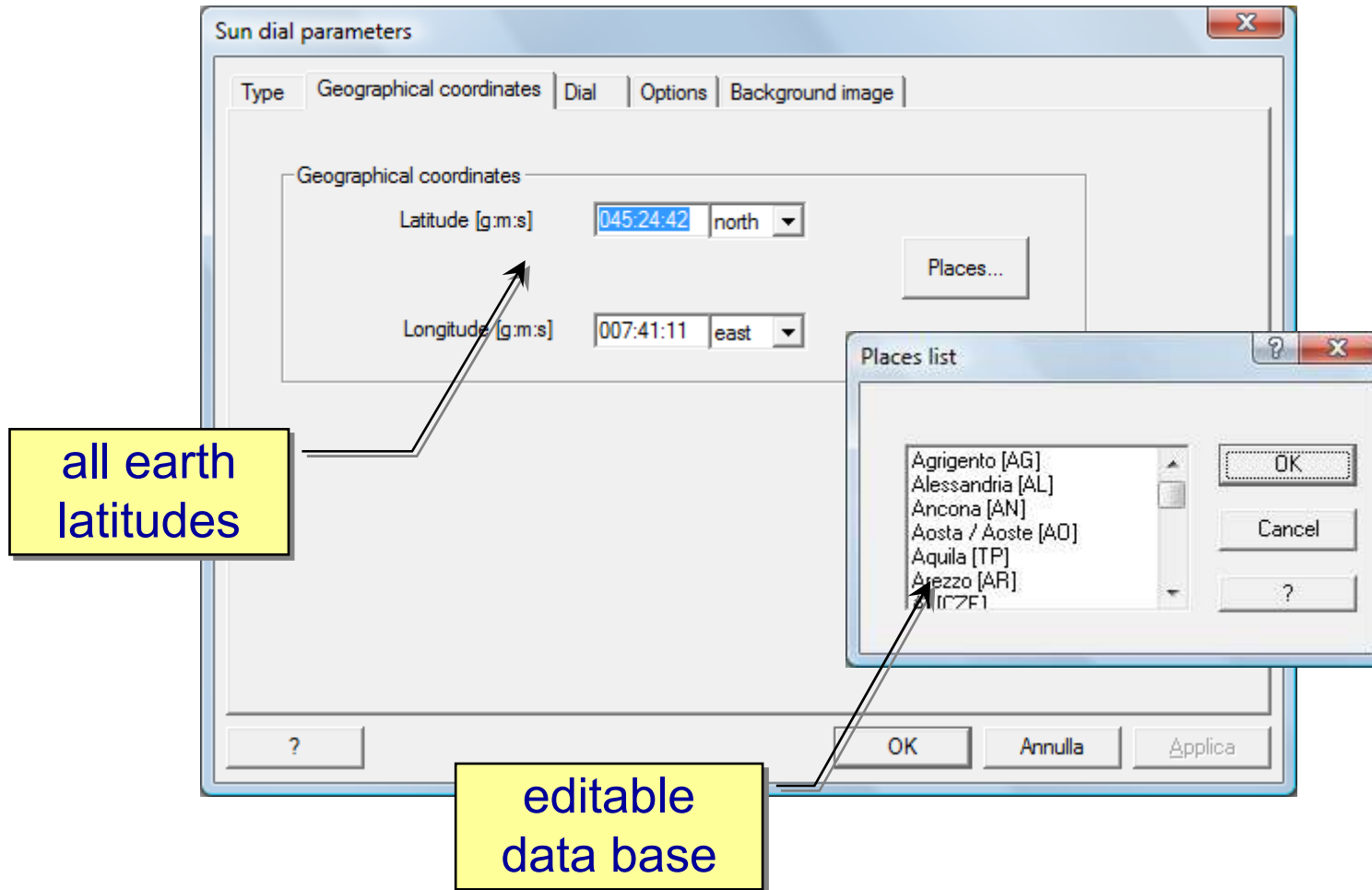
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New dial definition : coordinates



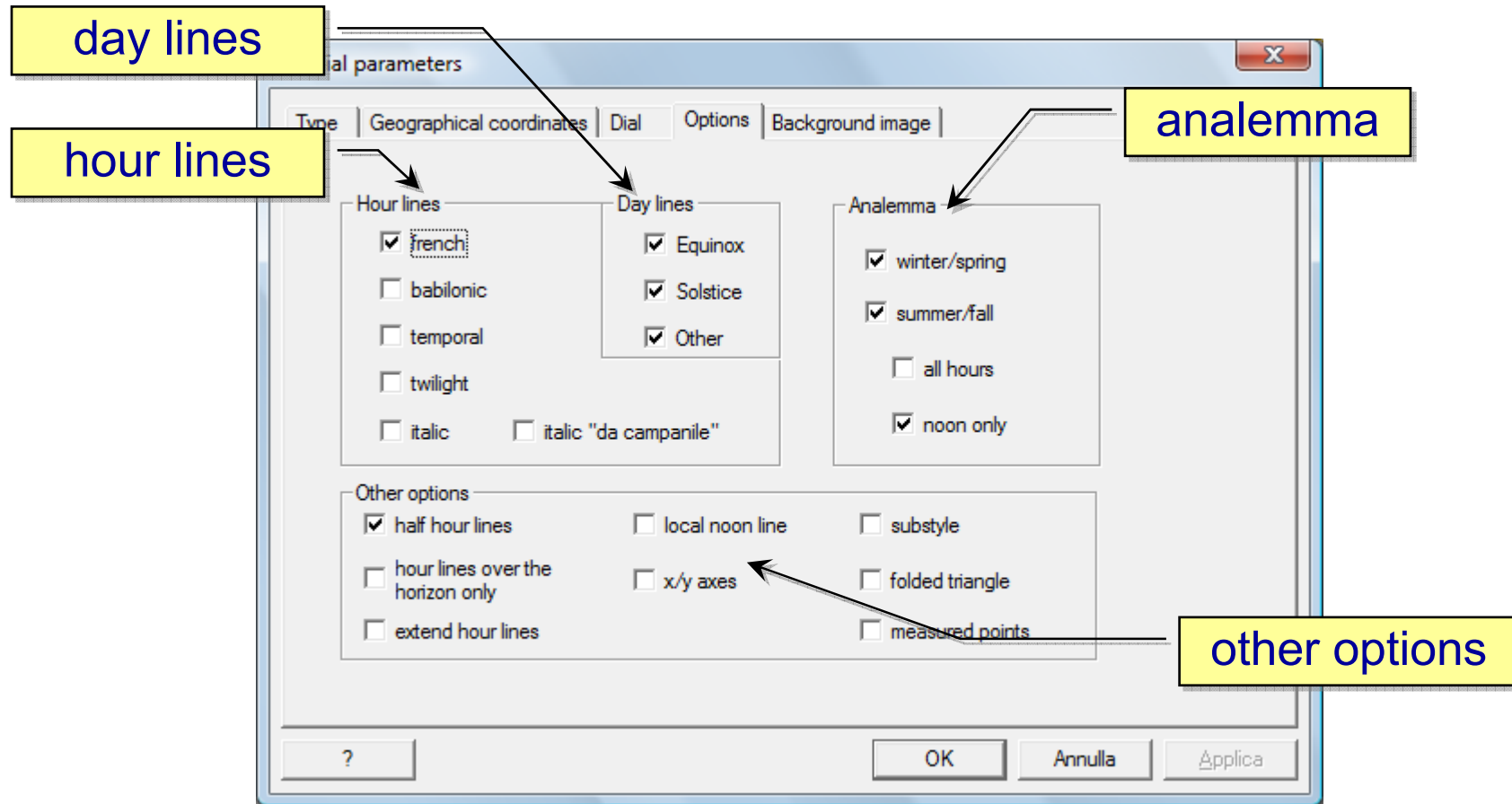
New dial definition : dial frame

The image shows a software dialog box titled "Sun dial parameters" with four tabs: "Type", "Geographical coordinates", "Dial", and "Options". The "Dial" tab is selected. The dialog is annotated with four yellow boxes and arrows pointing to specific fields:

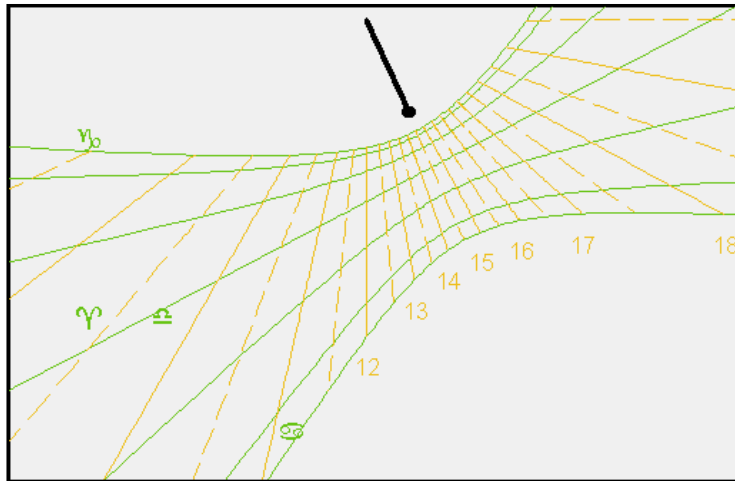
- declination**: Points to the "Wall declination" field, which contains the value "027:32:00" and a dropdown menu set to "west".
- inclination**: Points to the "Wall inclination" field, which contains the value "090:00:00".
- dimension**: Points to the "Dial dimensions" section, specifically to the "horizontal" and "vertical" input fields, which contain the values "250" and "162" respectively.
- orthostyle length**: Points to the "Ortostyle" input field in the "Style dimensions" section, which contains the value "25".
- orthostyle position**: Points to the "% above the ortostyle" input field in the "Dial dimensions" section, which contains the value "22".

Other fields in the dialog include "limit for substyle height < ... (0-45 deg.)" with a value of "28", "% at the left of ortostyle" with a value of "50", and a "?" button at the bottom left. The bottom right contains "OK", "Annulla", and "Applica" buttons.

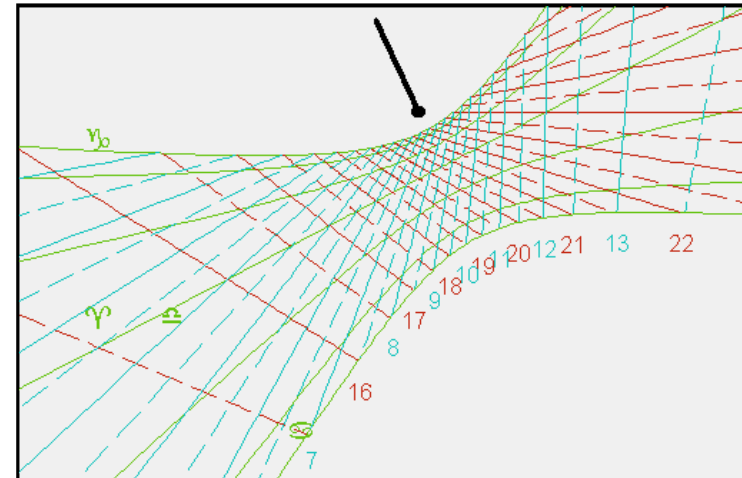
New dial definition : options



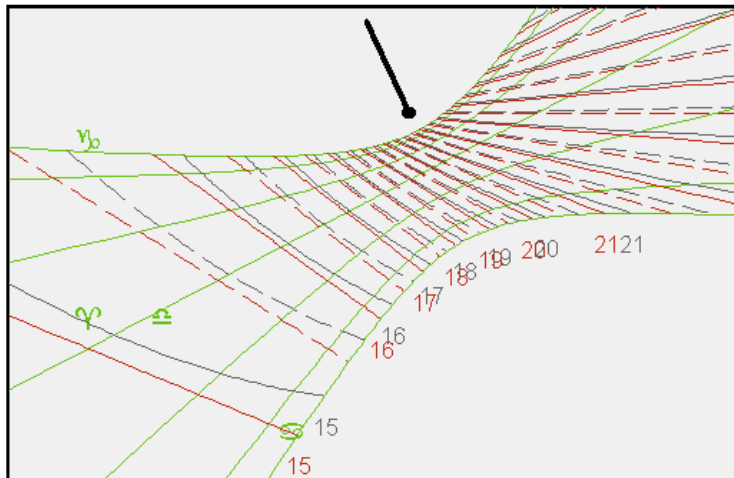
Hour line types



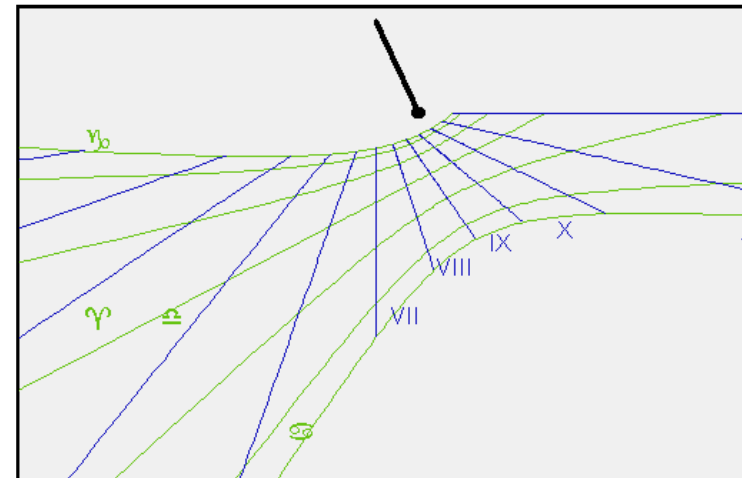
astronomical (french)



