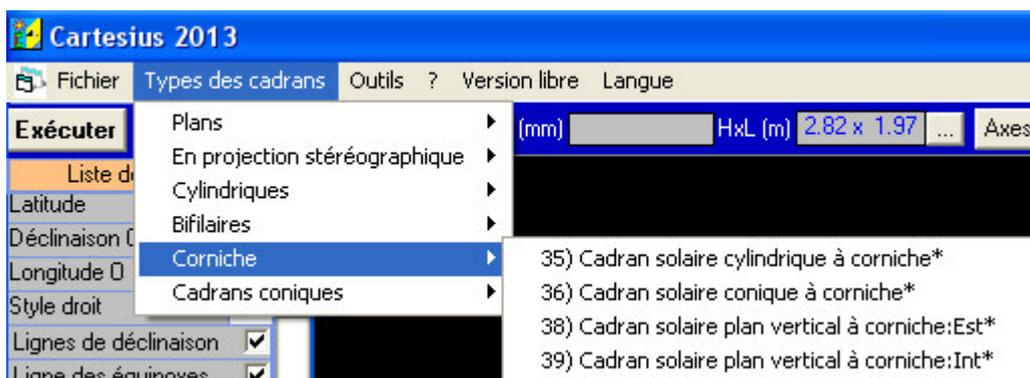
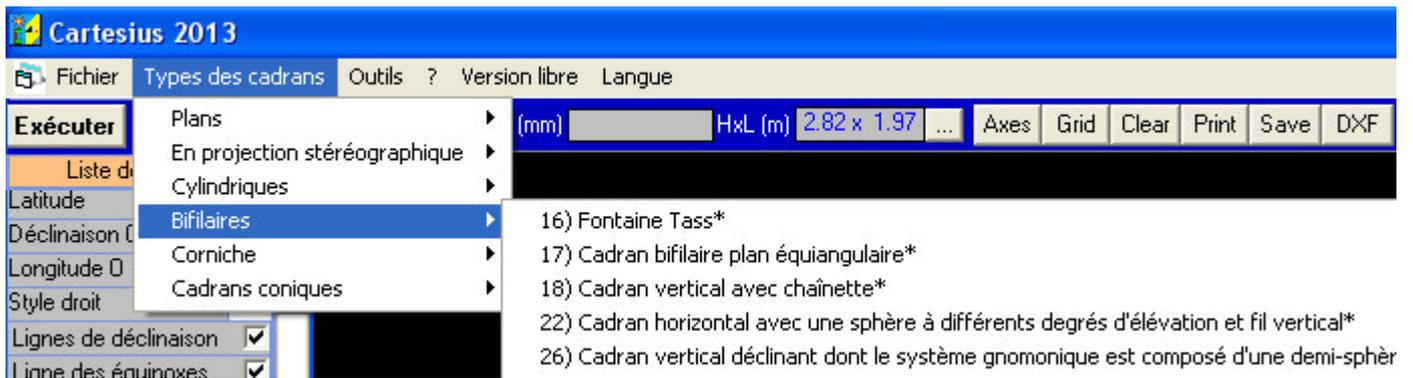
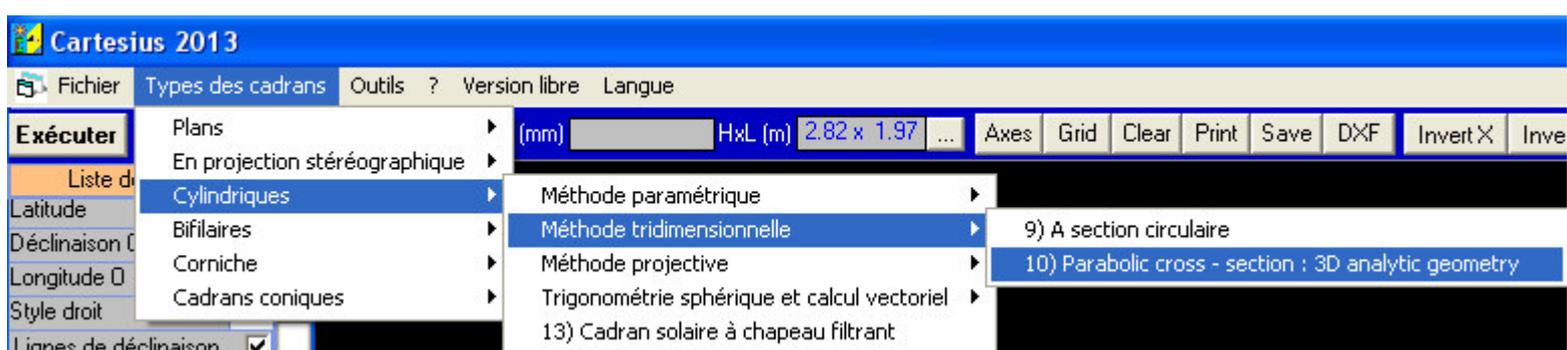
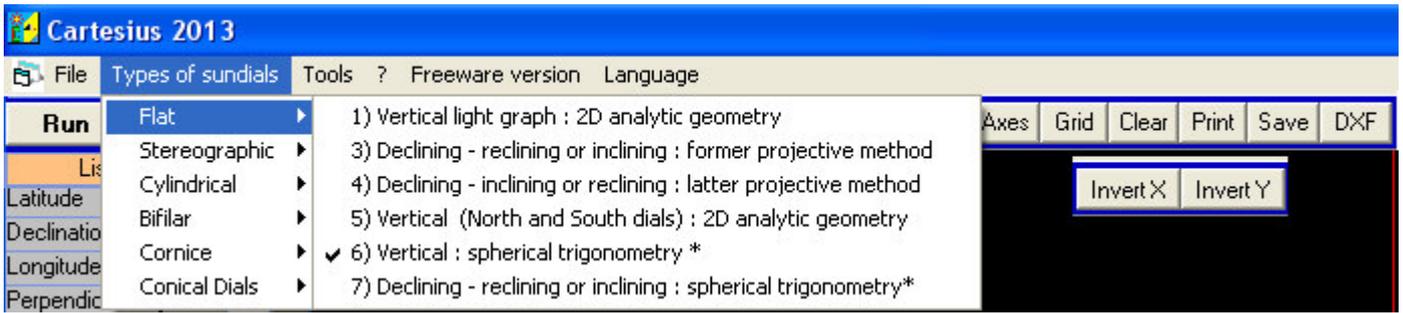
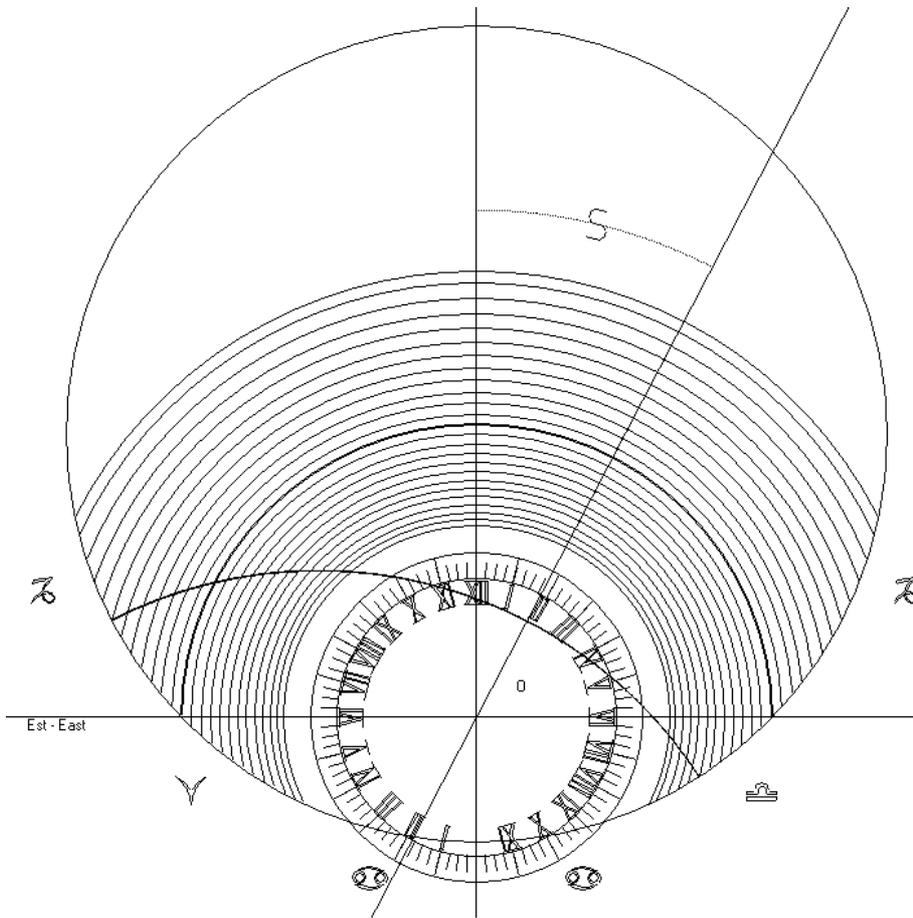


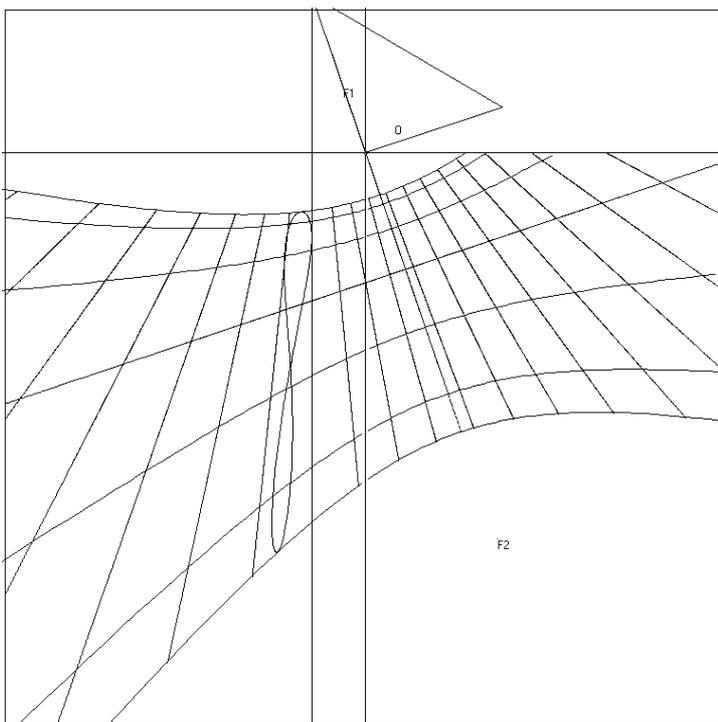
SOFTWARE CARTESIUS 2013



Instructions



Cartesius 2013 is a freeware program in Demo version, written in Visual Basic 6. It produces graph of sundials to scale 1:10 or 1:1 or DXF files. By using scale 1:1 it is possible to create a serial of prints A4 that can be joined together in order to have a sole large sheet. It is advisable to use an ink-jet printer for a more precise print. Other types of printers may cause distortion as they heat the paper. **Cartesius 2013** is easy to use – it has one basic screen with easy-to-follow commands. Click **TYPES OF SUNDIALS** in the top left-hand corner and the following list appears:



FLAT

- 1) Vertical light graph;
- 3) Declining - reclining or inclining former projective method;
- 4) Declining - reclining or inclining latter projective method;
- 5) Vertical (North and South dials): 2D method;
- 6) Vertical (special and optimised, default): spherical trigonometry method, this is the program that comes up automatically at the start-up.
- 7) reclining flat dials by spherical trigonometry.