italic and babilonic



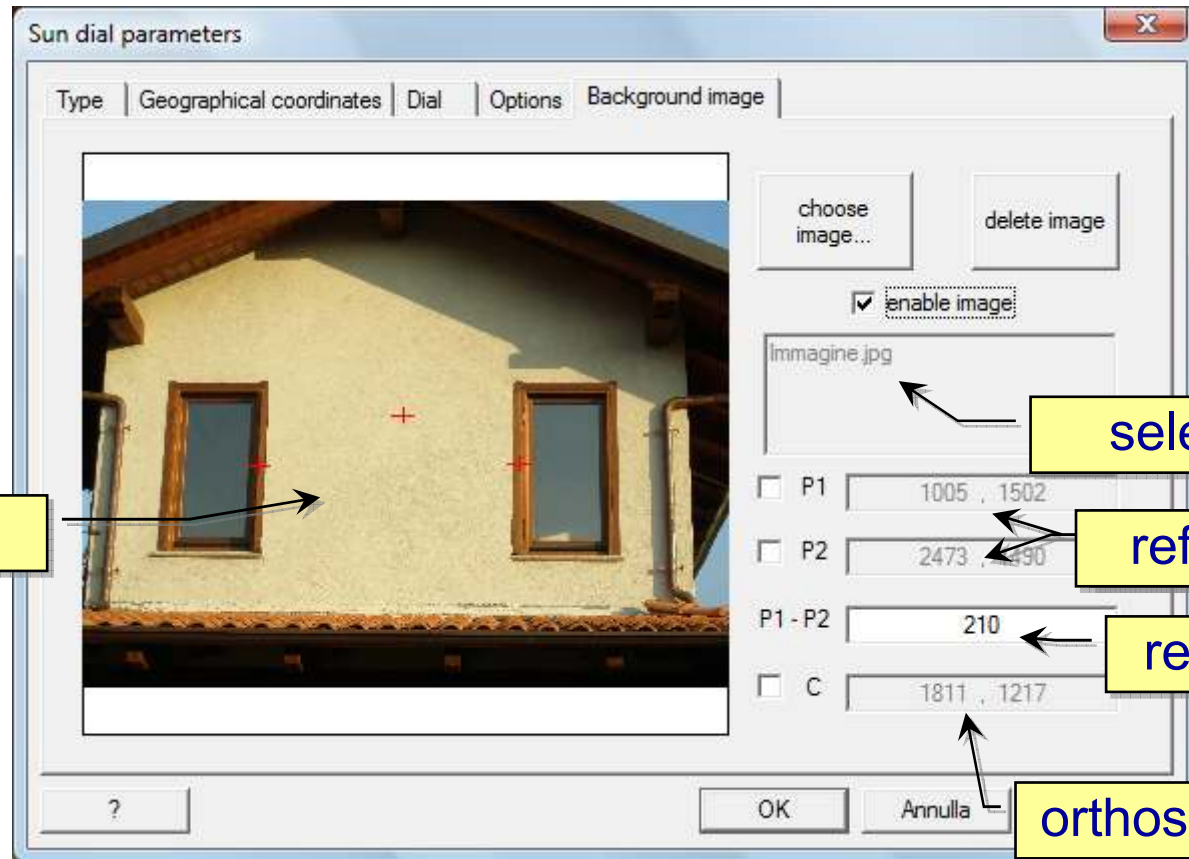
"da campanile" and twilight



temporal

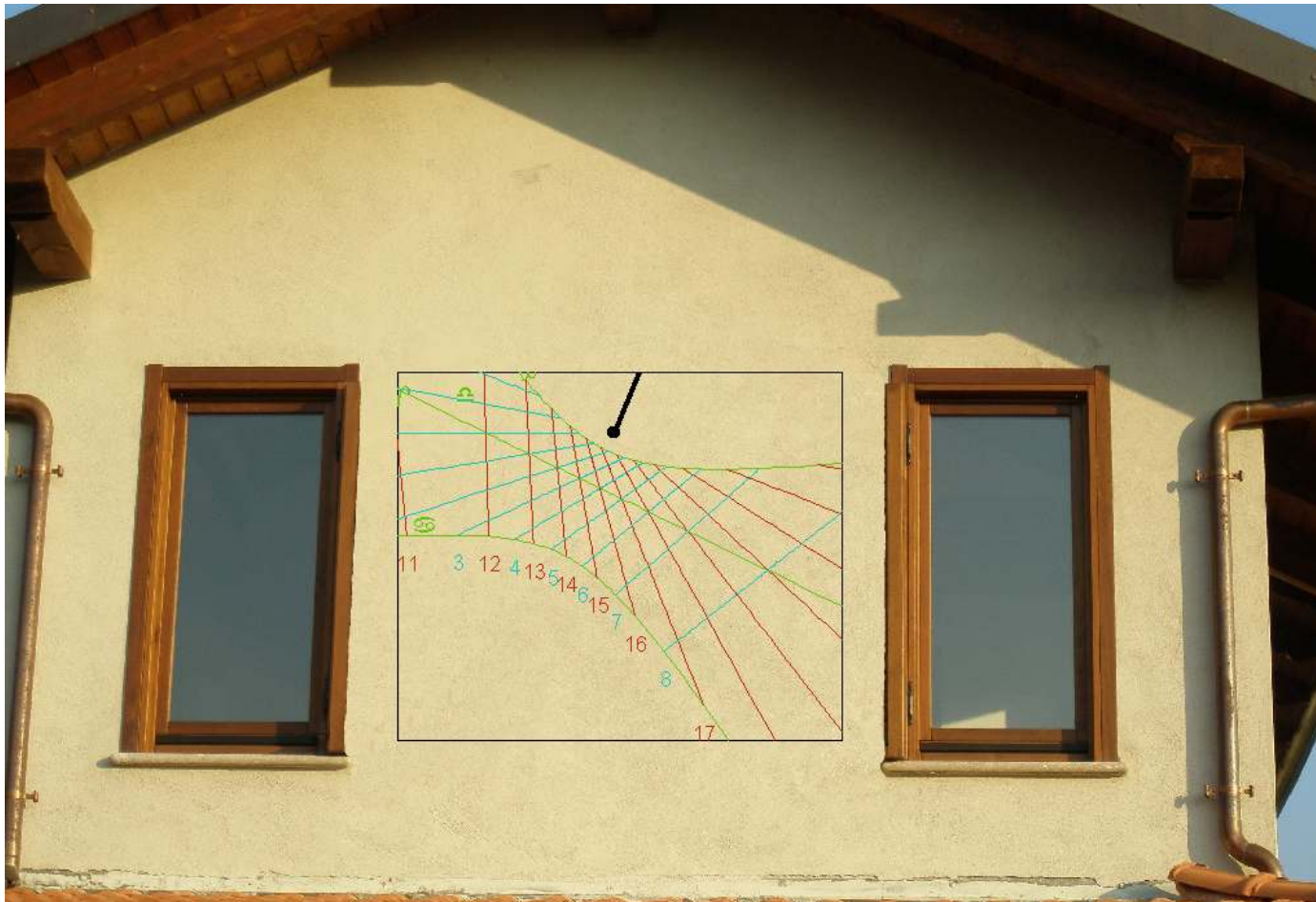
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New dial definition : background image



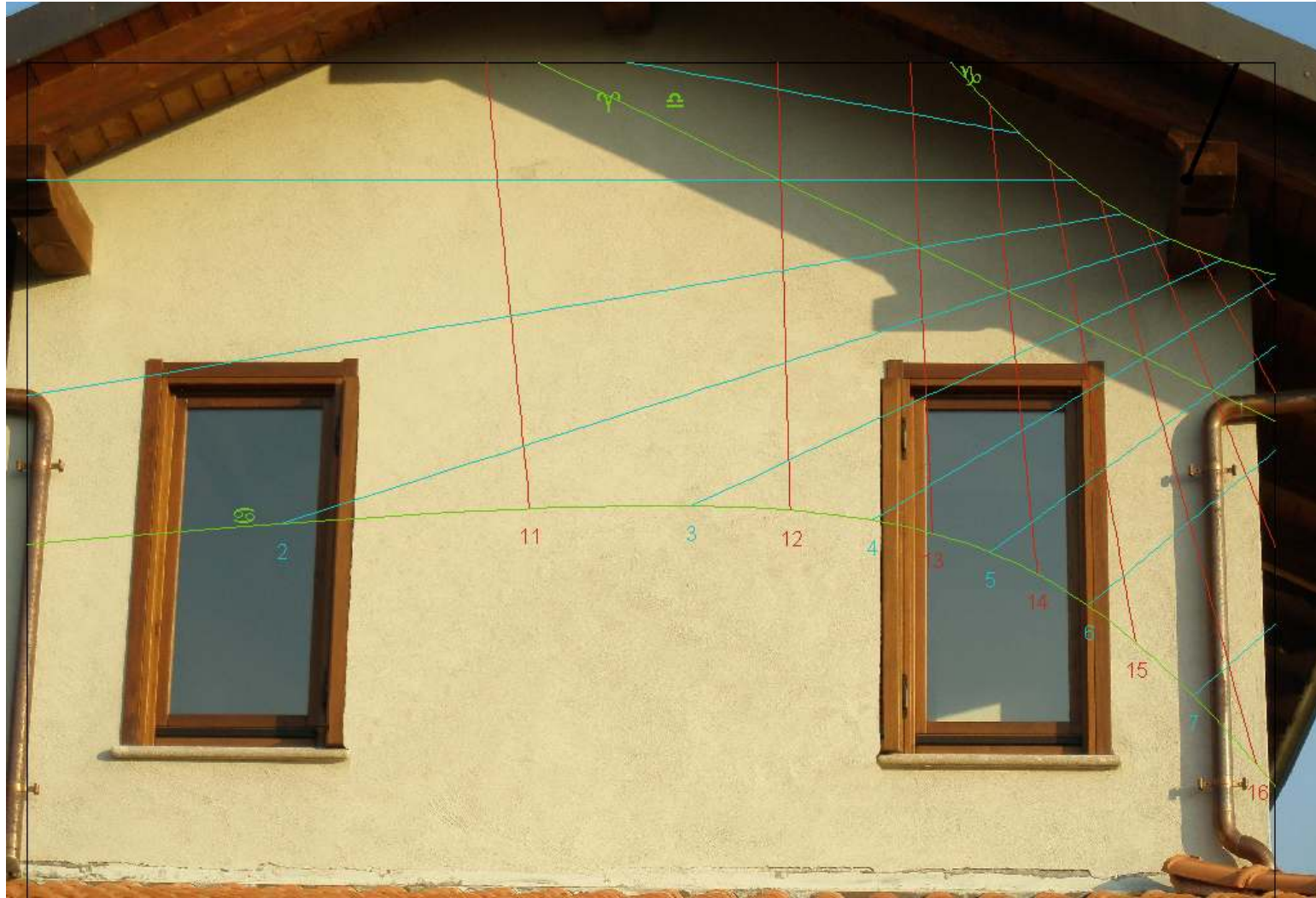
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Positioning and dimensioning



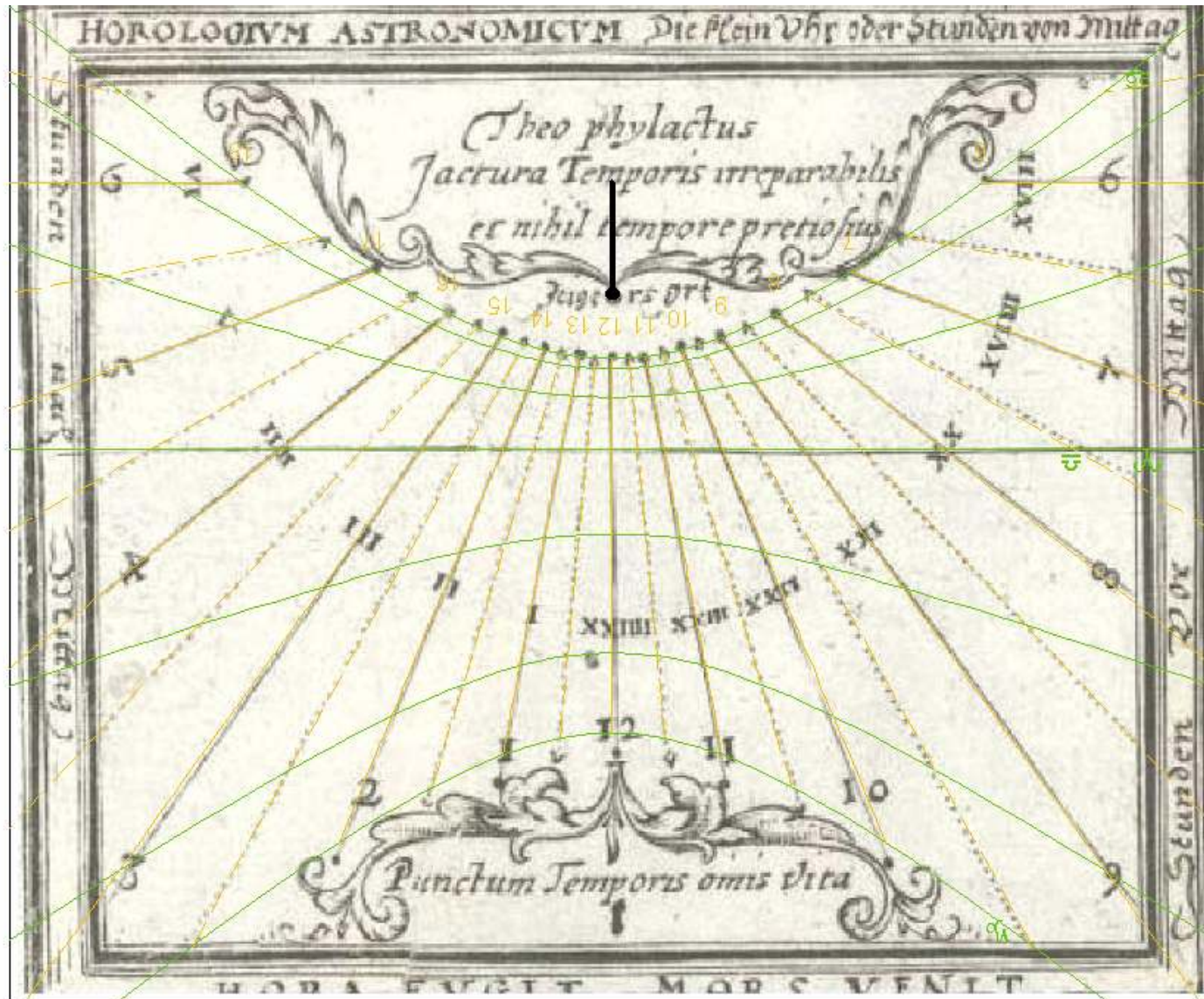
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Compute shadow of obstacles



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Existing dials simulation



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View : tables

The image displays a software application with five overlapping windows, each showing a different table of astronomical or time-related data. The windows are titled as follows:

- Linee Orarie Francesi**: Shows a table with columns for 'ora' and 'angolo'.
- Linee Orarie Italiane**: Shows a table with columns for 'Italiane', 'ora', 'ora fr.', 'x', and '21-dic'.
- Linee Orarie Babilonici**: Shows a table with columns for 'Babilonic', 'ora', 'ora fr.', 'x', and '21-dic'.
- Linee Orarie Temporali**: Shows a table with columns for 'Temp.', 'ora', 'ora fr.', 'x', and '21-dic'.
- Linee Orarie Crepuscolari**: Shows a table with columns for 'Crep.', 'ora', 'ora fr.', 'x', and 'y'.
- Tabella delle Lemniscate**: Shows a table with columns for 'Lemn.', 'ora', and pairs of columns for dates: '1-gen', '11-gen', '21-gen', '1-feb', and '11-feb'.

Each window contains numerical data organized in columns, with some windows including a vertical scrollbar on the right side. The windows are layered, with 'Linee Orarie Francesi' at the back and 'Tabella delle Lemniscate' at the front.

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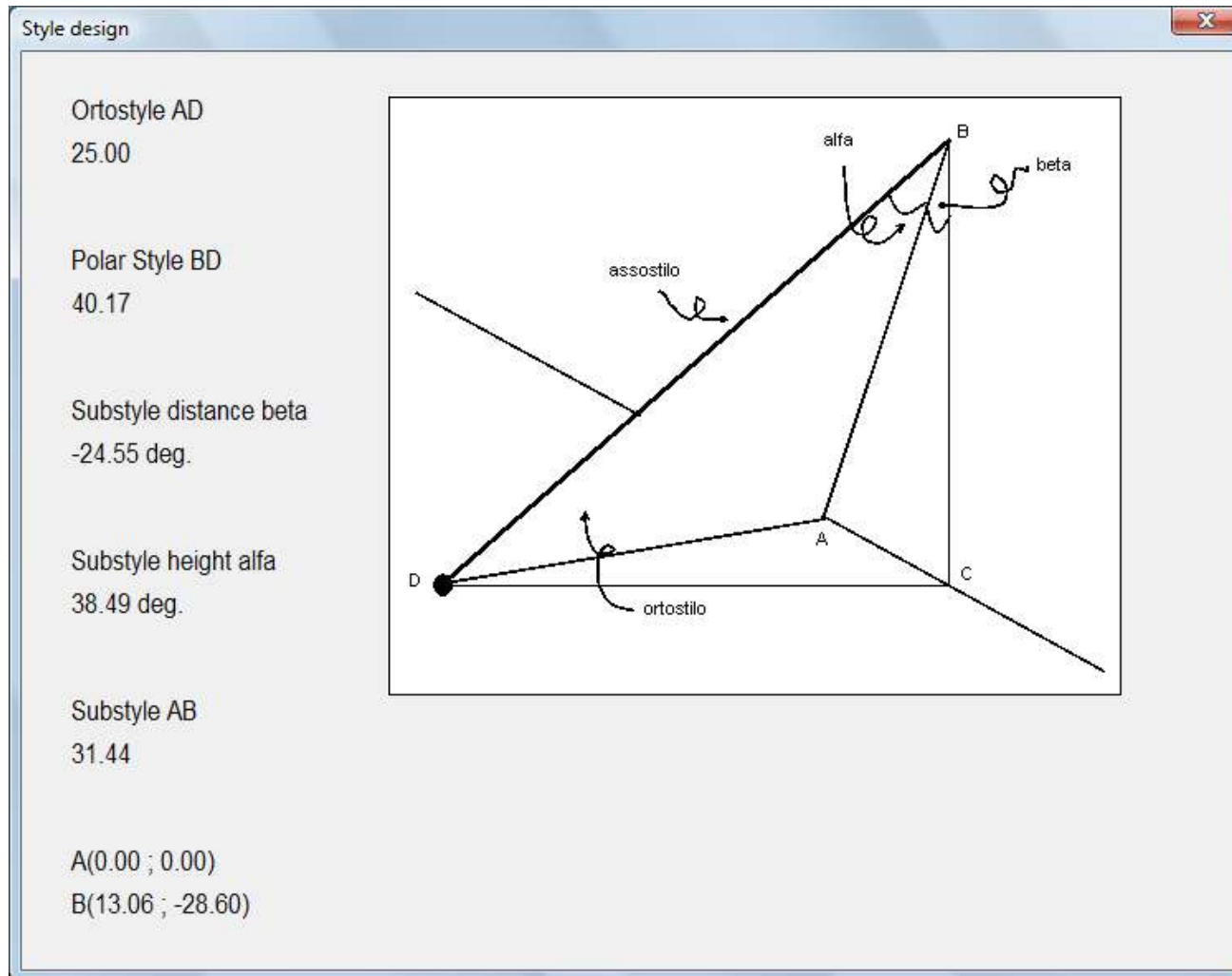
View : tables

The image displays a software interface with several overlapping windows, each showing a different astronomical table. The windows are titled as follows:

- French Hour Lines:** A table with columns 'hour' and 'angle'. It lists values for hours from 0:00 to 21:30.
- Italic Hour Lines:** A table with columns 'Italic hour' and 'fr. hour'. It lists values for hours from 0:00 to 21:30.
- Babilonic Hour Lines:** A table with columns 'Babilonic hour' and 'fr. hour'. It lists values for hours from 0:00 to 21:30.
- Temporal Hour Lines:** A table with columns 'Temp. hour' and 'fr. h.'. It lists values for hours from 0:00 to 12:00.
- Twilight Hour Lines:** A table with columns 'Twilight hour', 'fr. h.', and 'x'. It lists values for hours from 0:00 to 12:00.
- Analemma Table:** A large table with columns 'Anal.', 'jan-1', 'jan-11', 'jan-21', 'feb-1', and 'feb-11'. Each of these columns has sub-columns 'x' and 'y'. It lists values for hours from 0:00 to 21:30.

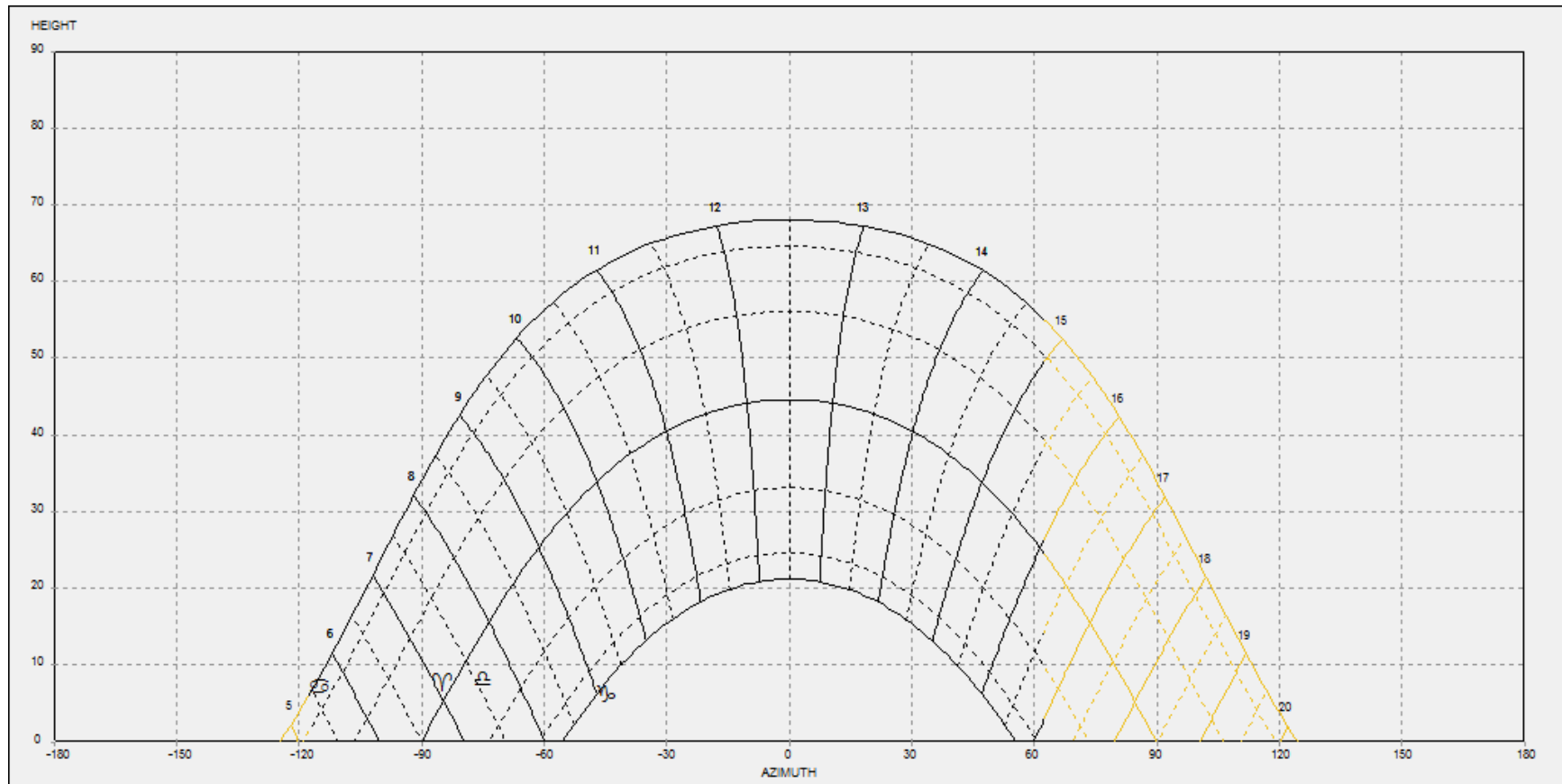
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View : style parameters