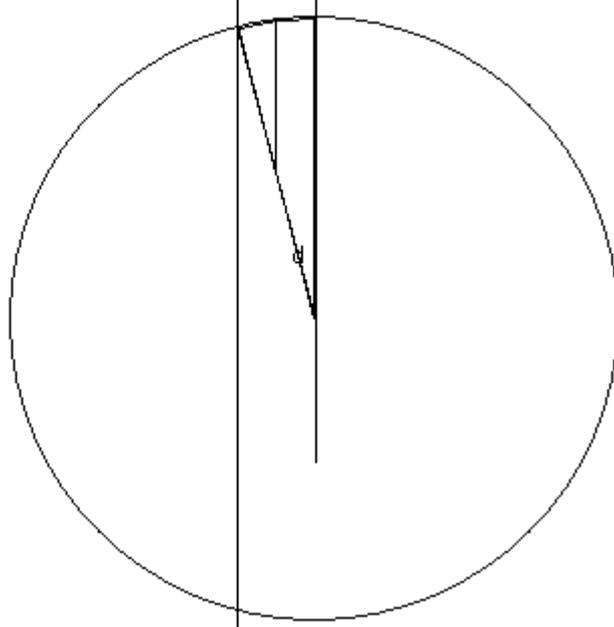
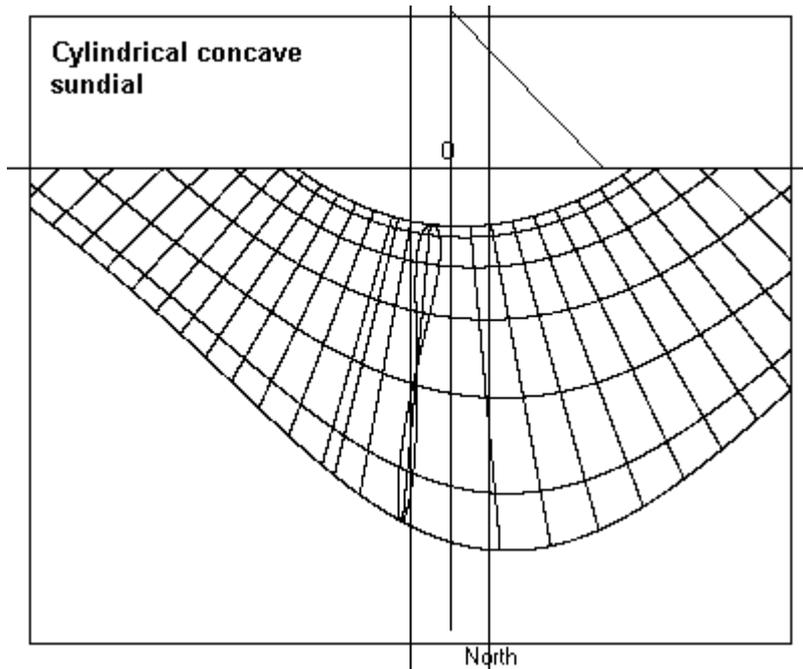
Stereographic diagram

CYLINDRICAL

Circular cross-section: parametric method;

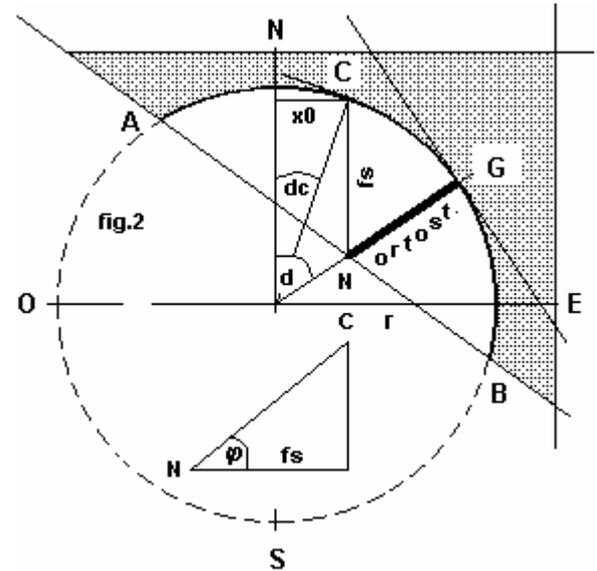
Circular cross-section: 3D method;

9) Circular cross-section by spherical trigonometry;



program, Vertical light graph, shows the hidden features. The graph can be superimposed on the one obtained from program 6. This way, the hidden features are also visible in the background. The graph that appear on the screen can even be printed on a scale of 1:1 by selecting and highlighting different rectangular areas

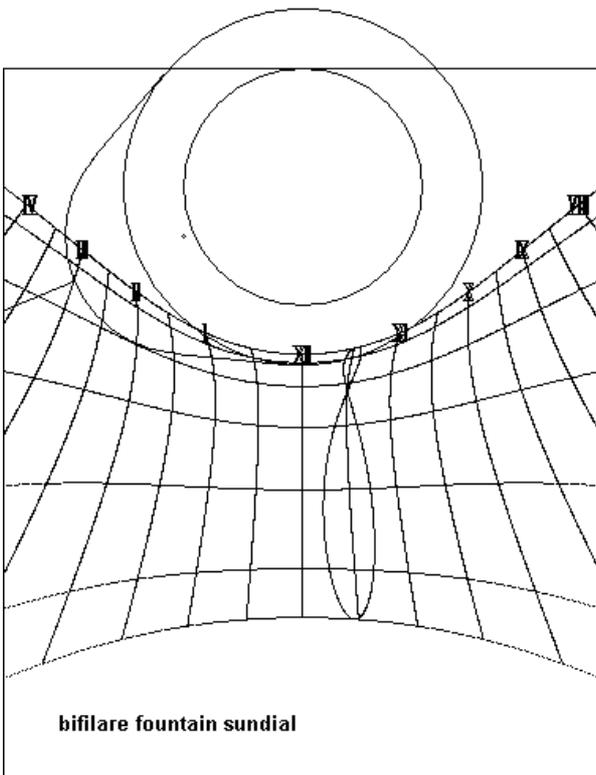
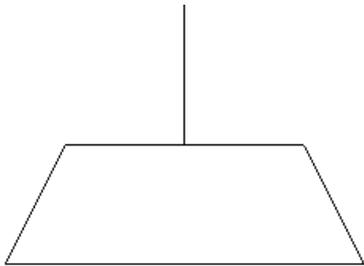
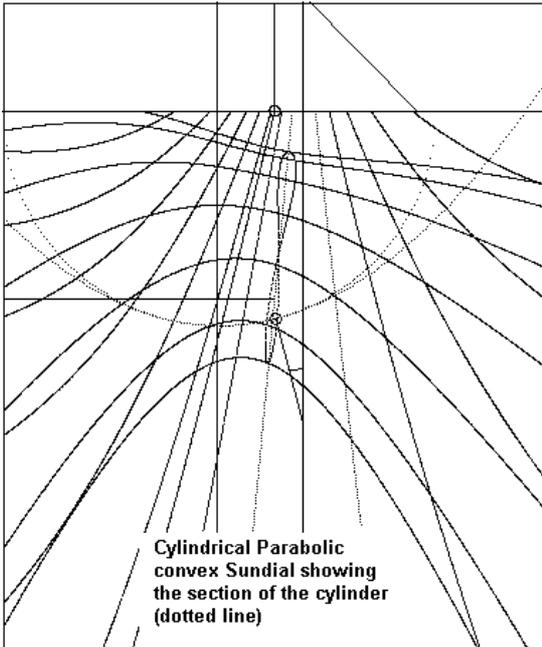
10) Parabolic cross-section: 3D method.



Circular cross-section: projective method;

Spherical trigonometry method

Cartesius 2013 allows the user to produce an image of a flat or cylindrical sundial, on screen or on paper. Cylindrical sundials are generated on a flat surface and can then be simply adapted to the cylinder. Program 6, which applies only to the Northern Hemisphere, permits a more realistic image of the sundial to be produced, because parts superfluous to the sundial have been eliminated. The different parts of the dial can be shown individually or all together by using different commands. Another

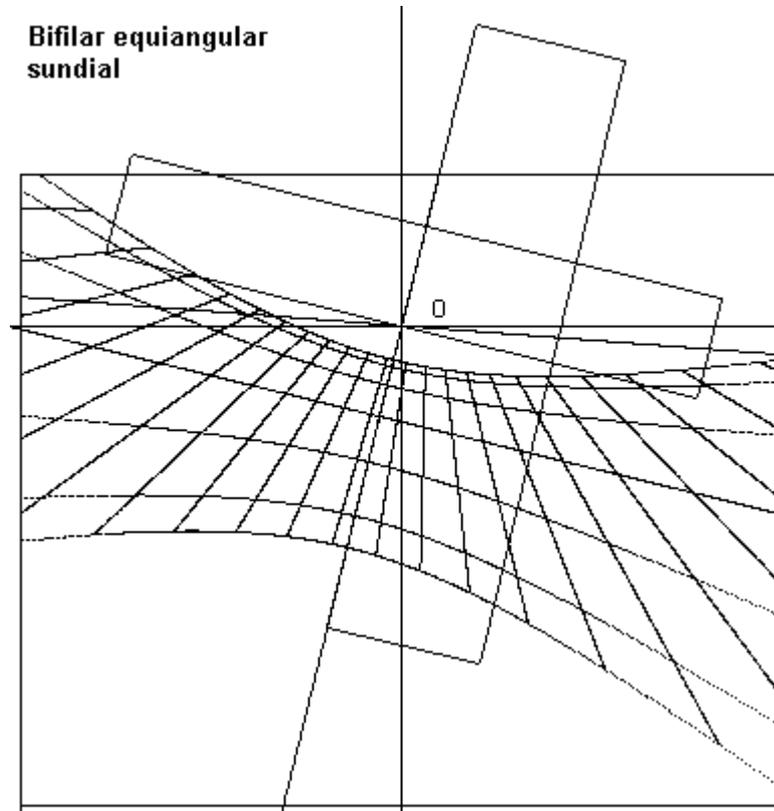


equivalent to an A4 or A3 sheet of paper. Almost all of the programs included in **Cartesius 2013** are capable of drawing astronomical hours, local hours or hours belonging to a specific longitude. These can be activated by clicking on "Standard Meridian Time". It is also possible to plot time according to the old Italic or Babylonian systems. The mean time analemma can also be inserted at any hour or fraction, by varying the longitude. Program 6 also offers the possibility of using a conical style, preferably with Italic or Babylonian hours. The use of a conical style allows Italic and Babylonian hours to be read on a normal quadrant that bears astronomical hours. To make it easier to learn to use **Cartesius 2013**, the program carries default values so that if you simply click on **Run** the program automatically produces a sundial.

Program no. 5 has been produced using two-dimensional analytical geometry and so permits the creation of a vertical quadrant practically anywhere. As to programs 3 and 4, these two are unusual programs that use the projection method, which only works for flat sundials, but they have some limitations. These programs have been placed here purely out of scientific zeal, as have nos. 8, 9, 10 and 11, in the hope that they may be of interest. The projection method creates areas of shadow which cannot be completely eliminated and which are due to the very nature of the method. In both cases a quadrant known as a source is used, which in program 3 faces south precisely, whereas in 4 it is a flat vertical quadrant with variable declination. In the former case, the element quadrant is fixed while the receiving quadrant is variable. In the latter case, the opposite happens. The two programs allow the user to compare an inclined vertical quadrant with a vertical one. Carry out the following test with program 4: use the following values: $j = 40$, $d = 20$, $l = 0$ and $iz = 20$. Then click on **Data** where the following alternative values should appear: $j' = 58.23611$, $d' = 29.84838$ and $l = -12.8391$. Choose Program 1 and insert these new values without deleting the graph you have. Click on **Standard Meridian Time** and then **Run**. The new image should superimpose itself precisely over that of the inclined quadrant.

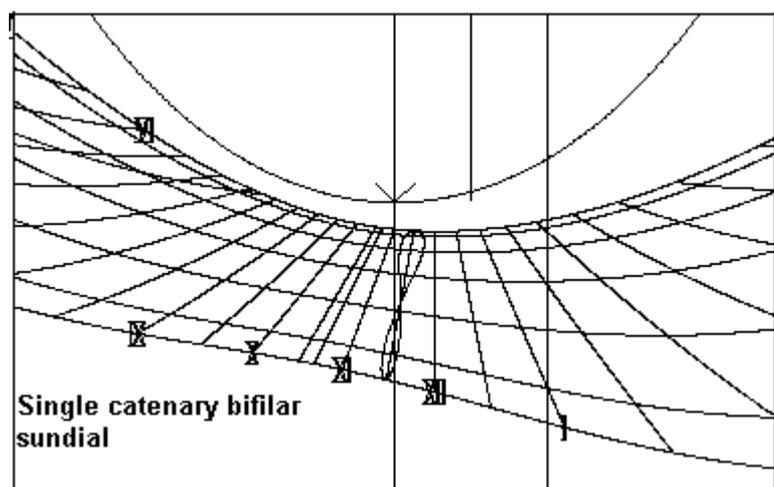
By **Cartesius 2013** you can plot sundials on screen, and print them out, using different mathematical solutions. For cylindrical sundials with a circular cross-section, four different methods are put forward.

Stereographic diagram



Very useful tool for calculating the times of the illumination of a flat sundial through the year. Program 7 uses 3D analytical geometry. It uses a perpendicular style which is always aligned with the centre of the cylinder. However, the program constructs the triangle of the style using the style itself and an **inappropriate gnomon** that runs from the tip of the style, or perpendicular style, to the cylinder, the intersection with the cylinder being perpendicular to the element, which passes through the centre of the dial from which the style emerges. Choosing a perpendicular style has permitted the creation of a program that is capable of producing any cylindrical sundial, be it concave or convex, with a circular cross-section. The declination of the dial, in this program, means that of the plane

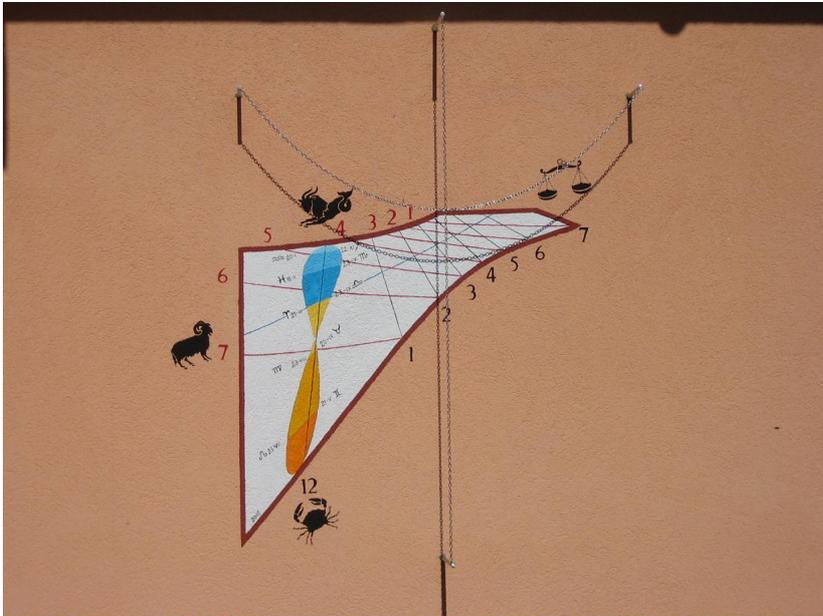
which is tangential to the cylinder along the "element" that passes through the foot G from which the perpendicular style emerges. This, and the use of programs 7, 8, 9, 10 and 11, is illustrated in figures 1 and 2.