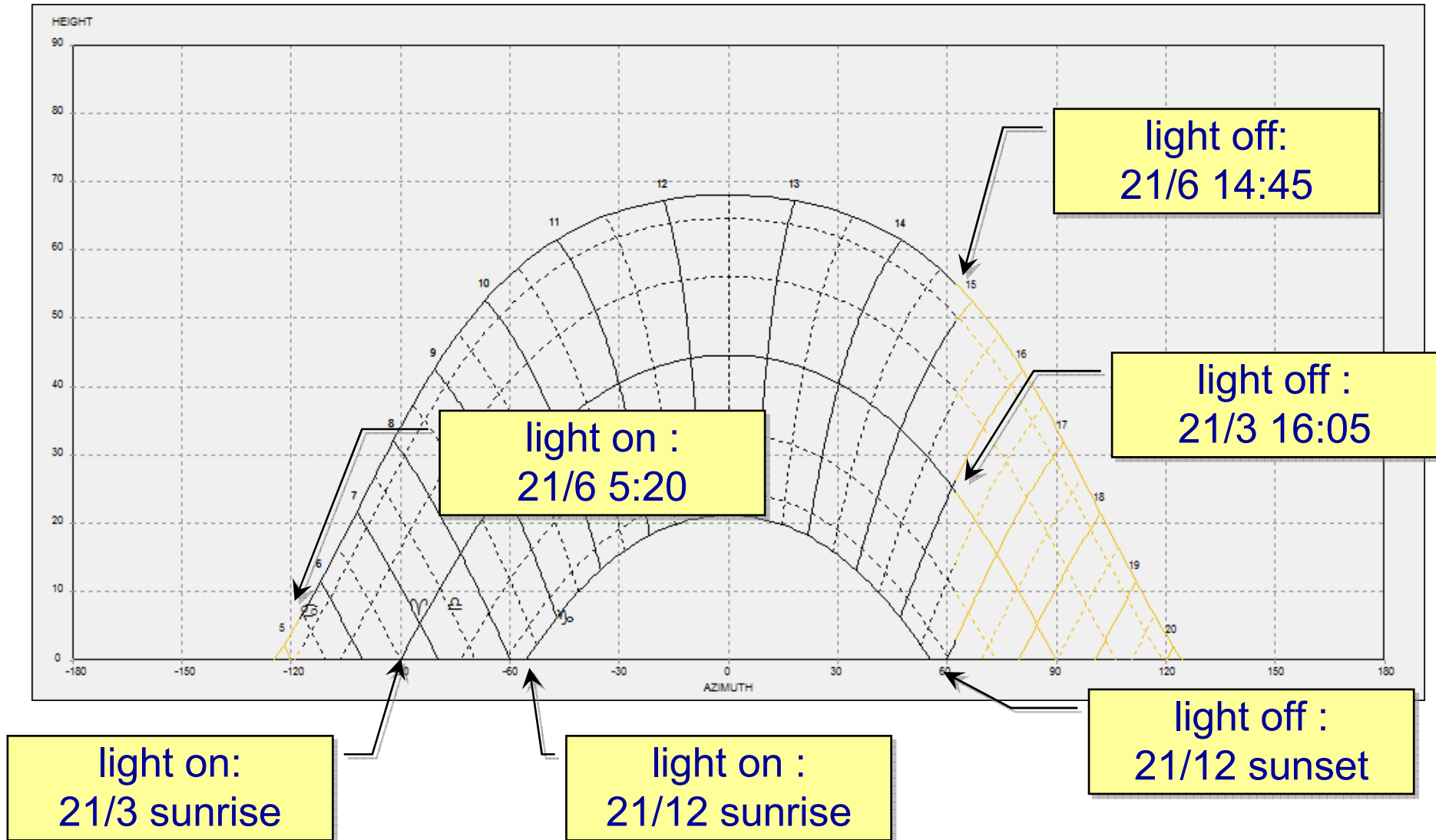
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View : lighting conditions



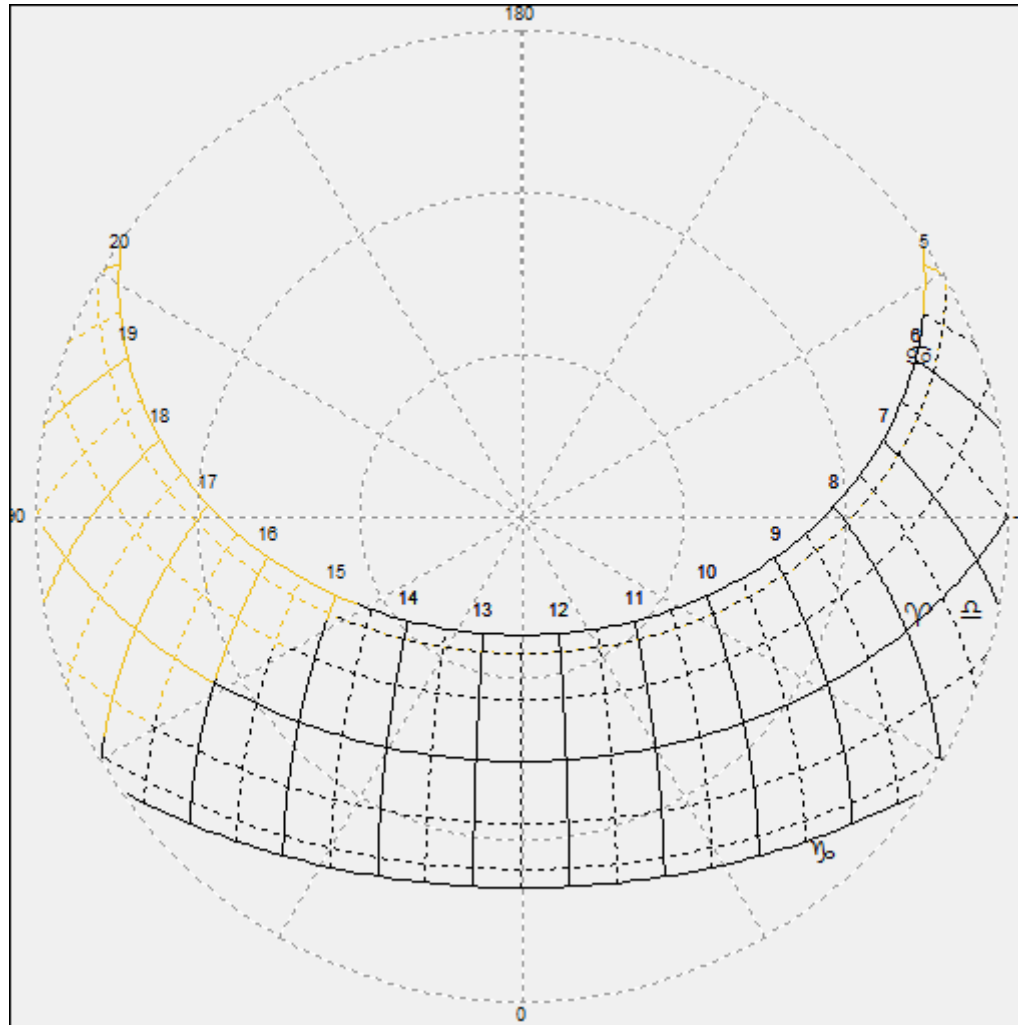
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View : lighting conditions



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View : lighting conditions

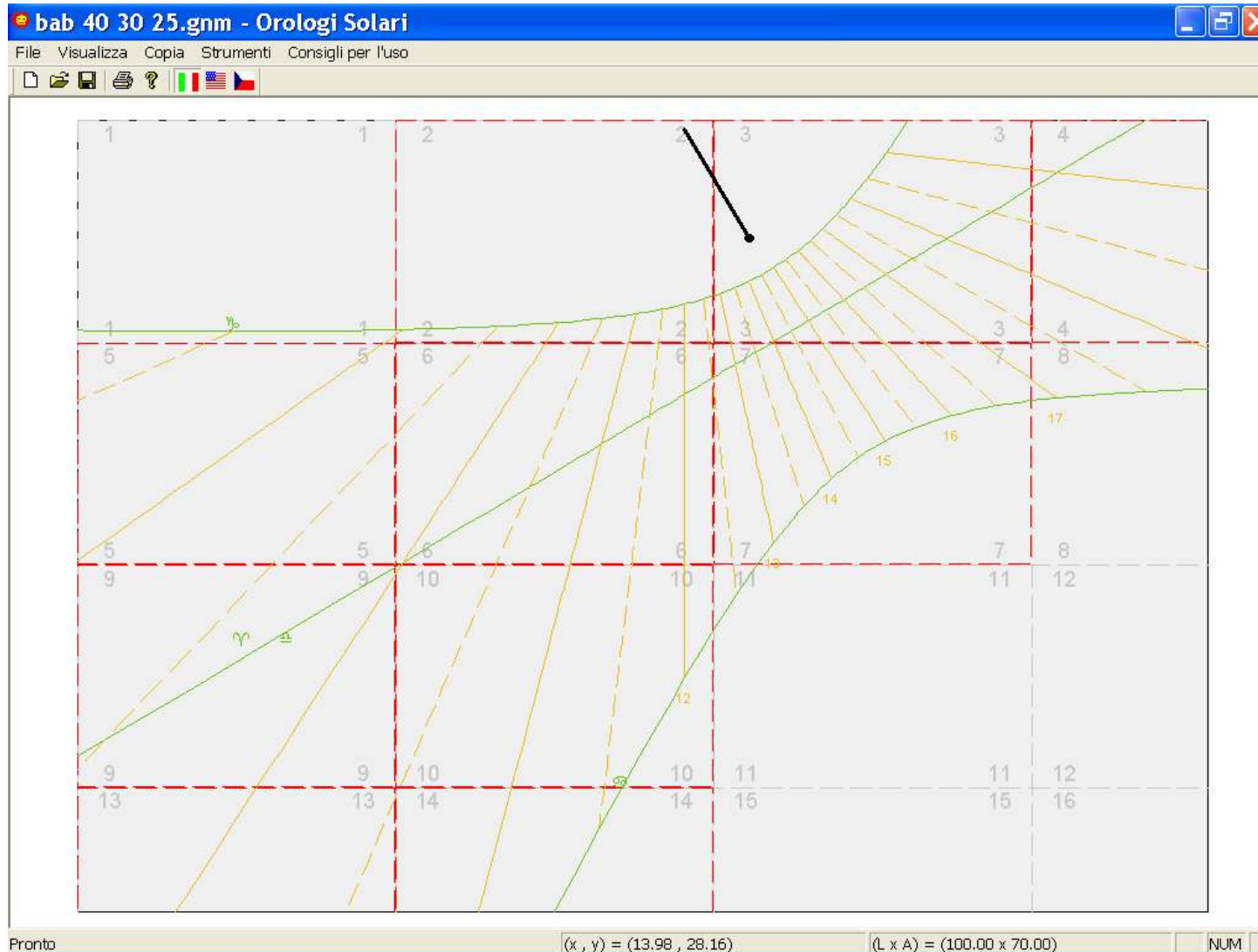


Print, save, export

- copy graphs and tables to the clipboard
- print report with selected graphs and tables
- export to DXF vector file
- export to JPG, TIF, GIF, PCX, BMP raster file
- 1:1 multipages print

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1:1 multipages print



Help

Orologi Solari Help

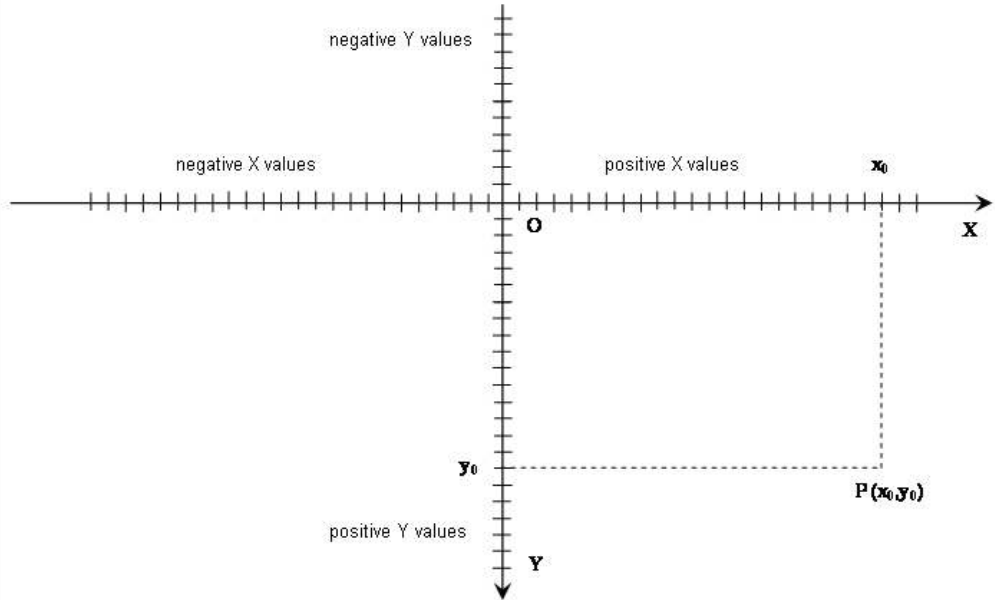
Nascondi Precedente Stampa Opzioni

Contenuto | Indice | Cerca

- Introduction
- Basic concepts on sun dials
- User interface
 - Main window
 - Mouse and keyboard
 - Coordinate system
- Menu
- How to design a new dial
- Glossary
- Version
- Screen Saver
- Acknowledgements

Coordinates

The following cartesian reference system is used in the program when referring to the coordinates of a point:



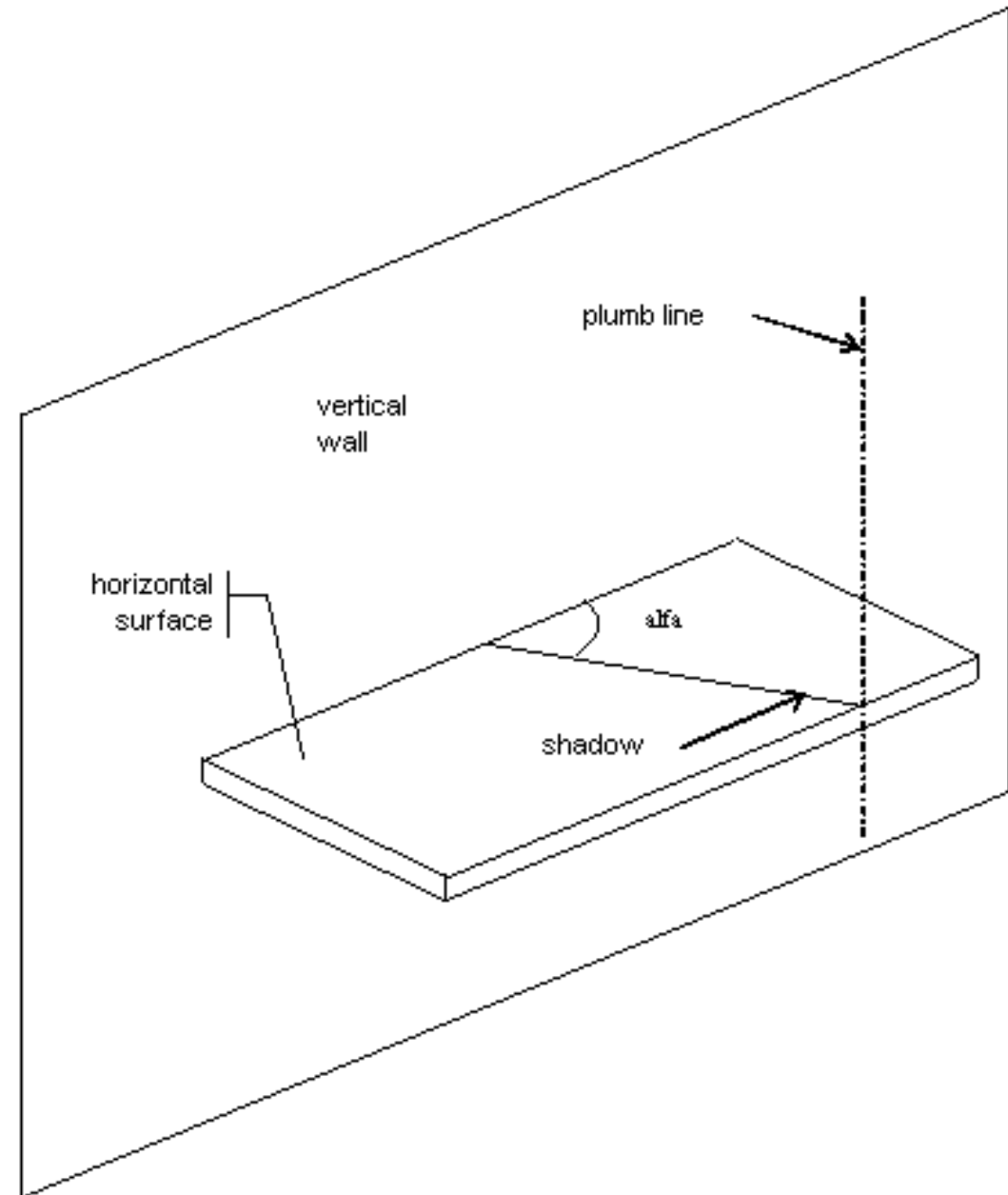
The center O corresponds to the base of the orthogonal style (for the analemmatic dials it corresponds to the style position at the equinox).

Each point in the plan is identified by the two values X_0 and Y_0 as shown in the picture. Note that x has negative values at the left of O and positive values at the right of O, and y has negative values above O and positive values below O.

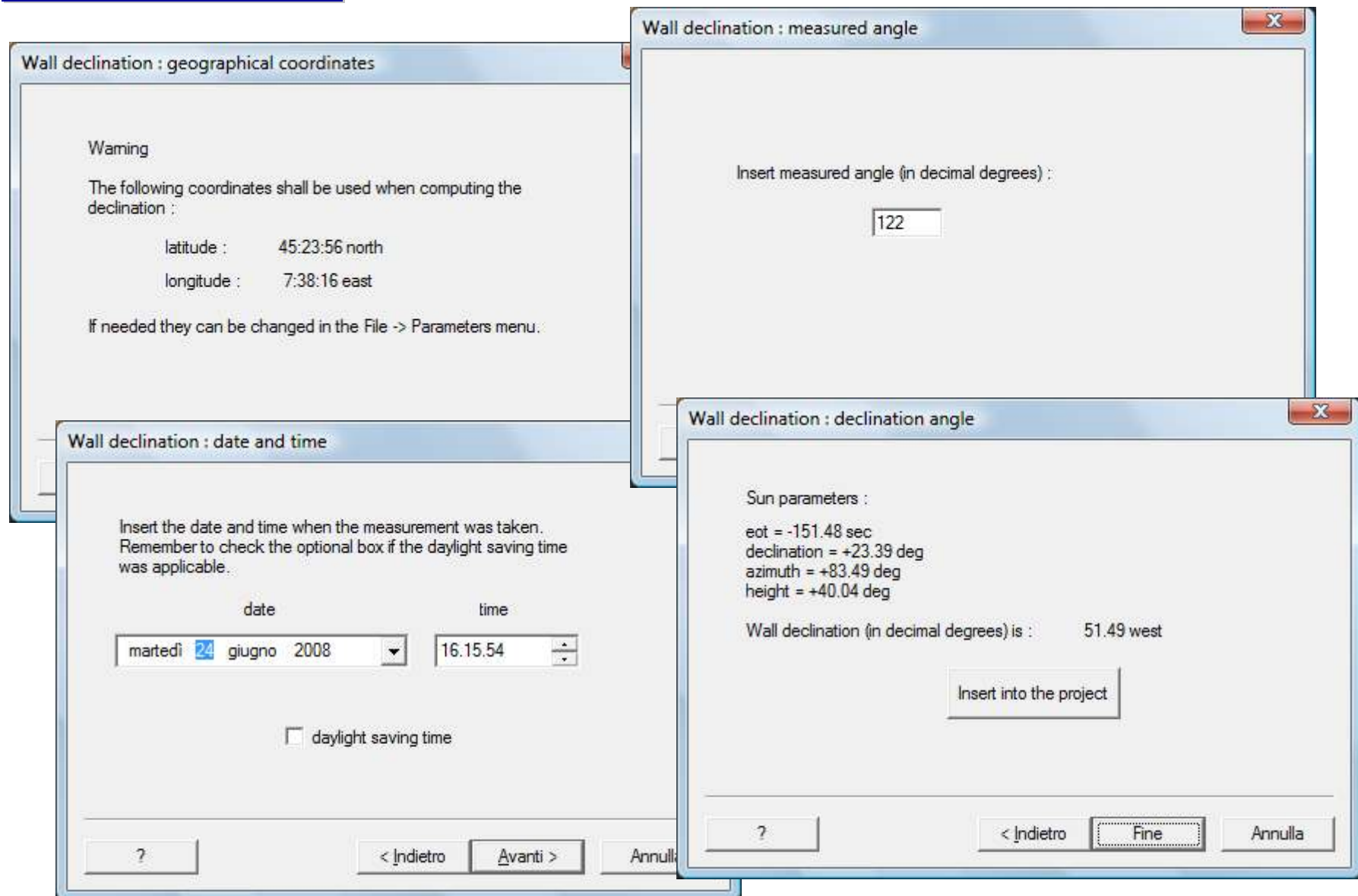
When moving the mouse pointer over a dial, you can see the current mouse position in real world coordinates in the bottom right part of the display as (X_0, Y_0) .

Wall declination

- Based on the shadow/wall angle
- compute sun parameters and wall declination
- put the result into the actual project



Wall declination



Shadow simulation and sun parameters computation

- simulation of any sun dial type (directional, azimuth)
- simulation time : current, manually set or dynamically changed (date / time)
- main sun parameters computation (declination, azimuth, height ...)
- current time shown for any time measurement system
- show sunrise, sunset, local noon, twilight

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Shadow simulation and sun parameters computation

The screenshot displays the 'Orologi Solari' software interface. The main window shows a gnomon shadow simulation on a sundial dial. A gnomon is positioned on the dial, and its shadow is cast onto the hour lines. The dial is marked with hour lines and zodiac signs. A dialog box titled 'Dial is lighted' is open, providing detailed sun parameters for the current date and time.

Dialog Box: Dial is lighted

Date: martedì 24 giugno 2008 Civil time: 16:18:30 TMEC DST DeltaT = 66.1

Sun longitude : 93:25:49 (+93.43029)	Equation of time : -00:02:30 (-150.98s)
Sun right ascension : 06:14:57 (+6.24920)	Sun hour : 15:15:59
Sun declination : 23:23:44 (+23.39564)	Longitude error : -00:29:15
Sun azimuth : 71:03:45 (+71.06275)	Local sun time : 14:46:43
Sun height : 49:48:57 (+49.81602)	

Sunrise : 05:47:29	Italic hour : 19:02:35
Noon : 13:31:44	"Campanile" it. hour : 18:32:35
Sunset : 21:15:55	Babilonic hour : 10:30:52
Twilight : 21:59:35	Temporal hour : 08:09:19
	Twilight hour : 18:18:55

Current time Simulation Time Date

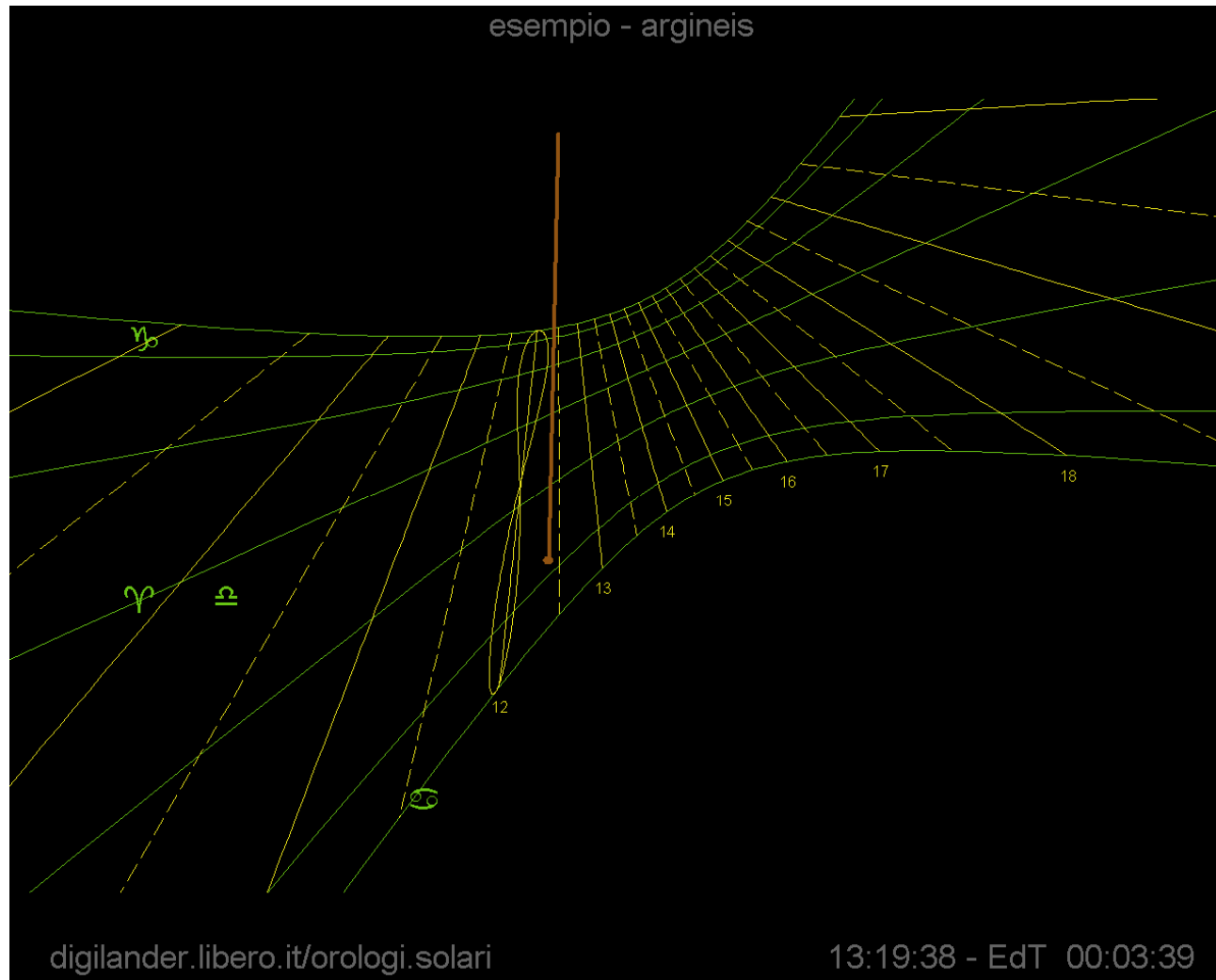
Halt speed polar stile ortostyle triangle

OK ?