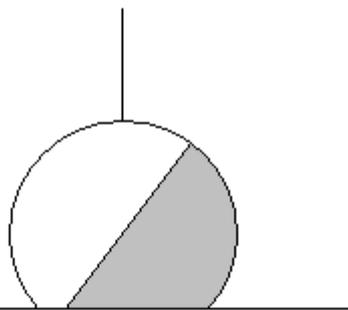
Program 8, which concerns a cylindrical sundial of circular cross-section, uses parametric equations. It takes the cylindrical sundial as the locus of points common to the cylinder and to the flat dials lying on the declining tangential planes. All these flat dials have the same tip of the style and the same line of the horizon as the cylindrical sundial. In this case, the plane that is tangential to the cylinder along the "element", which passes through the centre from which the style emerges, is taken as

the declination of the cylindrical sundial. Program 9 uses spherical trigonometry. Program 10 is based on the projective method. In this last case, a vertical dial for which the declination is known is projected onto the cylinder from the tip of the style, thus generating a cylindrical sundial. It is possible to check the accuracy of these four methods by generating a cylindrical sundial on screen

using one of these methods and then, without deleting the image obtained, repeating the entire operation using each of the other three methods. Each successive image should superimpose itself exactly over the previous sundial.

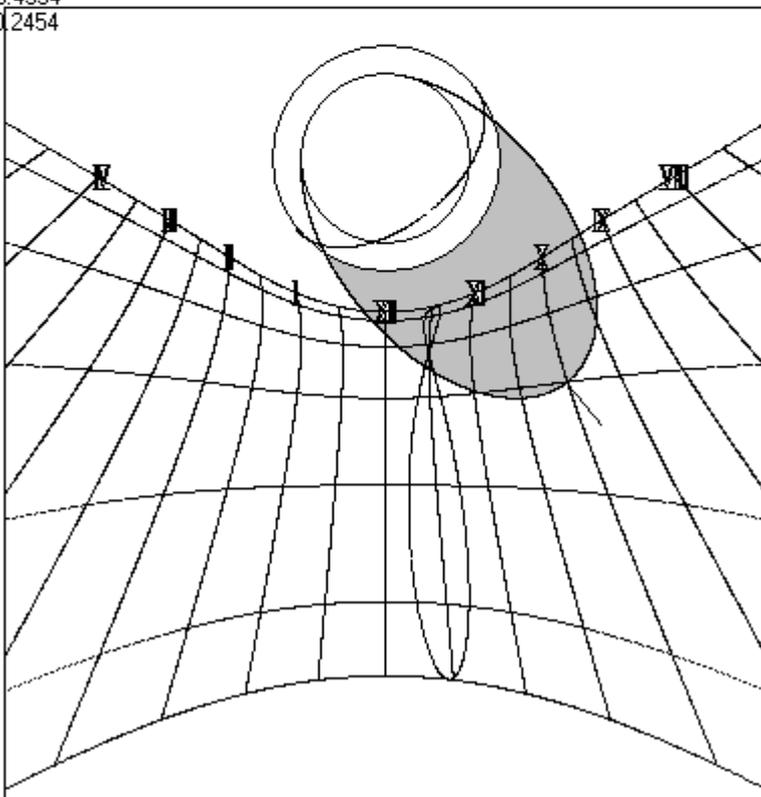


The last case, number 11, is purely theoretical. It concerns a cylindrical sundial with a parabolic cross-section. In this case, as in the previous one, the perpendicular style is used. In order to pinpoint the dimensions of the cross-section parabola, those of the osculating circle at the vertex are used - they supply the proportions of the parabola quite adequately. Declinations of no more than 20° are recommended so that the image does not go off the screen. Click on **Section** to see a cross-section of the chosen cylindrical sundial along with the position of the perpendicular style and the figures pertaining to the triangle of the style, where one exists.



Bifilar horizontal spherical dial by vectors

0.4954
0.2454



Bifilar Sundials 2013

Cartesius 2013 allows the user to trace the following types of bifilar sundials

16) Fountain sundial by T.Tasselli

17) Flat declining vertical sundial with equiangular hour lines

18) Flat vertical single catenary dial

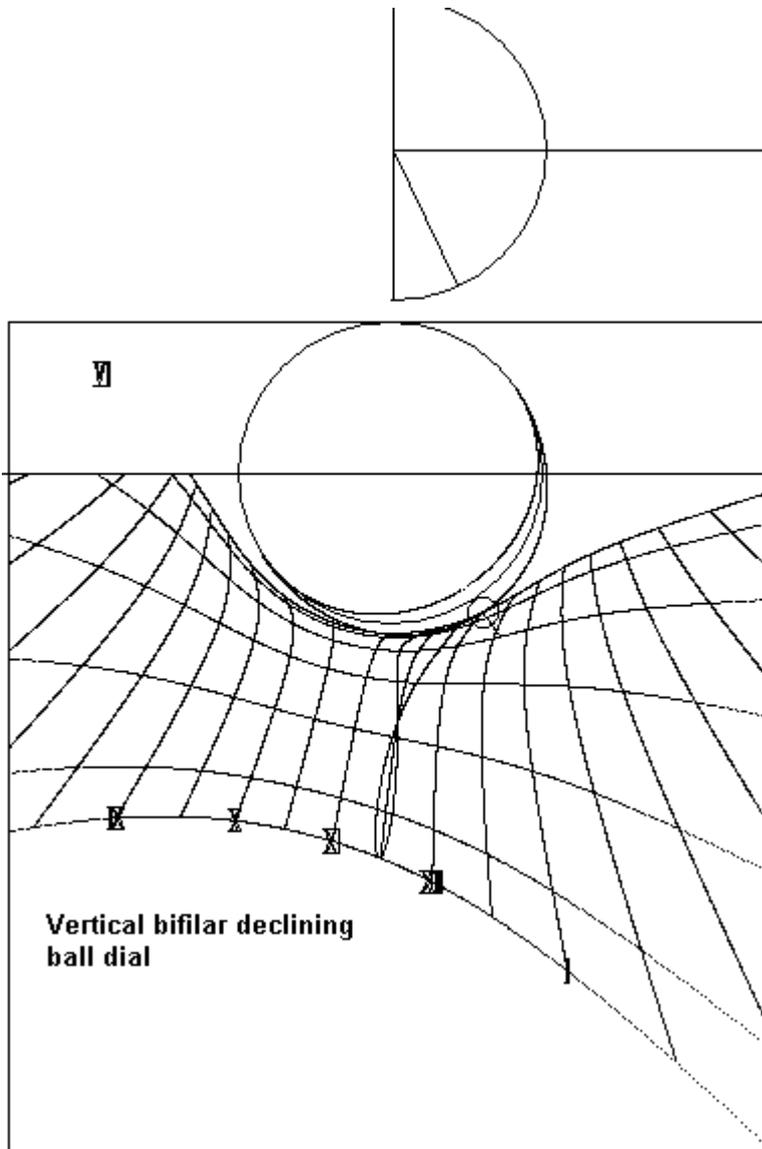
22) Flat horizontal sundial with sphere and vertical pillar as gnomon

26) Flat vertical declining dial with hemisphere and horizontal pillar as gnomon

28) SOLER, (doble catenaria) two catenary dial (invented by Rafael Soler Gayà) available only file DXF

29) Two catenary vertical declining dial; only file DXF

In order to facilitate the use of the software please use the data suggested in the wizard section at the far end.



input data of the textboxes: hour angle and delta.

16) Fountain sundial presented by ing. Tonino Tasselli during the seminary of gnomonics held in Chianciano on the 6/7/8th October 2006.

In his lecture T.Tasselli calls this dial: bifilar sundial on a flat surface (profile 1, vertical straight leg, profile 2 : circular horizontal edge.). Introduce the latitude, the longitude, the height of the edge (or the distance between the circular profile from the horizontal plane) by the voice of the menu "ortostilo" and the radius of the pot (or circle) by using the voice "radius" of the menu for the upper base and R2 for that of the lower base. It is possible to supply the graph with Roman or Arabic numbers. If the two checkboxes are both clicked on, no hour will be shown. Clicking off one of the two voices, numbers of the other voice will be available. For positioning the hour numbers please use the voice "line of declination" (enter appropriate value of declination) followed by the command "RUN". When the checkbox of "Triangle of the style" is clicked on, the section of the pot (fountain) and the simulation of the shade will be shown in function of the

17) Flat declining vertical sundial with equiangular hour lines

The complex of the style is composed of two perpendicular wires placed on different layers parallel to the table of the dial. One is to be positioned over the substyle line at distance "a"; the second one, at distance "b" shorter than the first one, is perpendicular to the first one. The point of intersection of the two shadows is the indicator of the sundial. In order to obtain equiangular hour lines the distances of the two wires must respect the rule: $b = a \cdot \cos(\text{fi}) \cdot \text{abs}(\cos(d))$. First of all it is necessary to individuate the substyle line by the formula $\tan S' = \sin(d) / \tan(\text{fi})$.

Introduce the distance of the closer wire by the voice “style”, “**a**” in the formula; the distance “**b**” of the second wire (over the substyle line) will be calculate automatically. The value of “**a**” and “**b**” will be available on the bottom of the menu. The figure shows the complex of the style fold down.

No Analemma, no Temporary hours.

18) Flat vertical single catenary dial

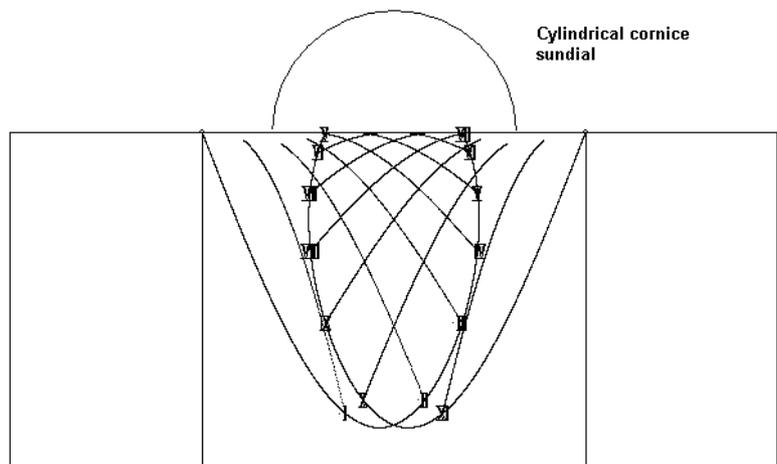
Bifilar vertical declining sundial whose complex of style is composed of a catenary parallel to the plane and a vertical wire also parallel to the plane but farther than the catenary. The distance of catenary from then vertical plane is **d1** whose input textbox is on the bottom of the menu with a pink background. The vertical wire is at distance **d2** value to be introduced in the style textbox. The abscissas of the hanging points of the catenary wire are under the heading radius. Vertex (ordinate) of the catenary is under the heading **y0** (pink background). It is possible to add hour numbers either Roman or Arabic just clicking on the appropriate checkbox. If the two checkboxes are both clicked on no numbers will be shown. Clicking off one of the two checkboxes the other choice will be visible on the screen. . For positioning the hour numbers please use the voice “line of declination” (enter appropriate value of declination) followed by the command “**RUN**”. The green line of the optional date will be traced after “**RUN**”. If the “**F**” is checked on, the line of declination will be automatically positioned on the equinoctial line. The range of the Italic and Babylonian hours sometime may present a few undesired lines. Just to try to eliminate them it is advisable to vary the declination of the sun, that is activated by the “**F**” (on), and introducing a value smaller than the default one (23.445°). For instance, you can try by introducing the value 11.5° . The algorithm that creates Italic hours works between -23.445° and 23.445° . Now, introducing 11.5° the algorithm works between -23.445° and 11.5° for italic hours 22, 23 and 24. The same rule to be applied with Babylonian hours.

22) Flat horizontal sundial with sphere and vertical pillar as gnomon

It works similarly to the Fountain sundial but in place of the circle there is a sphere. Consequently, the circular edge is represented by a maximum circle perpendicular to the sun’s direction. The sphere is not necessarily tangent to the horizontal plane. The distance between the sphere and the plane is measured from the centre of the ball with the heading **d1** (at the bottom of the menu: pink background). If first you click on “Triangle of the style” followed by “**RUN**”, it is possible to see the position of the sphere and its shadow on the plane. The program allows the user to simulate a particular moment. By introducing an optional hour angle into the textbox **HA** (pink label) and a value of sun’s declination (delta) the shape of the shadow will be visible after ”**RUN**”. It is possible to supply the graph with Roman or Arabic numbers. If the two checkboxes are both clicked on, no hour will be shown. Clicking off one of the two voices, numbers of the other voice will be available. For positioning the hour numbers please use the voice “line of declination” (enter appropriate value of declination) followed by the command “**RUN**”.

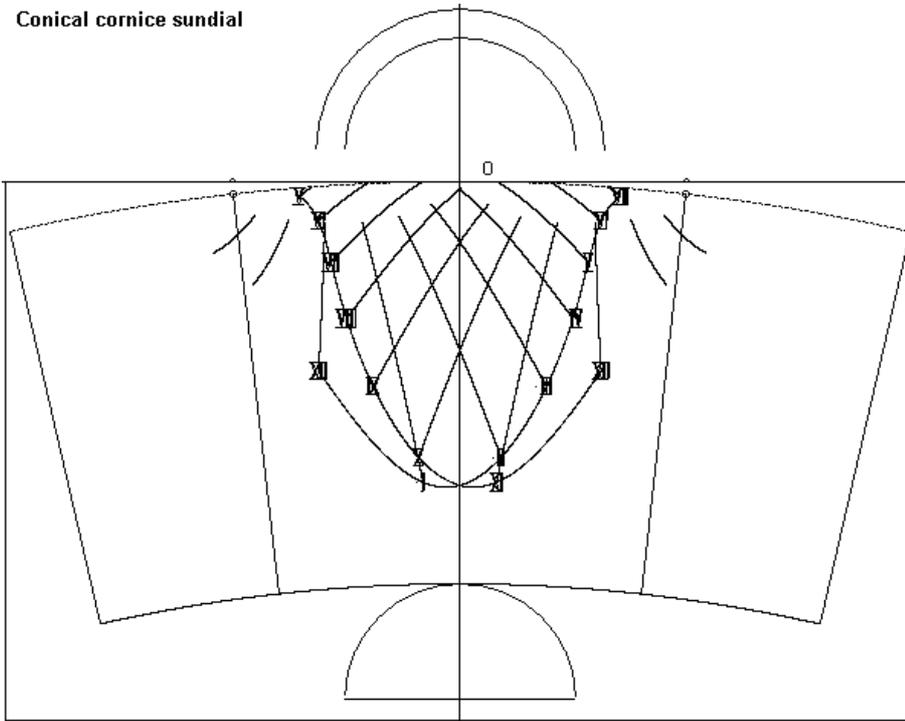
26) Flat vertical declining dial with hemisphere and horizontal pillar as gnomon

It is the vertical version of the previous sundial (22). In this case the hemisphere is fixed. Cartesius allows



representing an optional instant of the functioning dial. By introducing an optional hour angle into the textbox HA (pink label) and a value of sun's declination (delta) the shape of the shadow will be visible after "RUN". It is possible to supply the graph with Roman or Arabic numbers. If the two checkboxes are both clicked on, no hour will be shown. Clicking off one of the two voices, numbers of the other voice will be available. For positioning the hour numbers please use the voice "line of declination" (enter appropriate value of declination) followed by the command "RUN".

Conical cornice sundial



**Cartesius 2013
Cornice Sundials**

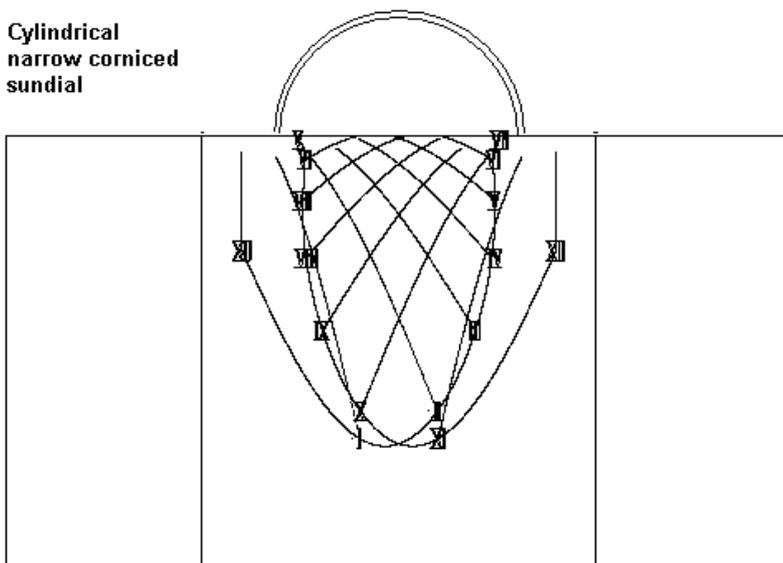
- 35) Cylindrical cornice sundial
- 36) Conical cornice sundial
- 38) Vertical flat sundial Est
- 39) Vertical flat sundial Int

35) Cylindrical cornice sundial

Introduce the latitude, the radius of the cylinder and its height (d1). The concave side is used. In the graph the cylinder appears completely

developed over 360°. The shadow of the cornice indicates the hours in the instant the shadow is tangent to the hour lines. At right the morning hours, at left the afternoon hours. At noon the dial usually does not project any shadow. Even if it is possible to trace the solstice and the equinox lines it is preferable not to represent them because of the reading difficulty in these circumstances. It is possible to tighten the radius (R2) of the circle of the cornice with respect to the cylinder one. The two cases are proposed in the images.

Cylindrical narrow corniced sundial



36) Conical cornice sundial

This case is the more similar to that of the dam of Castellane (A.M.) in France. Actually the huge Denis Savoie's sundial has presented quite another difficulty as the shape of the irregular cone, surface partially conical and partially cylindrical. The case handled by Cartesius relates to a regular truncated cone whose bases, the upper radius R and the lower radius (ortostilo) are known. There are also known the height (d1: distance between the bases) and,

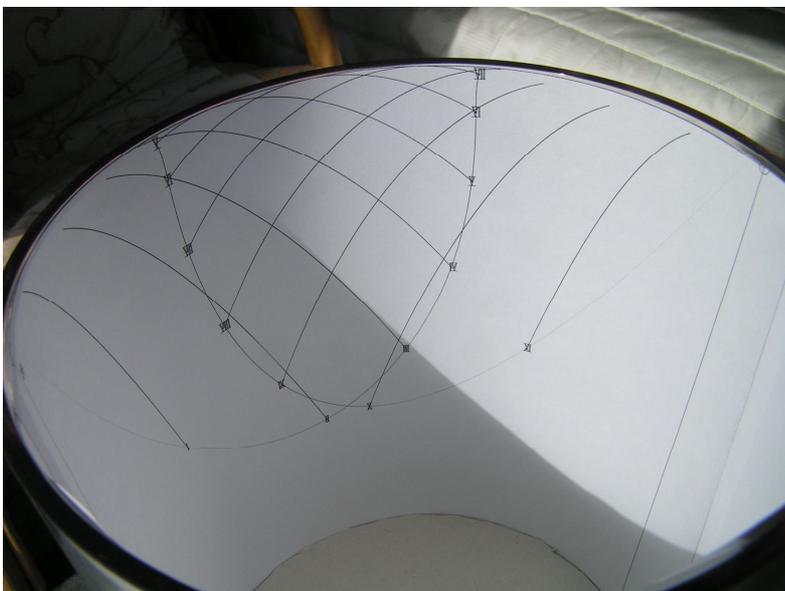
eventually, an upper cornice R2. Also in this example, it is taken into consideration half concave

facing south cone whose development concerns the whole solid. Once the graph is printed it is ready for the use simply leaning it on the conical surface.

38) Vertical flat sundial Est

39) Vertical flat sundial Int

If a complete circular cornice casts its shadow on a flat vertical surface the result is a double cornice vertical flat sundial. As it is possible to exploit two diametrically points where the hour plane is tangent to the same points we obtain two separate sundials. In the photo where a DVD functions as a cornice two sundials are represented. In order to trace the graph it is necessary to introduce: latitude, declination of the vertical flat surface, radius of the cornice supposed tangent to the plane.



Frame

This useful function used for framing the dial so that the dimensions are exactly established is also applied to DXF files in order to limit the extension of the graph. Please pay particular attention to the values of the coordinates introduced. A wrong choice may stunt the vision of the graph.

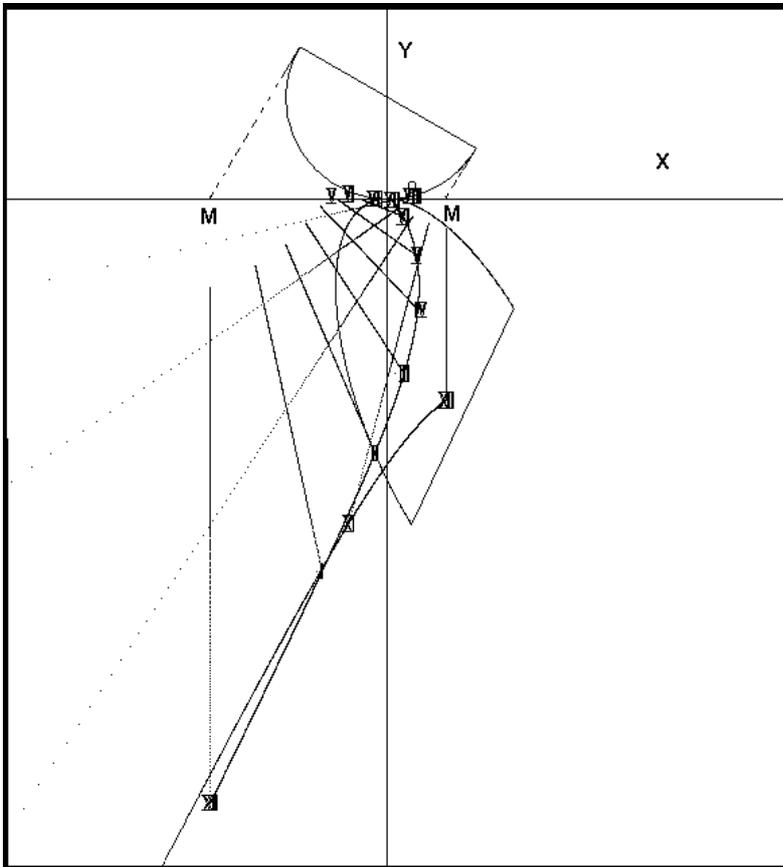
Language

English is the original language of Cartesius.

Cartesius may use one of the following languages: English, Italian, French. Special glossary files are available: DBItalianoC2006.txt, DBFranceseC2006.txt and DBC2006.txt. The first two are the vocabularies of the voices used in the program; last one is a file where the language used is uploaded. All these files must be kept near the icon of Cartesius.exe. Once Cartesius is switched on, a small label takes place on the upper side of the screen. Open the combo and choose the language. Then get out of cartesius (switched it off) and switched it on again. If the procedure has been followed correctly, the voices of the menu will be available in the chosen language. If a file is saved in one language, it must be reopened in the same language in order to

avoid mixture of voices in different language. I do advice to do a initial choice and not to change it in future. The use of English language does not need any glossary file.

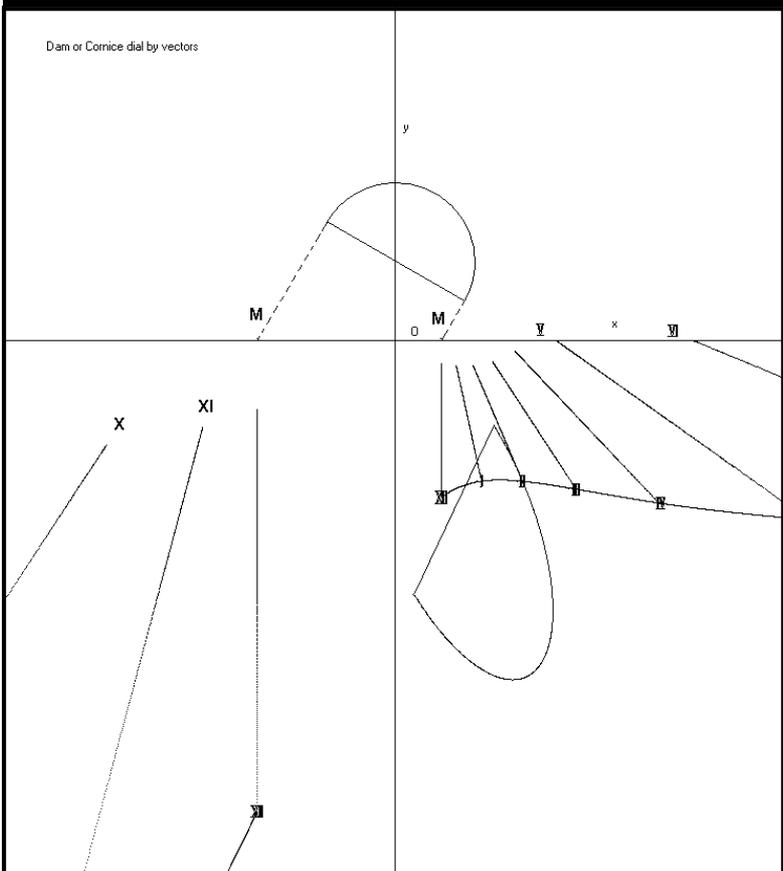
How to save a file visualised on the screen



Click on the voice “File“ on the upper left side of the screen
Click on Save
A frame will appear where the name of the file must be chosen
Let us suppose that “Solary” is the chosen name
Write: “Solary.sun”(without asterisk)
Click on “Save” after having chosen the destination on the file
The saved files will be available in future with the same characteristics

How to download a saved file

Click on the voice “File“on the upper left side of the screen
Look for and click on the same area where the file was saved
Once found the desired file click on it
After clicking on “Download” the saved file will be shown with its original characteristics on the screen.