Ready (x, y) = (-76.14, -37.96) (L x A) = (250.00 x 162.00)

“Screen Saver”

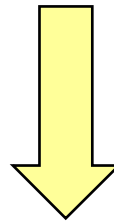
- based on any sundial you designed with the program



Reverse engineering

Problem

given an old dial with only some elements left
(lines, points, style ...)



compute the original design parameters
(latitude, declination, style ...)

Reverse engineering

Classical approach

For any particular situation : measure an element and then find the unknowns by means of trigonometric relationships.

ex. equinox line is available => measure angle, find declination

Disadvantages:

- huge number of possible situations, a program can not cover them all
- program would be a long list of commands, one for each situation / unknown

Reverse engineering

Innovative approach

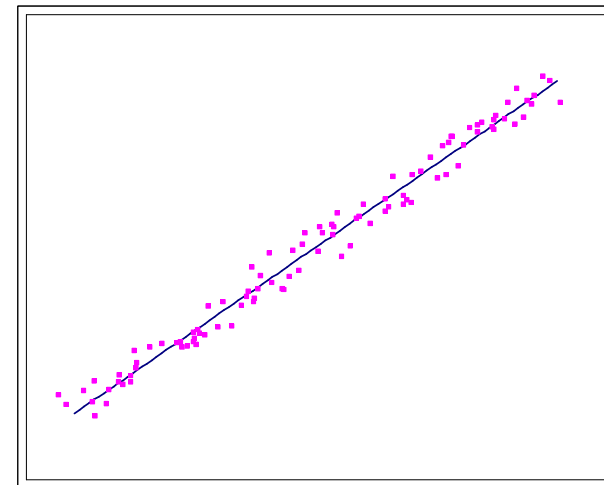
Consider the problem as a “data fitting” situation :

“given a list of measured values, find the parameters of the given model that best match measurements”

ex. linear regression

$$Y = a * X + b$$

Given measurements (X_i, Y_i) find parameters a and b that best approximate the results.



Reverse engineering

ex. declining vertical dial showing local time

$$\left\{ \begin{array}{l} X_i = X(\omega, \delta, \varphi, d, \lambda, x, y) \\ Y_i = Y(\omega, \delta, \varphi, d, \lambda, x, y) \end{array} \right.$$

ω = known hour angle

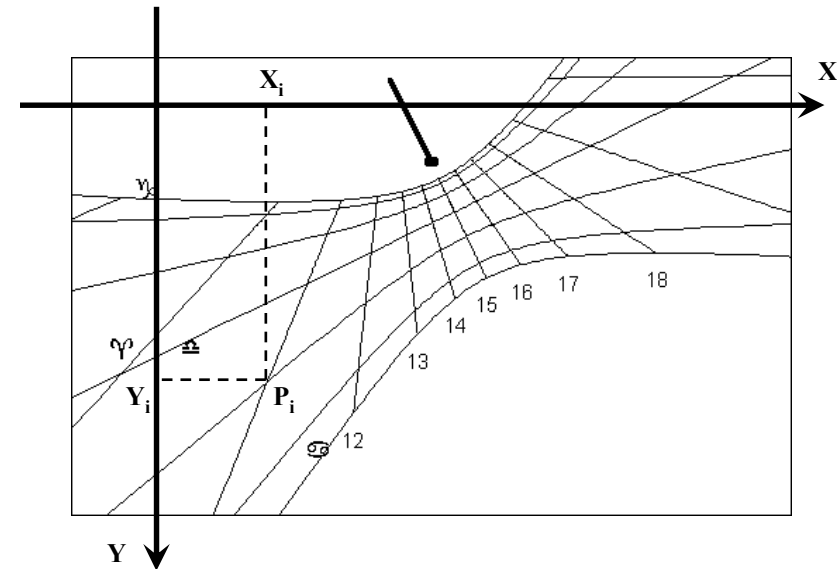
δ = known sun declination

φ = latitude

d = wall declination

λ = orthostyle length

x, y = orthostyle base coordinates



Reverse engineering

1. measure the position of N points (with known ω e δ)
2. make a system of $2*N$ non-linear equations with 5 unknowns

$$f_i(\varphi, d, \lambda, x, y) = k_i \quad i = 1 \div 2N$$

where k_i are the measured coordinates of N points.

3. solve the system and find the 5 unknown parameters

Reverse engineering

Levenberg-Marquardt algorithm

Consider the cost function

$$F(\varphi, d, \lambda, x, y) = \\ = \sum_{i=1}^N (f_i(\varphi, d, \lambda, x, y) - k_i)^2 = \sum_{i=1}^N \varepsilon_i^2$$

equal to the sum of squares of residual errors between model and measurements.

The algorithm will look for a minimum of F through an iterative process that should converge to the local minimum nearest to the initial starting hypothesis.

Reverse engineering

The screenshot shows a software window titled "Reverse engineering data" with two main panels: "linee" (lines) and "punti" (points). The "linee" panel lists three items: "1 Babilonic - hour 1.0 - 2 points", "2 Babilonic - hour 3.0 - 2 points", and "3 Babilonic - hour 4.0 - 2 points". The "punti" panel lists ten items, with the first three being "1 Babilonic-Equinox - hour 24.0", "2 Babilonic-Equinox - hour 3.0", and "3 Babilonic-Equinox - hour 2.0". Each item has "edit" and "delete" buttons. Below the panels are search buttons ("Global search", "Local search", "Insert into the project"), input fields for "latit.", "longit.", "declin.", "ort. length", and "ort. pos.", and "OK", "Cancel", "Open...", and "Save..." buttons. Annotations in yellow boxes point to these elements: "list of measure lines" points to the "linee" list; "list of measured points" points to the "punti" list; "find a solution" points to the search buttons; "solution" points to the "OK" button; "save / open input data" points to the "Open..." and "Save..." buttons.

linee	punti
1 Babilonic - hour 1.0 - 2 points	1 Babilonic-Equinox - hour 24.0
2 Babilonic - hour 3.0 - 2 points	2 Babilonic-Equinox - hour 3.0
3 Babilonic - hour 4.0 - 2 points	3 Babilonic-Equinox - hour 2.0
	4
	5
	6
	7
	8
	9
	10

Annotations:

- list of measure lines
- list of measured points
- find a solution
- save / open input data
- solution

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Reverse engineering : input of measured lines and points

Line parameters

	x	y	line type
1	118.380	105.280	BABILONIC HOUR
2	206.380	113.990	
3			
4			
5			
6			
7			
8			
9			
10			

hour 1

+ 1/2 hour

OK Cancel ?

line type

hour

point coordinates (min. 2)

point type

Point parameters

x	y	point type
114.430	100.000	BABILONIC-EQUINOX

hour 24

+ 1/2 hour

OK Cancel ?

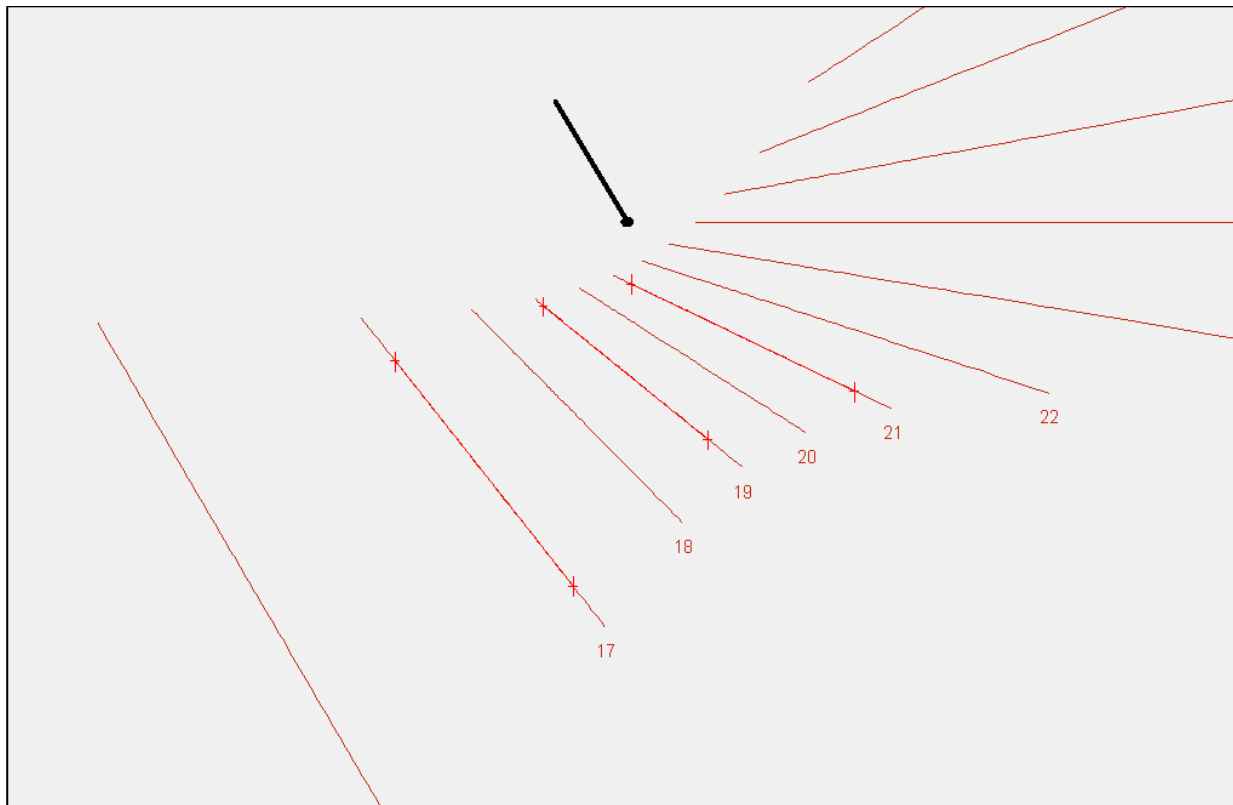
point coordinate

hour

Reverse engineering

ex. italic hour dial, three hour lines known

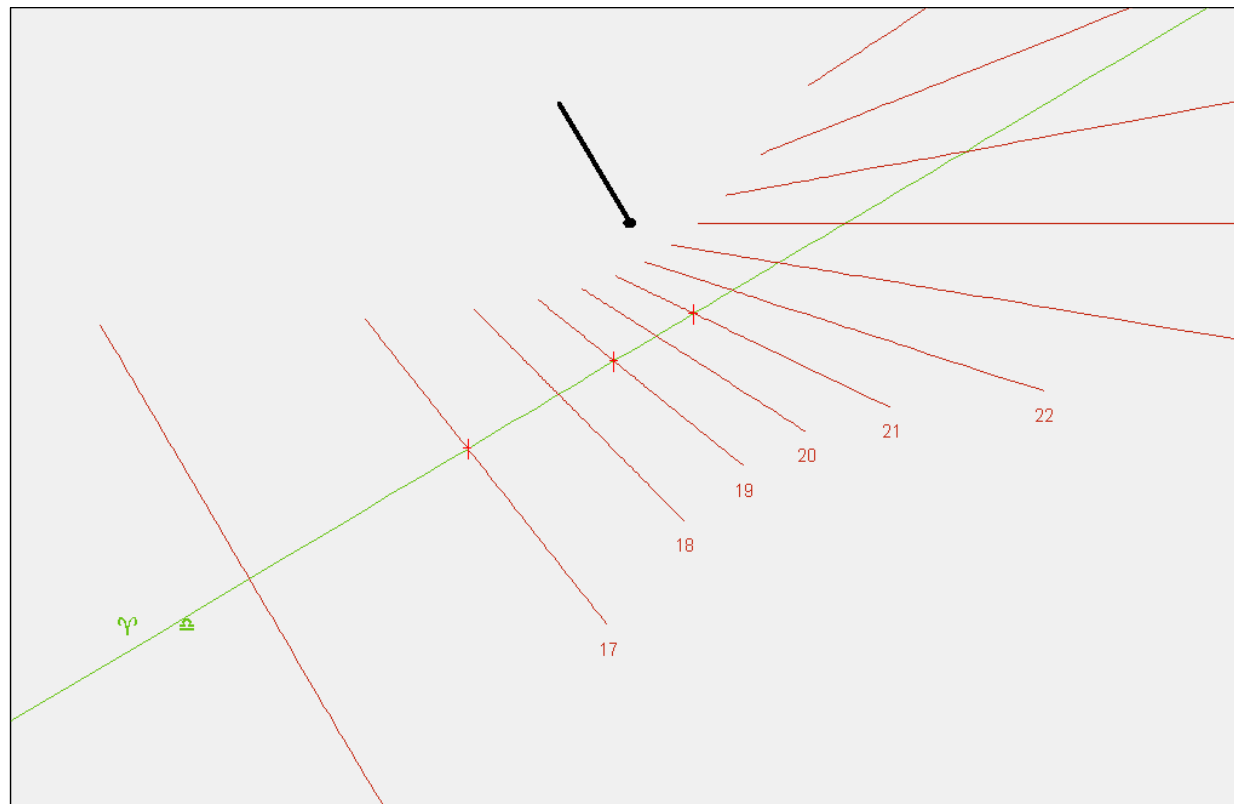
recovered dial :