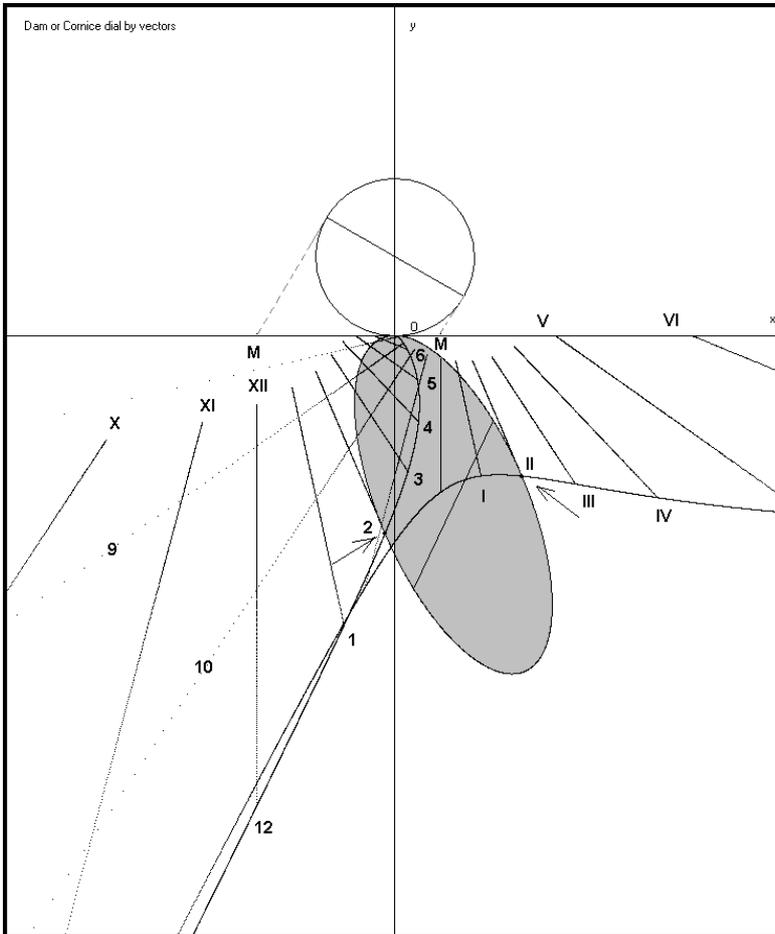


How to save the Data of the menu

Some data of the menu may be saved before getting out of Cartesius.
Below the command “Run” there is the label “List of inputs”.
On its right there is a small aria showing an exclamation point.

If you click on this area next time you start Cartesius you find the same values

Data



After clicking on “RUN”, the Data label, not available before, appears.

A serial of important data will be shown on the screen. If is in use program 6) a large range of data allow the construction of the dial by rule and compasses. It is advisable the print them for a better vision of the data..

How to change the coordinate axes

In the upper side of the screen there is the box “Axes”. Clicking on it a small frame appears showing the values in use. In general, these are default values.

The coordinate origin is located on the upper angle at left O(0,0). The axes are orientated: x-axis positive towards the right: y-axis downwards, unlike the analytic geometry.

To the left of the box “Axes” there is nameless box and a small button. Clicking on it the dimensions of a cornice, multiplied by ten, appear.

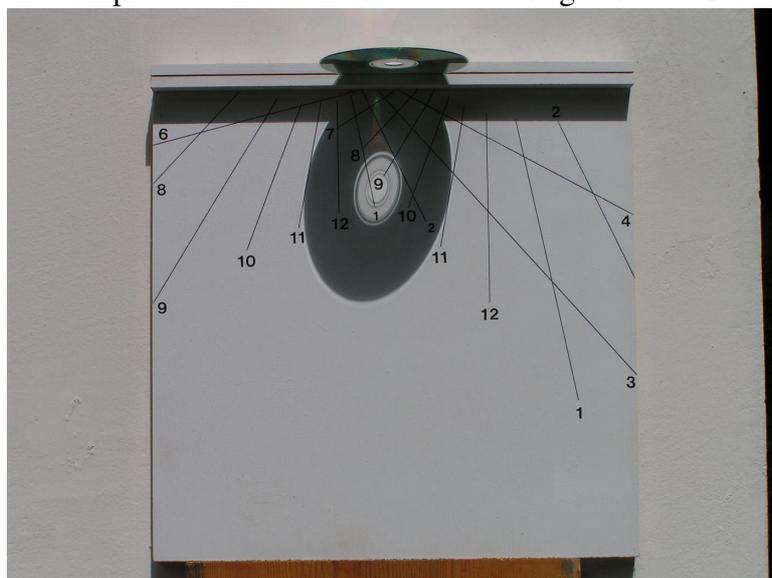
They relate to a frame to be inserted in a A4 sheet: H = 2.82 metres, L = 1.97 metres. This is the size of the screen in metres to scale 1 : 1. Since it is in use the scale 1 : 10 the screen is the tenth of the complete frame of the screen. The origin of the Cartesian coordinates utilized by Cartesius in

the graph is worth half of the two sides. Therefore $x = 0.98474$, $y = 0.84579$. In order to move the origin it is necessary to modify these values and then click on update. The operation is not handy as it is non-immediate the conversion.

The new values are automatically cancelled when Cartesius is switched off.

How to change the dimensions of the screen

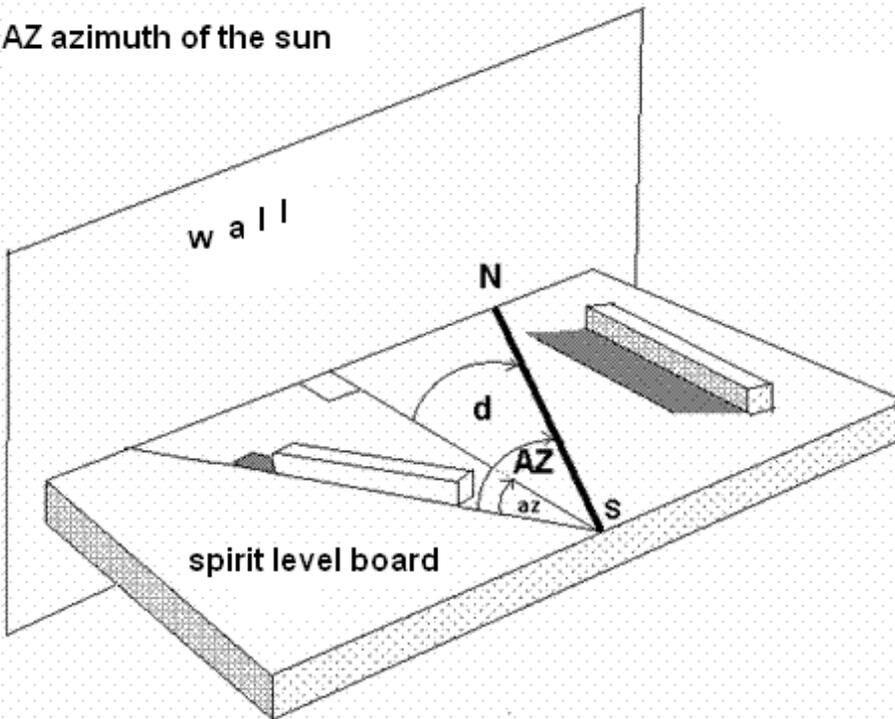
It is possible to change the default values: H = 2.82 m, L = 1.97 m for



visioning a part of the graph that is out of sight. Substitute the default values with new ones and then click on “update”.

The new values are automatically cancelled when Cartesius is switched off.

AZ azimuth of the sun



az angle between the direction of the sun and the perpendicular to the wall

Utility board

Conversion table

	Decimal	Sexagesimal			
Latitude	44.77738	+	44	46	38.5680
Longitude	-10.98418	-	10	59	3.0480

Exit Transfer to main screen...

Declination table

Date (dd,mm,yyyy) 25 04 2009 UT (hh,mm,ss) 10 30 15

Angle az : see instructions -12 Instructions...

Standard Time Zone -1 DST Run

Results

```

Sun's Azimuth -19.9204
Declination of the dial: -7.9204 East
Equation of time: 2 3.30 2.0550

Latitude: 44 46 38
Longitude: -10 59 3

Longitude of the standard meridian: -15
Local longitude in h m s -0 : 43 : 56

time of the dial: 11 16 14
noon: 12 14 0
hour angle: -10.9396
    
```

Grid

By clicking on Grid a network composed of A4 sheets appears all over the screen.

These rectangular areas are to scale 1:1 and they show how they fill the entire screen. Positioning the cursor on any point of the screen and then clicking on, the frame on the upper left side identified by xy (mm) indicates the Cartesian coordinates in mm of the selected point with respect to the visible axes when

Axis is clicked on. In the meantime a rectangular numbered area equivalent to an A4 sheet containing the selected point displays.

Print

Set the scale to 1:10

Clicking on PRINT, without having previously clicked on a zone of the screen, the print of the graph visible on the screen takes place at once. If, on the contrary, one or more numbered rectangles have been clicked on, a special pop-up frame appears offering the option of either a print of the entire screen to scale 1:10 or the separate print of the numbered areas to scale 1:1.

The precision of the print depends on your printers and not on Cartesius. Eventually superimposed written appears perfectly readable once printed.

Clear

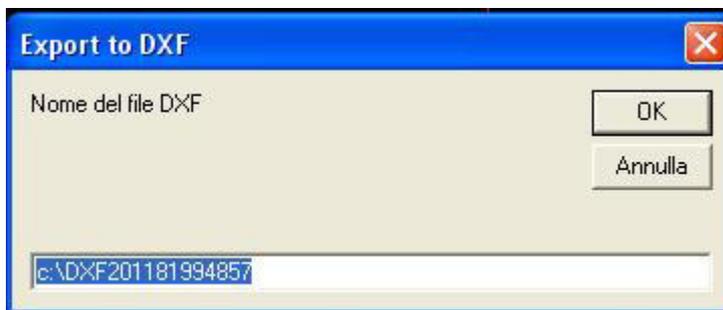
This command clears the screen

Save

This command saves the image of the screen in BTP format.

It would be very much appreciated if users would signal any problems with the programs to the authors as it will help us to produce improved versions.

DXF



For a few sundials it is automatically carried out the exportation of the graph in DXF files for use with Autocad. The sundials supplying such a characteristic are marked by an asterisk. The Dxf file becomes available inside a folder (**CartesiusDXF**) in the disc C. To click on the DXF box above the screen

generates a Dxf file with only one layer on the disc C outside the previous folder, easily recognised by the date and time. This function is being upgraded..

Tools

Under the heading "Tools" there are available the "*instructions*" for calculating the wall (surface of the sundial) declination, by exploiting the azimuth of the sun and the perpendicular line to the wall. It is necessary the use of a rectangular wooden board leaning the wall in a perfect horizontal position. A precise watch or a radio controlled watch showing the GMT. A wooden parallelepiped whose dimensions are about 20 cm for 5 cm for 5 cm. In order to determine the direction of the sun, (the wooden solid) must be posed horizontally on the board and then dragged until its side shadow disappears. When this particular position is reached the parallelepiped is perfectly aligned with the sun. Using the same wooden solid as a rule, trace a segment by a pencil in order that this straight line crosses the perpendicular line to the wall. Then note down the exact time of the reading. It is advisable to use a graph paper for recording the data. The gnomonic declination is due to the formula $d = AZ - az$ where Az is the azimuth of the sun depending on the latitude, the longitude

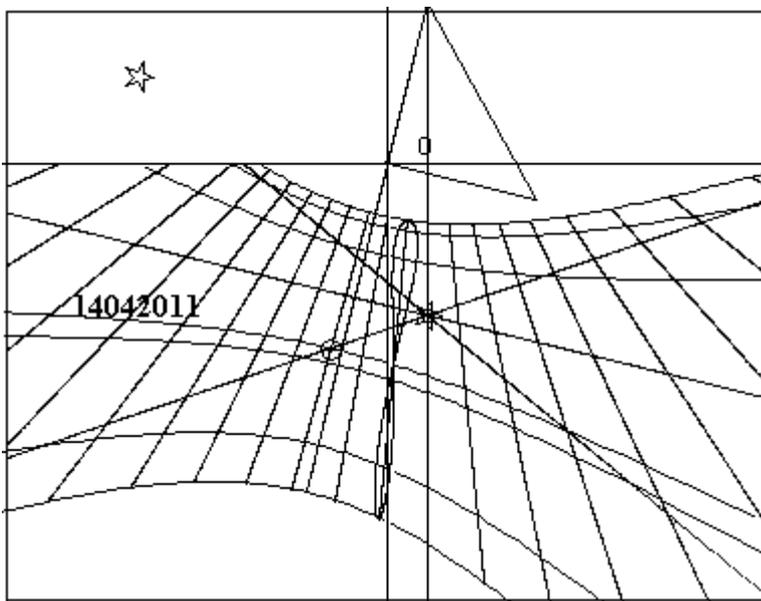
and the GMT and az is the angle between the traced line and the perpendicular to the surface measured from this last one with positive sign if clockwise.

Cartesius calculates automatically the value (AZ) once the data are introduced in the Utility Board and all the other operations. The sense of rotation of the angles represented in the instructions is in use with the azimuth. Please have a look at the survey shown in the “*instructions*” where there are represented all the possible combinations of Az and az.

Use the Utility Board for calculating the declination of the dial.

Suppose the latitude is 44.77738, the longitude -10.98418 (east of Greenwich), the date is 25th April 2009, the time (UT) of the measurement 10h 30p 15s and az = -12. After RUN you get: Sun’s azimuth = -19.9204, declination of the dial = -7.9204 (east) plus other interesting data.

Star Line



Besides representing sidereal hours available only with program 6), it is possible to know when a star is transiting over the meridian. The R.A. of the star and the declination of the sun on that date must be introduced. For instance, if we want to know when the vernal point is on meridian, we must introduce 0,0,0 values of the R.A. of this celestial point in the dedicated textbox on the bottom of the menu. After the command “RUN” two straight lines intersect in the point in which the equinoctial line meets the noon line. The yellow line is valid from the 21st of December till the 21st of June. The blue line from the 21st of June till the 21st of December. The

declination line corresponding to 14th April crosses the yellow line at about 10 and 30. As a matter of fact the vernal point anticipates the sun of an hour and 30 p a month before the equinox. The blue star line concerning the 29st august, that is the other date in which the sun presents the same declination, indicates that the vernal point crosses the meridian about 1 hour and half after the midnight. If you use “Tools” and introduce any date followed by RUN of this menu, the R.A. of the sun will be transferred to the main menu with the declination (delta). Now if you click on R.A. followed by “RUN” of the main menu, two star lines will show themselves

F – this key (Function) allows the user to extend the properties of some functions or to modify them completely. It must be clicked before RUN.

When program n°6 is in use the **F** reduces the lines of declination from seven to three.

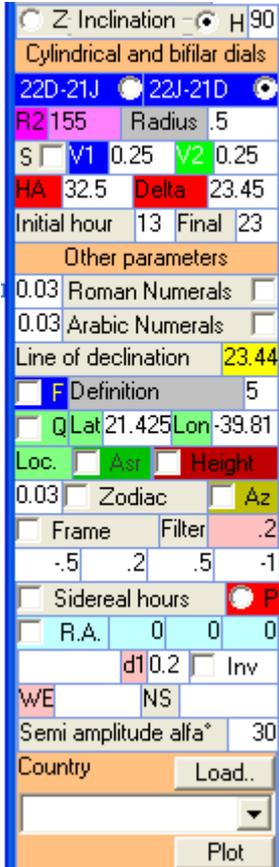
With programs n°6 and n°7), used with Zodiac, it places the zodiacal symbols on the analemma.

With program 6 it modifies the style triangle showing the short style only; it traces the steeple Italian hours.

If activated, while **diagram** is in use, it shows the execution data.

With some bifilar sundials, the **F** activates the simulation of the shadows in function of the Hour Angle and the input declination.

Clicking on “**Data**” after “**RUN**”, the lighting of a flat sundial for $\delta = 23.445^\circ$ displays. If “**F**” is clicked on before “**RUN**” the value used for the lighting relates to the “Line of declination”



Definition, with certain programs increases the number of points of a line..

Roman Numerals, adds Roman Numerals on certain programs in correspondence of the hour lines. The dimensions of the characters may be changed writing the wanted value in the textbox aside

The digits may be moved from their initial position by varying the “Line of declination”.

Arabic Numerals, adds Arabic Numerals on certain programs in correspondence of the hour lines. The dimensions of the characters may be changed writing the wanted value in the textbox aside

The digits may be moved from their initial position by varying the “Line of declination”.

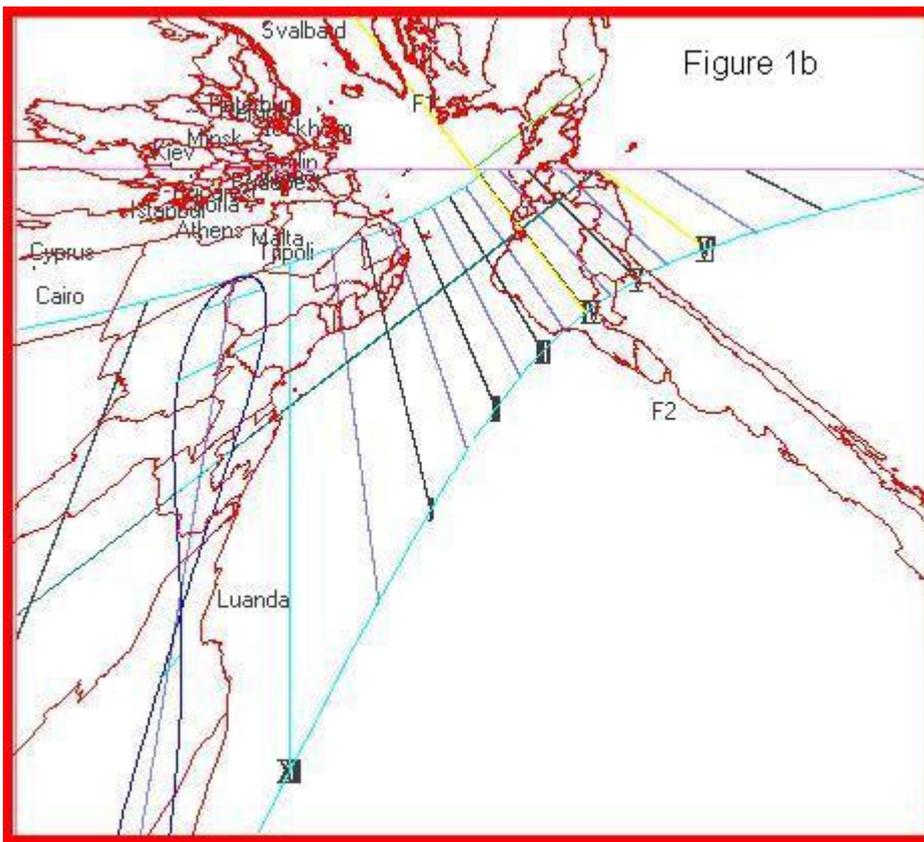
The use of Roman Numerals and Arabic Numerals is reciprocally alternative.

The numbering of Italic, Babylonian and Temporary hours is possible only with program 6). Nevertheless, the digits are fixed and are not printable.

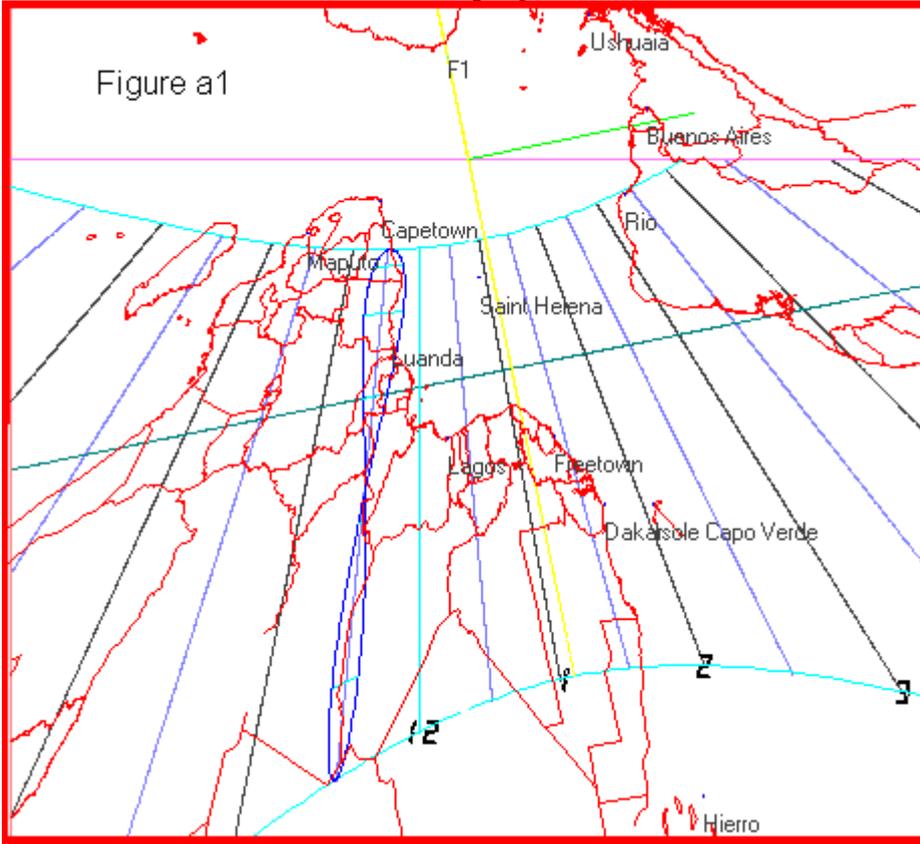
Line of declination is a daily line corresponding to an optional declination that may also represents a special date. The same line places the Roman numerals and the Arabic numerals on a invisible line. In general it is

necessary to click on “**F**” before “**RUN**” for tracing the wished line of date.

Q, initial of *Qibla*, indicates the direction of Mecca, because the default values refer to this locality, Holy Sanctuary for the Muslims. It is possible to get the indication of any place by inserting its latitude and longitude. The **Q** function makes appear a line of azimuth on the graph so that when the shadow of the style crosses it the sun shows the direction of this particular place. This



function is not available with all the programs.



Loc, overwriting “loc” with a name of a locality this word ‘ll appear on the graph but not on the print.

Asr is a Muslim prayer that should be said when the shadow of the style will reach it. Program 6 only

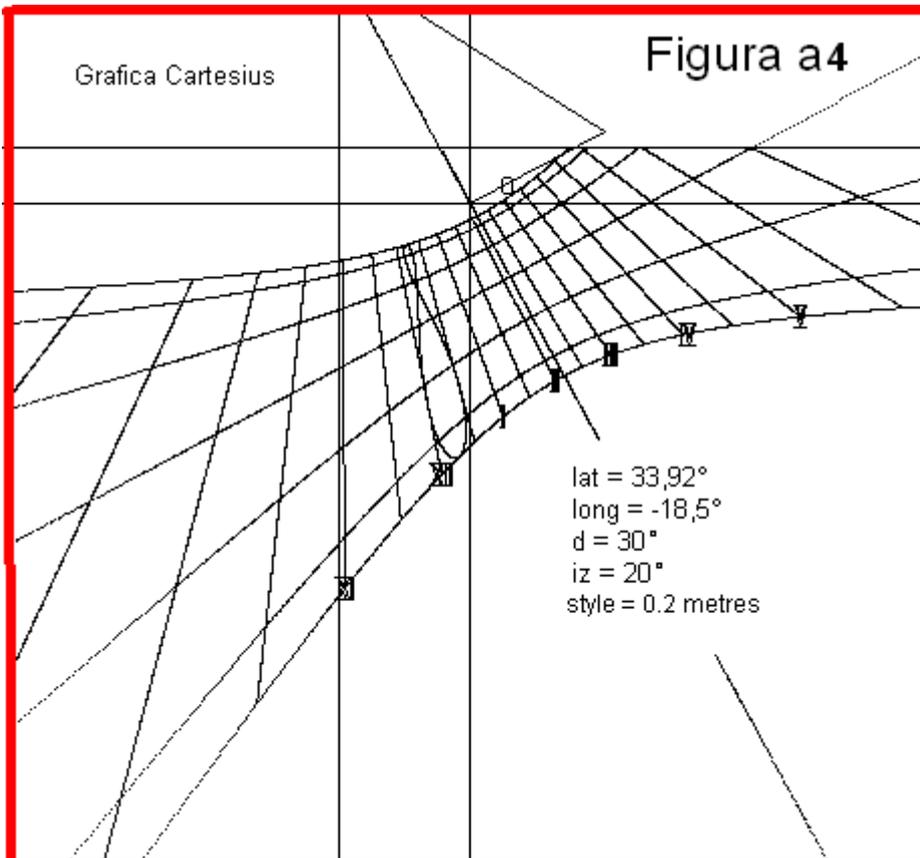
Height, Almucantar – the graph will show the lines that represent the same angular height of the sun. Program 6) and 7).

Zodiac introduces the zodiacal symbols around the analemma but only with programs 6) and 7). The dimensions of the symbols are adjustable by the aside textbox.

Az, initials of azimuth,

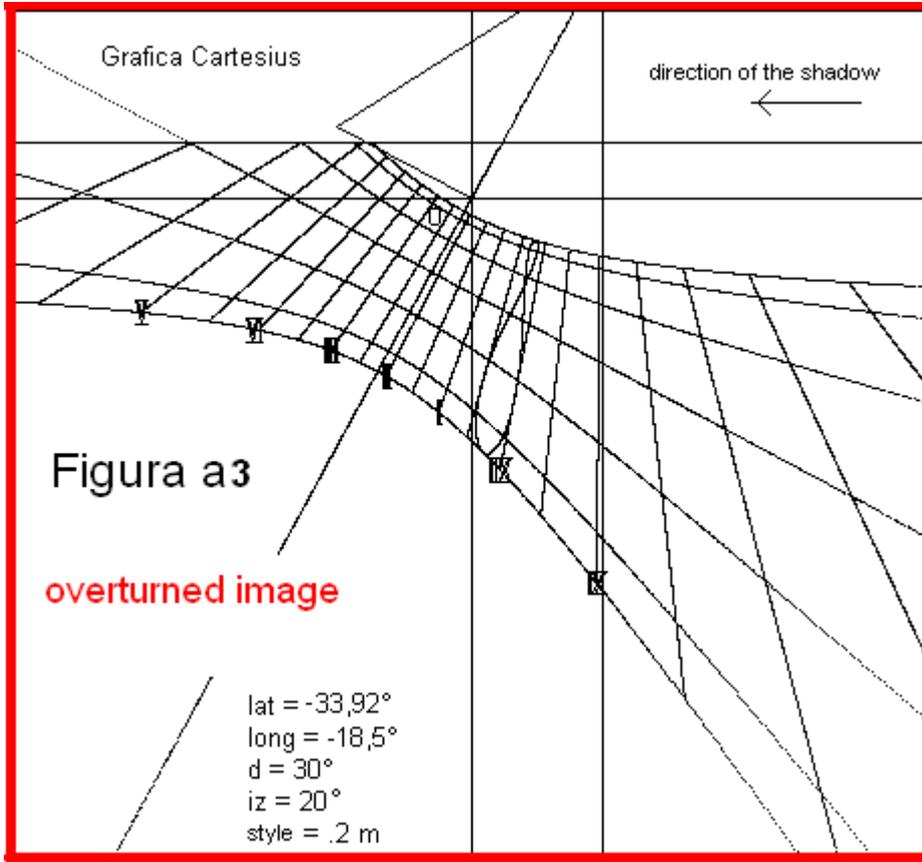
are segments of line that like the Quibla indicate the Azimuth. Program 6) and 7).