Reverse engineering

ex. italic hour dial, three points known (intersection between hour lines and equinox line)

recovered dial :



Reverse engineering

ex. italic hour dial, three points known (intersection between hour lines and day lines)

recovered dial :



Reverse engineering

ex. italic hour dial

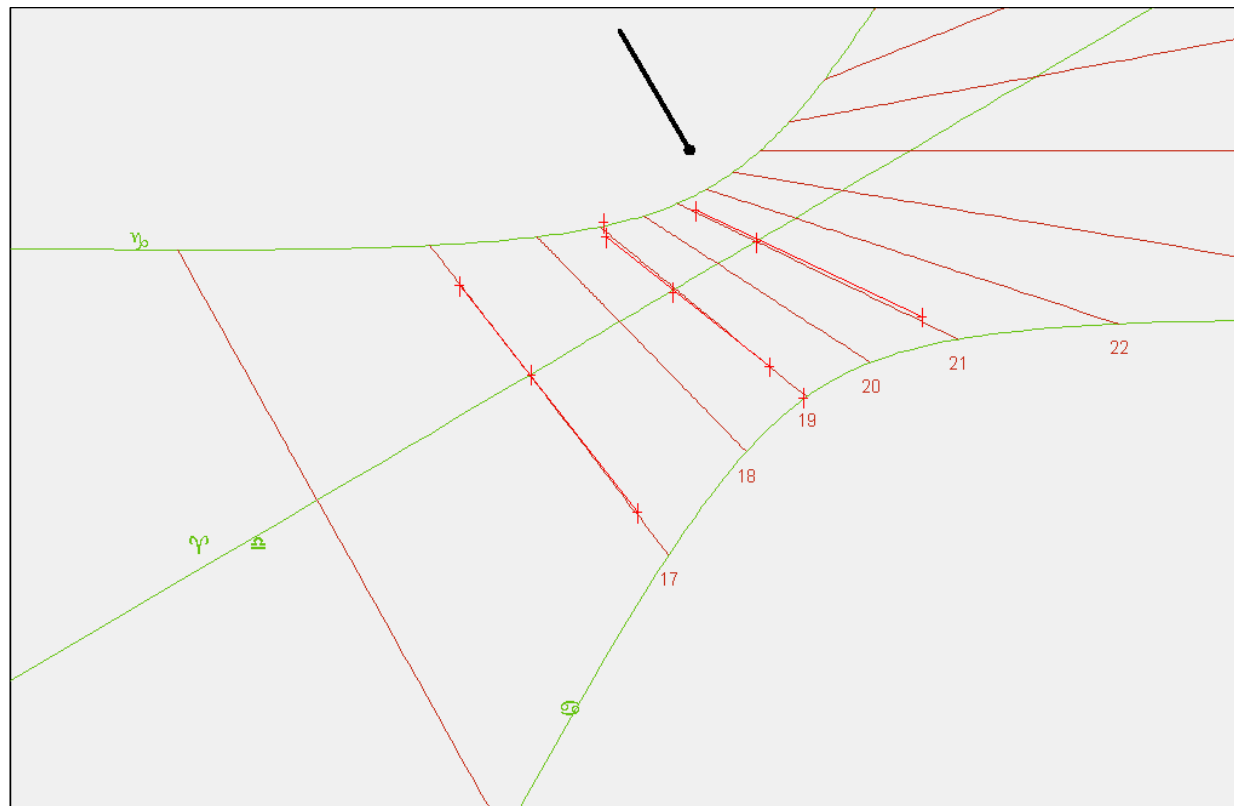
results :

unknown	true value	case 1	case 2	case 3
φ	40.00	40.03	40.01	40.02
d	30.00	29.92	30.05	30.00
λ	25.00	25.19	24.98	25.02
x	125.00	125.36	125.06	125.03
y	37.00	37.11	37.01	36.99

Reverse engineering

ex. italic dial ± 1 cm error : in the presence of errors use as many data as possible

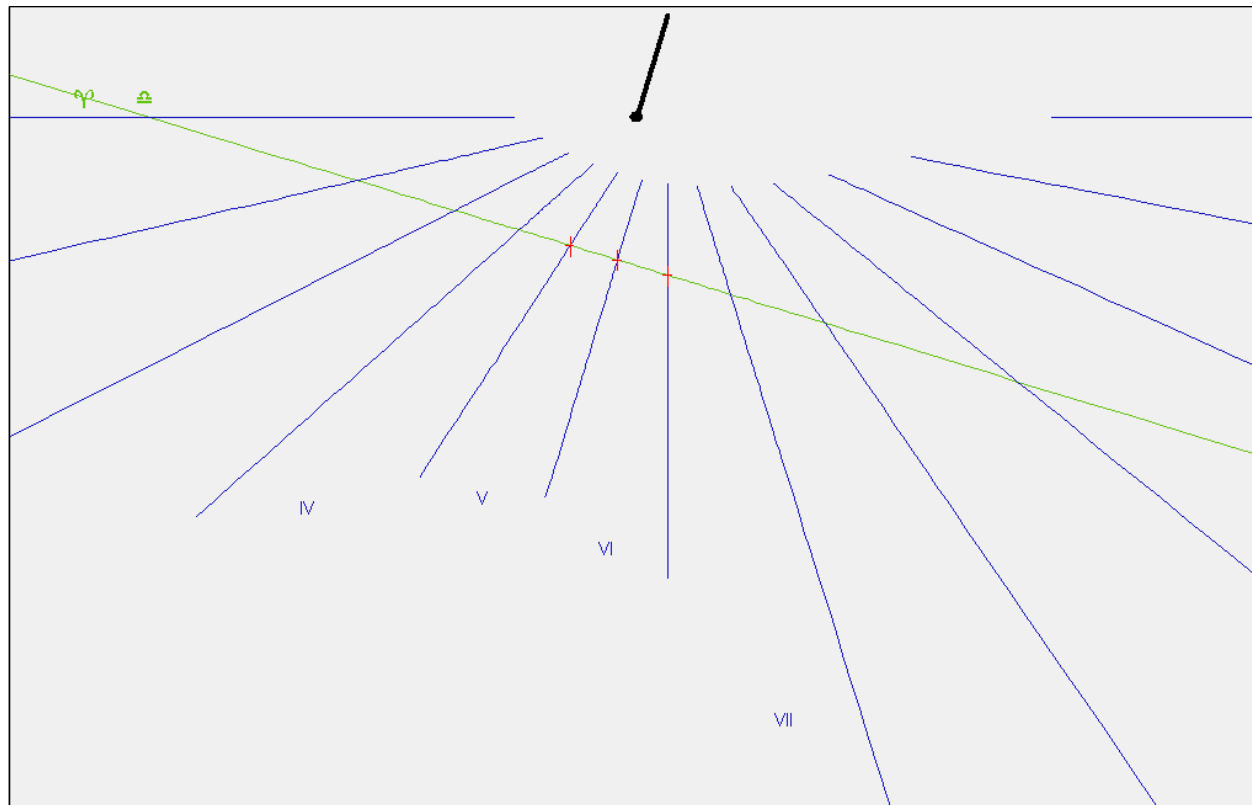
recovered dial :



Reverse engineering

ex. temporal hour dial, three points known (intersection between hour lines and equinox line)

recovered dial :



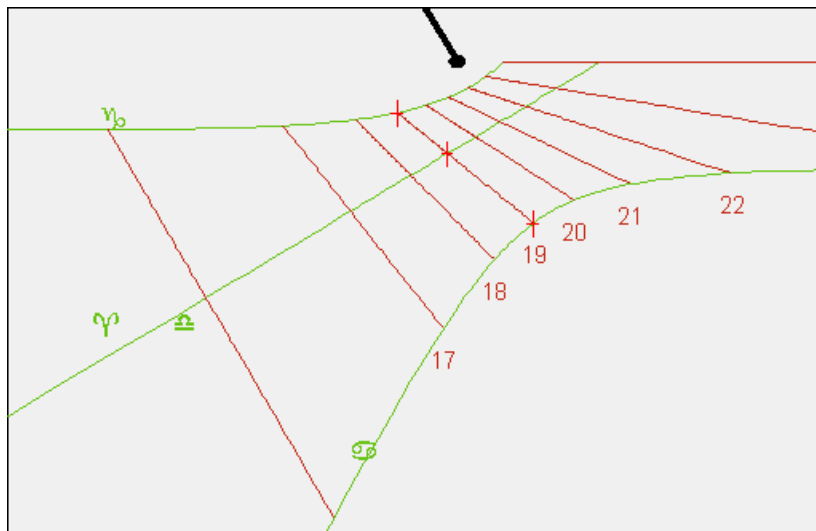
Reverse engineering

Measured elements must allow the identification of one and only one dial.

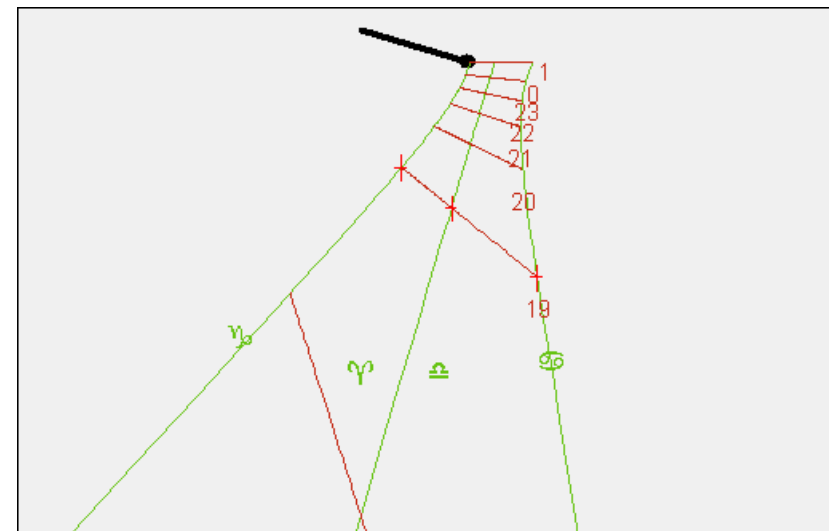
ex. left: italic dial with three hour lines / day lines intersections known, right : recovered dial

=> more than one solution exist

starting dial



recovered dial



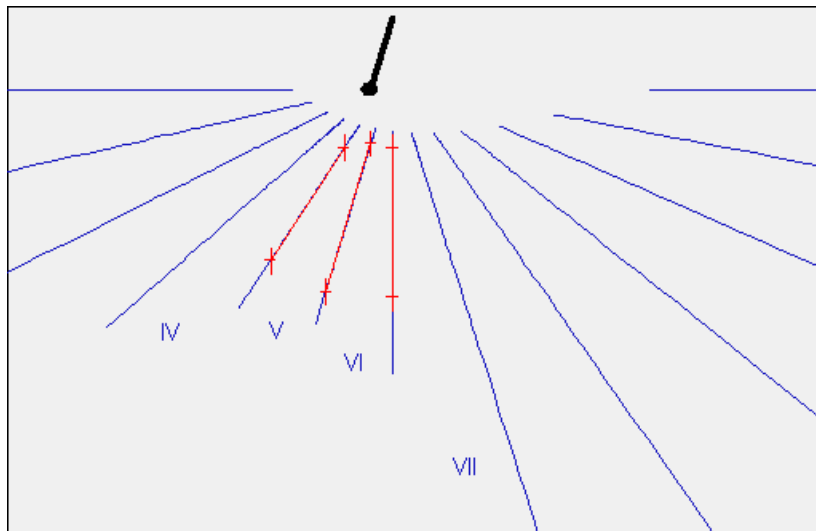
Reverse engineering

Measured elements must allow the identification of one and only one dial.