P - Point works with programs 6) and 7). After the command "Run" a red option button appears at the bottom of the menu. Clicking P, after having placed the longitude = 0, a small white star,



surrounding a yellow circle, with blue interior, is positioned on the chart at the point with coordinates chosen with the values entered in the red textboxes (HA and Delta). This function can also be used for highlighting one or more geographical points by which to build a universal sundial. In this case, enter the latitude in degrees and decimal in the textbox delta while the longitude of the chosen location (in degrees and decimal) in the textbox HA. For example, if the sundial is being built in Milan (lat. = $45^{\circ} 27' = 45.46^{\circ}$, long.

= $-9^{\circ} 11' = -9.183^{\circ}$), and you want it to indicate the noon of Madrid (lat. = $40^{\circ} 25' = 40.17^{\circ}$, long. = $3^{\circ} 42' = 3.7^{\circ}$) then the value ± 40.17 should be entered in the textbox delta and 3.7 in the textbox HA. Cartesius is able to automatically provide the positioning of many capitals and famous places that materialize on the graph with a yellow circle and red interior, clicking on P with F clicked. The position of the localities is, however, with east and west reversed. If you want to exchange the north



with the south of the map click INV on the checkbox before P. The number of places available (max 156) depends in part on the values entered in the textbox L2. There are two textboxes: the first on a pink background for the smaller number, the second with a white background for the greatest number. It was taken as a starting reference the International Date Line Change near the island of Tonga: 0 position. So all the other proceeding westward. Putting 0 in the first txtbox L2 and 100 in the second, you exclude almost all then USA, and what is even

further west. Universal sundials with geographical programs 6) and 7) can be fitted with the graph of the dial of a map. The universal sundial, so made, shows, in gnomonic projection, the profile of continents and countries that compose them. Since it is possible to invert the sign of the latitudes without affecting the function of the universal sundial there are two cases which need to evaluate the appropriateness of the choice. The first of the two images (1b) shows the north at the top with all the European capitals but it has reversed geographical East with the West. There is a clear reason for this anomaly depending on the gnomonic projection.

The second image (a1), with the south at the top, maintains the normal appearance of a geographical map with the four cardinal points arranged in the traditional manner, even if inverted. With this choice almost all images of European countries are lost while favouring those Southern ones. The sequence of the capitals of Europe must find its place or on the frame or on a specific band, continuing to correctly indicate the south of the northern countries and their longitude, but not latitude.

To get the map you have to click on the bottom of the menu item Load in the combo Country. After a short while the voice World materializes. If you click on Plot, the graph forms a map that depends on the parameters of the dial: latitude, longitude, declination and inclination. However, if you act on the combo, you can choose one or more states that become visible on the screen after clicking on Plot .

Accuracy of the graph



If you have slight differences between the measures introduced and the printed chart, you should proceed using the program 6) to quantify and

eliminate the error. Enter a perpendicular style of 0.2 m as a reference. To print at 1:1 scale of the triangle of the style, and then check the length of the perpendicular style that hardly is of 0.2 m. To cancel any differences, which are generally below the half mm, multiply the length of the perpendicular style by a factor such that the next printing is in accordance with the length initially choice. Example: Suppose that using a style of 0.2 m is found a print of 0.1999 m. The new length of the perpendicular style be obtained by multiplying 0.2 by $0.2 / 0.1999$ equal to 0.20001 to get the printout of a perpendicular style equal to 0.2 m.

Reversing graphics

Clicking on the screen on the item InvertX the graph shown is tilted horizontally. Clicking on InvertY is tilted vertically.

This function is valid also for printing; you may want to trace reflection sundials and flat sundials in the southern hemisphere.

Southern Hemisphere

You can easily get flat sundials for the southern hemisphere using the program 7), the only pre-ordered to provide the analemma for negative latitudes. You first need to click F before creating the graph of the same dial in the northern hemisphere. Once you have the chart click on the button InvertX high above the screen. Immediately you obtain the required graph.

Here's an example: you want to draw a sundial in Cape Town in South Africa: Latitude = -33.92° , -18.5° east longitude (approximately the same of Tripoli in North Africa), declination 30° west, tilt (zenith) = 20° from the vertical plane, perpendicular style = 0.2 meters. You first introduce the data of the corresponding quadrant in the northern hemisphere: latitude = 33.92° , longitude = -18.5° , $d = 30^\circ$, inclination = 20° and style = 0.2 m. Then click F on the menu. Then proceed with the "Run" command to obtain the graph (Figure a4). The graph thus obtained is appropriate to draw a sundial in Puglia. The same observation is not, however, valid for the analemma of the standard time that cannot operate in the northern hemisphere. At this point you should click on the button InvertX getting the rollover image that shows the graph of the dial of Cape Town, on which an arrow shows the movement of the shadow of the style in indicating the hours (Figure a3). Roman numerals corresponding should be read as mirror reflected images. The analemma of the standard time was placed in assuming that South Africa has adopted the Central European Time zone. If not so, you can draw this line based on the standard time zone in use in that country simply by choosing the appropriated time zone before "Run."

Filter - The graphs obtained with the programs 6) and 7) may generate spurious lines, also in the maps, which can be eliminated by changing the value that appears in the adjacent text box. You need to introduce a different value, generally smaller, and, therefore, repeat the chart with "Run."

Suggestions for immediate start and easy continuation

Check immediately the International Settings. Cartesius uses the point for decimals. A different set generates an anomalous DXF graph.

First of all introduce the four coordinates of the frame (cornice) as follows from left to right: : $x1 = -0,5$, $y1 = 0,2$, $x2 = 0,5$, $y2 = -1$.

With the aim of getting acquainted with Cartesius 2013, some values of input are suggested in order to easy the learning of the procedures.

Flat sundials – for the programs 1 to 7 introduce latitude = 45, declination = 20, longitude = -7.6666 , style = 0.2 (metres). For the program n° 6 choose Arabic Numerals. For the n° 3), 4) and 7) add the reclination = 10 or, if you prefer, inclination from the horizontal = 80. For Diagramme Radius = 0.5.

Diagramme - after executing the programs 6) or 7) this useful tool will show the limits of functioning of the dial.

Cylindrical sundials - for all the cylindrical sundials put $R = 0.5$ ($r_2 = 0.02$), choose the option “concave” and then the checkbox “Section” before “RUN”.

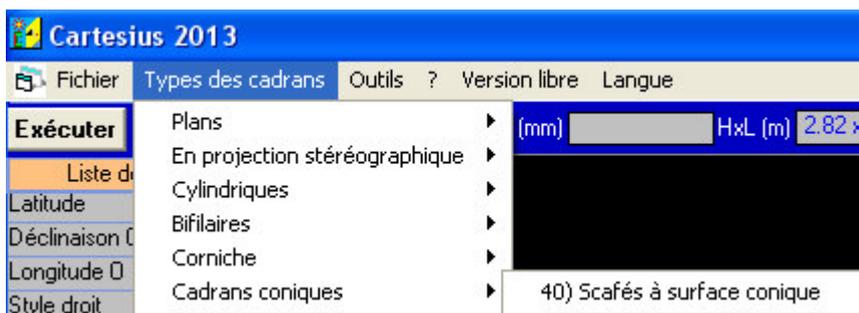
Bifilar sundials – for number 16) **Fountain sundial** introduce lat. = 45, long. = -7,6666, style (distance between bases) = 0.2, Radius (upper base) = 0.25, R2 (lower base) = 0.18. Click on “Triangle” and then introduce HA = 45, delta = 17. Then click on RUN: the graph of the sundial takes shape on the screen also showing the shadow of the style aiming at the point whose coordinates are HA, Delta.

For n° 17) Flat declining vertical sundial with equiangular hour lines, introduce lat. = 45, long. = -7,6666, d = 15 and style = 0,25 (distance between the wire parallel to the substyle line and the surface of the dial). Click on “Triangle” for visualising also the gnomonic complex with the graph. Then click on “RUN”.

For n° 18) Flat vertical single catenary dial (on demand), introduce lat. = 45, d = -15, long. = -7,6666, style = 0,2 (distance between the vertical wire and the surface of the dial, $y_0 = 0.25$ (vertical ordinate or distance between the vertex and the line of horizon); d1 = 0.1 (distance of the catenary from vertical plane), Radius (abscissas hanging points) = 0.4. Click on “Triangle” in order to have a complete graph with the complex of the style. Then click on “RUN”.

22) Flat horizontal sundial with sphere and vertical pillar as gnomon. Try latitude = 45, longitude = -7.6666, Radius = 0.3, d1 (on the bottom of the menu) = 0.1: d1 is the distance between the centre of the sphere from the plane. Introduce even HA = 30, delta = 23.445 and then click on “Triangle” followed by the cmd “RUN”.

26) Flat vertical declining dial with hemisphere and horizontal pillar as gnomon. Try latitude = 45, d = -15, longitude = -7.6666, Radius = 0.2, HA = 45, delta = -20. Then click on “Triangle” followed by the cmd “RUN”.



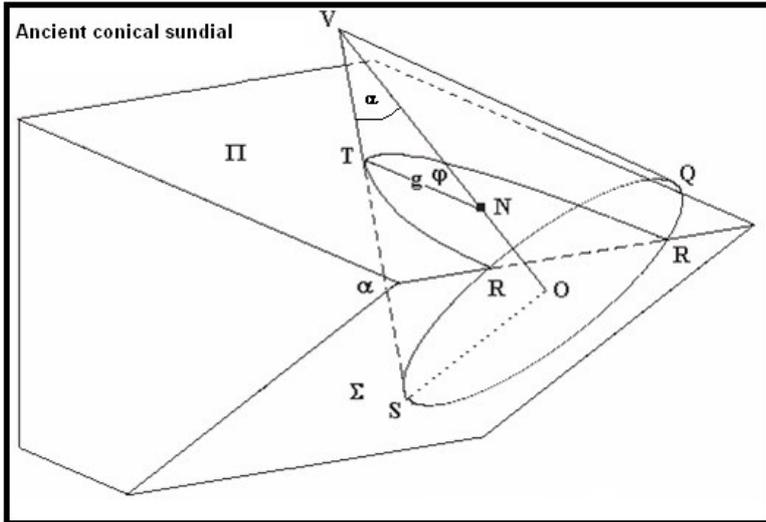
Ancient conical sundial

Cartesius plans a modern version of an ancient conical sundial widespread in the Mediterranean area by Romans. The characteristic of

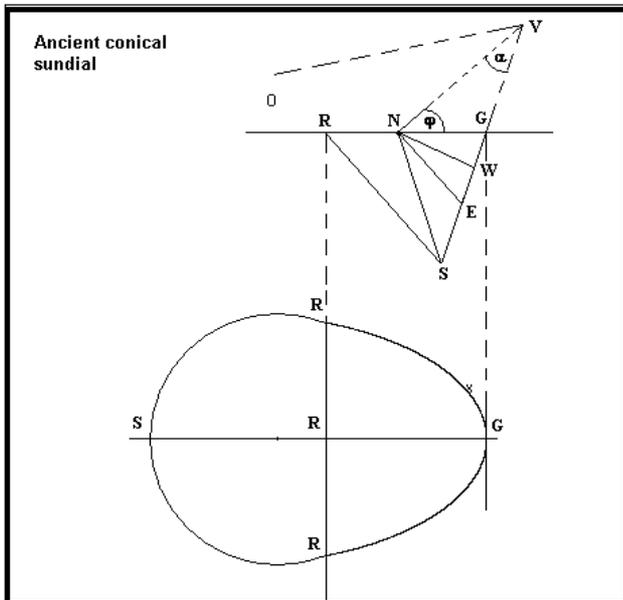
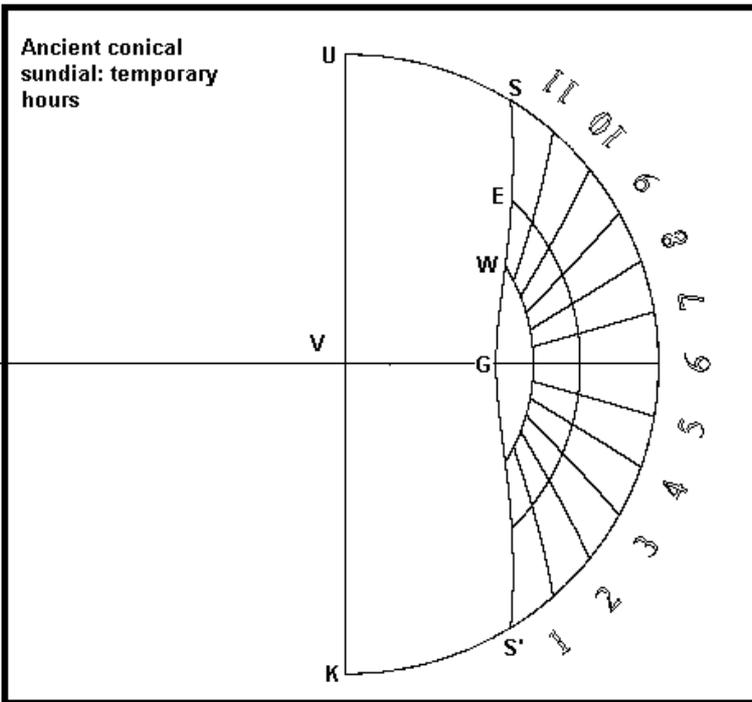
the proposed method is the realisation of the sundial by assemblage of the different flat surfaces that compose it, calculated and available graphically.