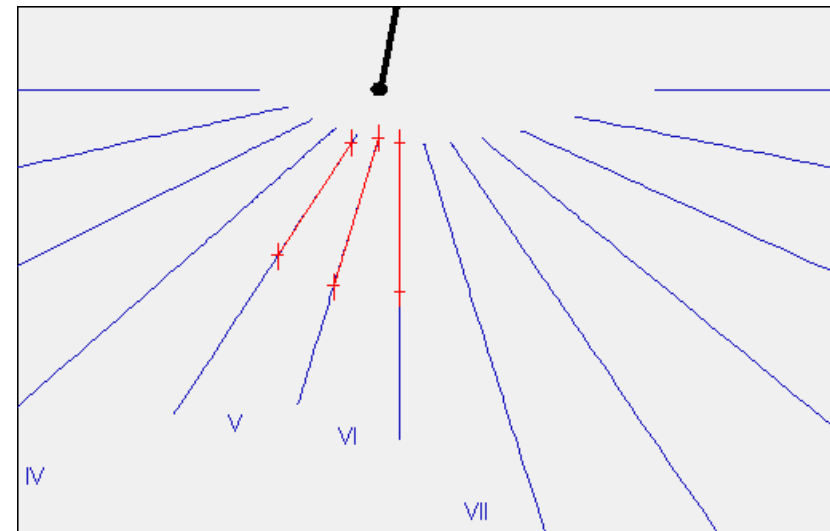
ex. left : temporal dial with three hour lines known, right : recovered dial

=> more than one solution exist

starting dial



recovered dial



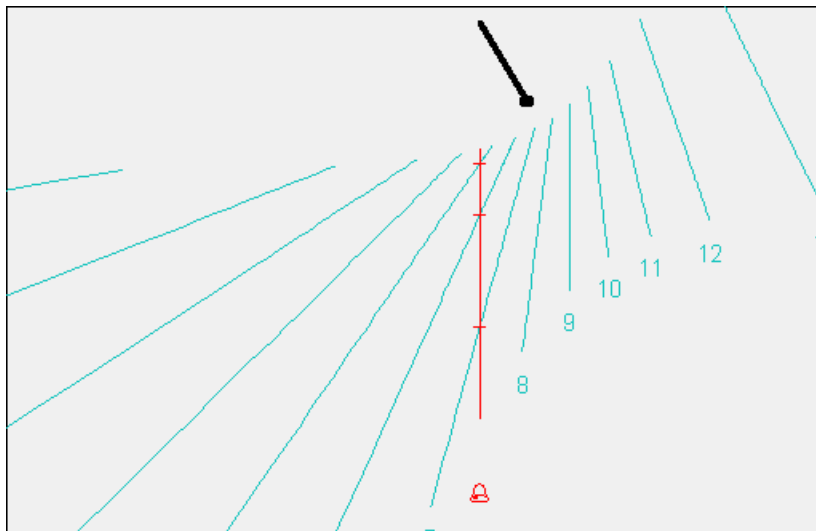
Reverse engineering

Measured elements must allow the identification of one and only one dial.

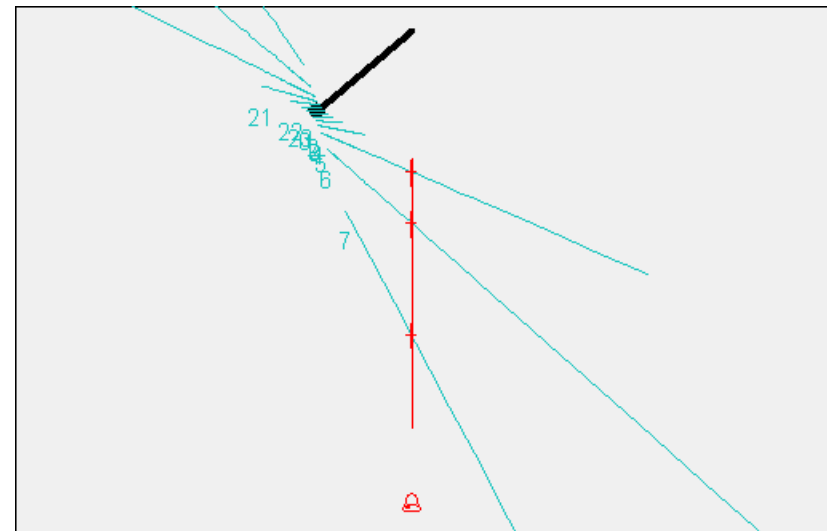
ex. left : babilonic dial with three meridian / hour lines intersections, right : recovered dial

=> more than one solution exist

starting dial



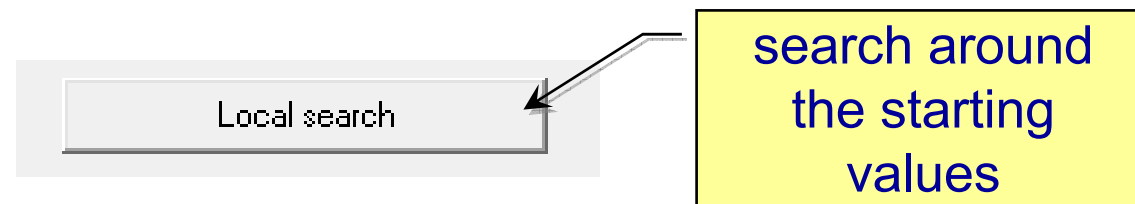
recovered dial



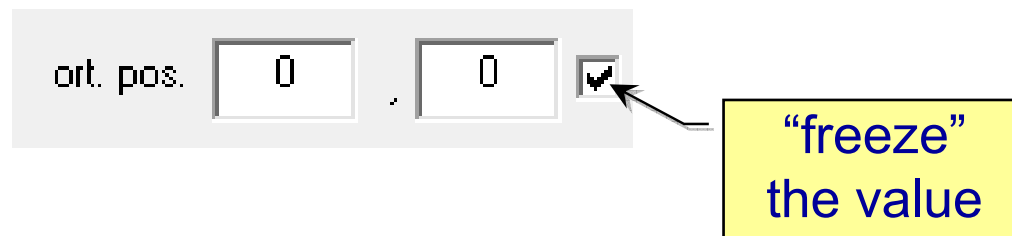
Reverse engineering

For good solutions it is advisable to :

- intrduce the larger possible number of input data
- use points instead of lines (as long as possible)
- try a local search starting from “good” starting values



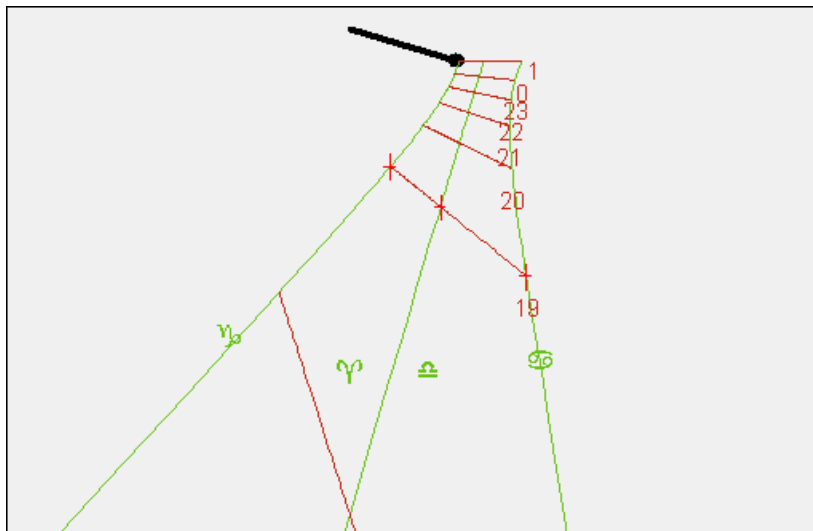
- “freeze” known values



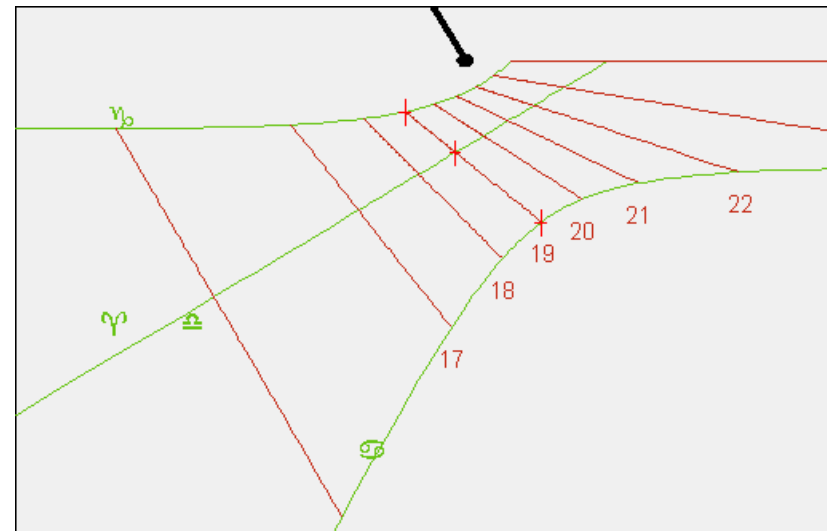
Reverse engineering

previous ex. (italic dial with three hour lines / day lines intersections known) : when the style position is known and introduced (“frozen”) we obtain the correct result

wrong



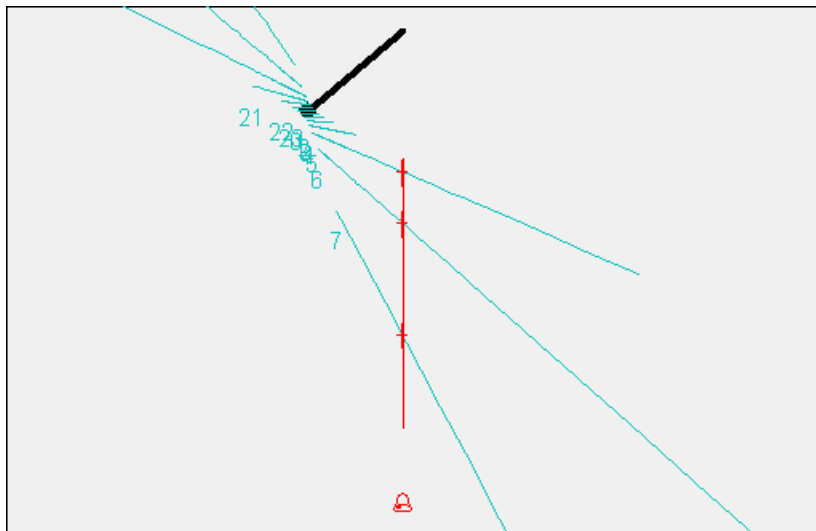
good



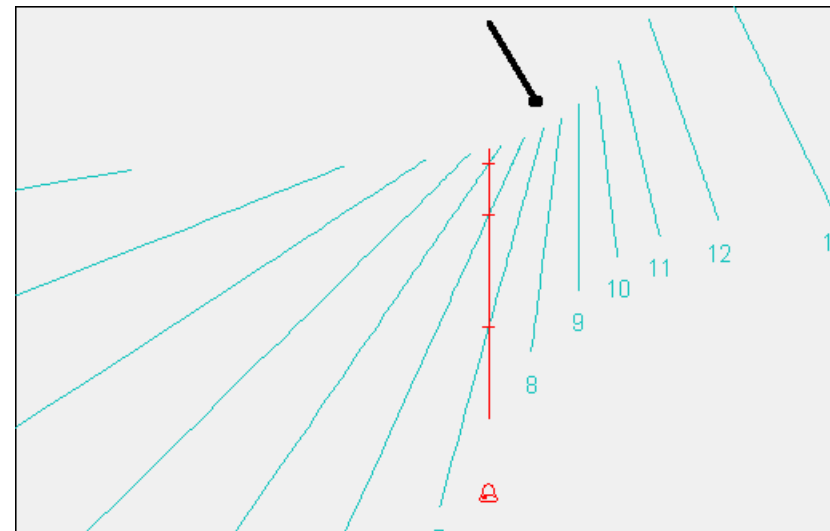
Reverse engineering

previous ex. (babilonic dial with three meridian / hour lines intersections known) : when the style position is known and introduced (“frozen”) we obtain the correct result

wrong



good



Future enhancements

New types of dials :

- sheppard cylindrical dial
- Joël Robic's cylindrical dial
- height dials
- reflection (mirror) dials
- bifilar dials

Future enhancements

Various :

- day lines for 12 months (azimuth dials)
- style position for 12 months (analemmatic dials)
- quarter of hour lines
- user preferences (line thickness, colour etc.)
- user interface and help files translated to new languages

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[Download, comments, suggestions, bugs ...](#)

<http://digilander.libero.it/orologi.solari>

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