Once the various components are ready, it is necessary to bring them on the chosen material and stick them. The necessary data are: the latitude, the length of the style and the semi amplitude of the cone whose axis is pointing at the north celestial pole.

Using these data the software calculates and draws the various parts necessary to assembly the conical sundial. A cone intersected by a plat surface generates a conic. In this particular case the inclined cone is sectioned by a horizontal plane generating either an ellipse or a hyperbola. The second plane that cuts perpendicularly to its axis generates a circle. The first image concerning this topic shows in the upper side the cone and the horizontal style gn. In the lower side it is visible the composition of the two sections of the cone joining according a dihedral angle. The left side is a



like the latitude. The α angle as big as the semi amplitude of the cone is chosen by the author of the dial.



circular sector, the right one an elliptic or hyperbolic sector depending on the eccentricity, profiles generates automatically by the software. In the top part of the graph, the cone is represented. The dotted part points out the solid but; actually, the useful part is surrounded by the RGS triangle. The point N of the style casts its shadow onto the conical surface reaching, at noon of the various seasons, the point S (21st June), E (on the equinoxes) an W (at winter solstice). The axis NV makes an angle φ with the horizontal plane like the latitude. The α angle as big as the semi amplitude of the cone is chosen by the author of the dial. The lower part shows the two sections that are placed on the upper part: the left one on the inclined plan RS, the right one horizontally on the plane RG.

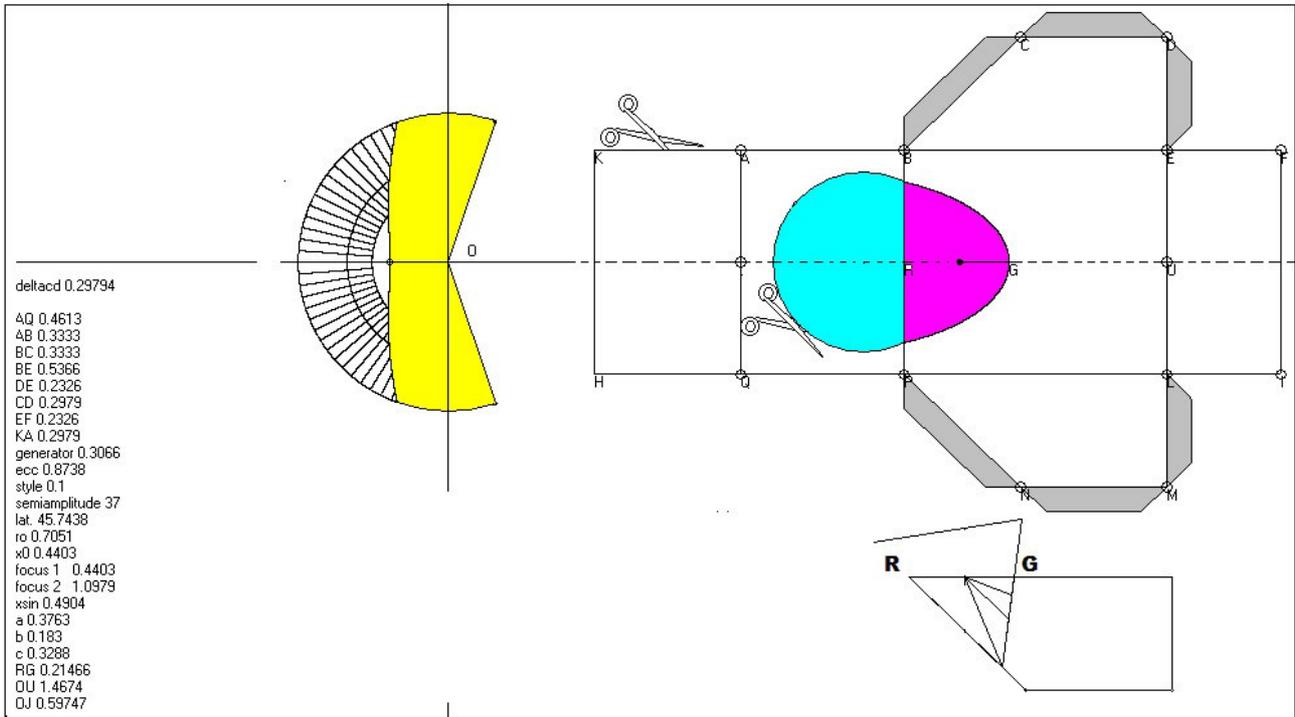
Once the two sections are fixed on a supporting structure the outline of the second figure included between the line S G S' and the arc of circle numbered by Temporary hours will match perfectly originating a conical surface.

The second figure shows the cone development that, in this particular case, covers 180°. If we cut out the half moon figure of the second image, we stick the two sides UV, and VK forming the diameter of the semi circle, we get a cone on which internal surface the graph of the hours is traced. This cone, theoretically,

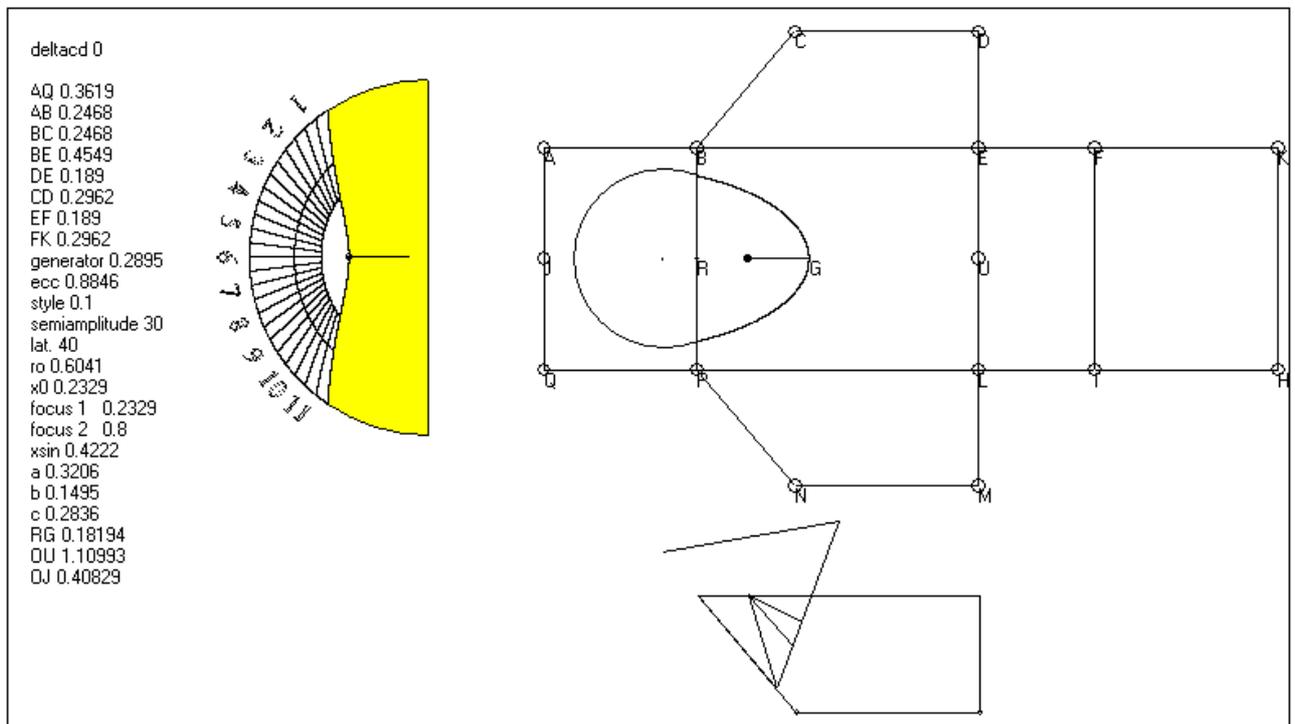
matches perfectly the supports represented by the two profiles circular and elliptic or hyperbolic. The third image shows an axonometric possible solution. The development is particularly demanding: it also requires modification of the axes.

Of Cartesius 2013 two versions are available: the first one is intended for a construction type like Origami, the second for a more substantial type like that adopted for the scaphen of photography. I do not recommend the construction of sundials when the horizontal conical is different from the parabola even because I do not think there are dials with this feature. For the cone I suggest the

use of the value $\alpha = 30^\circ$, semi amplitude of the cone, although a different choice can be made. With the first version, reserved for small scaphens of paper or Bristol board, click on the function F before Run. The graph will also show the extensions of the sides that once folded and glued, will give solidity to the time - teller. You will have to cut out all the profiles, and then you will have to bend the sides to get a solid composed of six flat surfaces.



The figure shows how the graph of the conical sundial looks like. After having folded the various



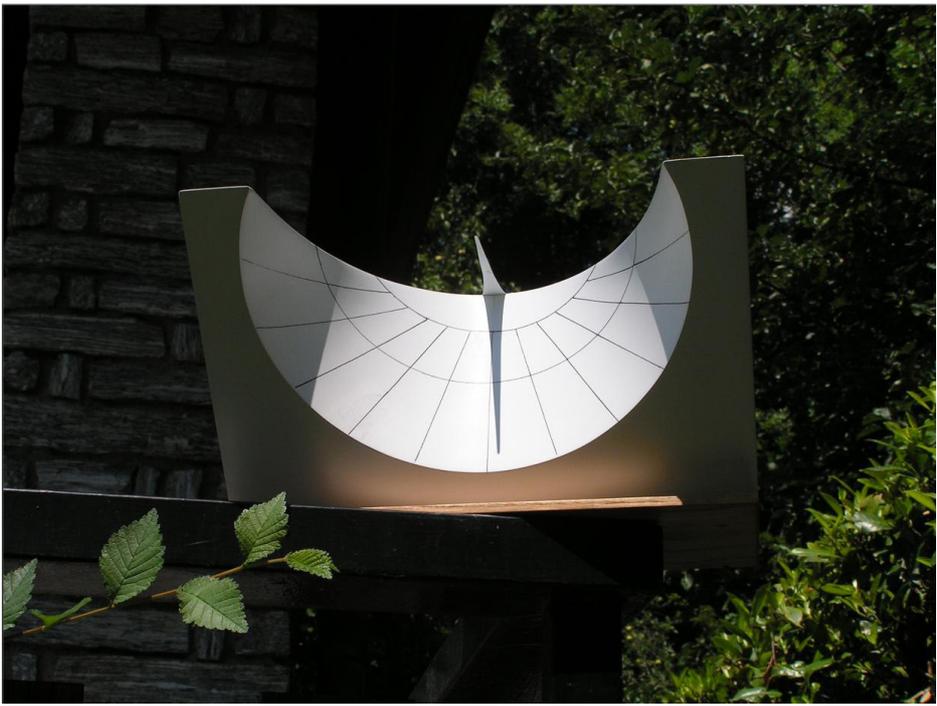
parts re-open the sheet and fold it along the vertical line between the areas coloured in blue and magenta. Keeping the pieces together cut following the elliptical profile of the cyclamen area, then, putting upside down the same, crop the second circular profile. When unfolded, you will notice both profiles. Moving to the left of the picture you can see the part with the hours. You must remove the

yellow zone. The area covered by the hour lines will lean, later, on the hole that will be evident after completing the installation. The parts highlighted in grey have to stick to give solidity to the clock. This other figure refers to the graphic more suitable for the construction of scaphen for assembly. First, I suggest setting the printer to the horizontal way in order to contain the graph completely on the screen.

After clicking on item 40) allowing the access to the program for tracing ancient conical watches, click the voice Axes on the top of the screen. Enter 0.5 instead of 0.98474, but leave unchanged the value of the Y-axis (0.84579). Click “update”, then click “hide”.

Enter lat. = 41.5, style = 0.085. Click daytime lines, equinox lines, temporary hours and horizon. Click on Figures D and possibly on Arabic numbers; finally, at the bottom of the menu, enter the value 28 as angle alpha, semi amplitude of the cone. Then proceed with the "Run" command. After a few seconds, a triple composite image will show on the screen, from left to right, the graph of the conical dial, the section view from a side and the section showing the two conical profiles, hinged along the segment that represents the corner formed by the two planes that cut the cone. In practice, the first figure inherent to this type of watches.

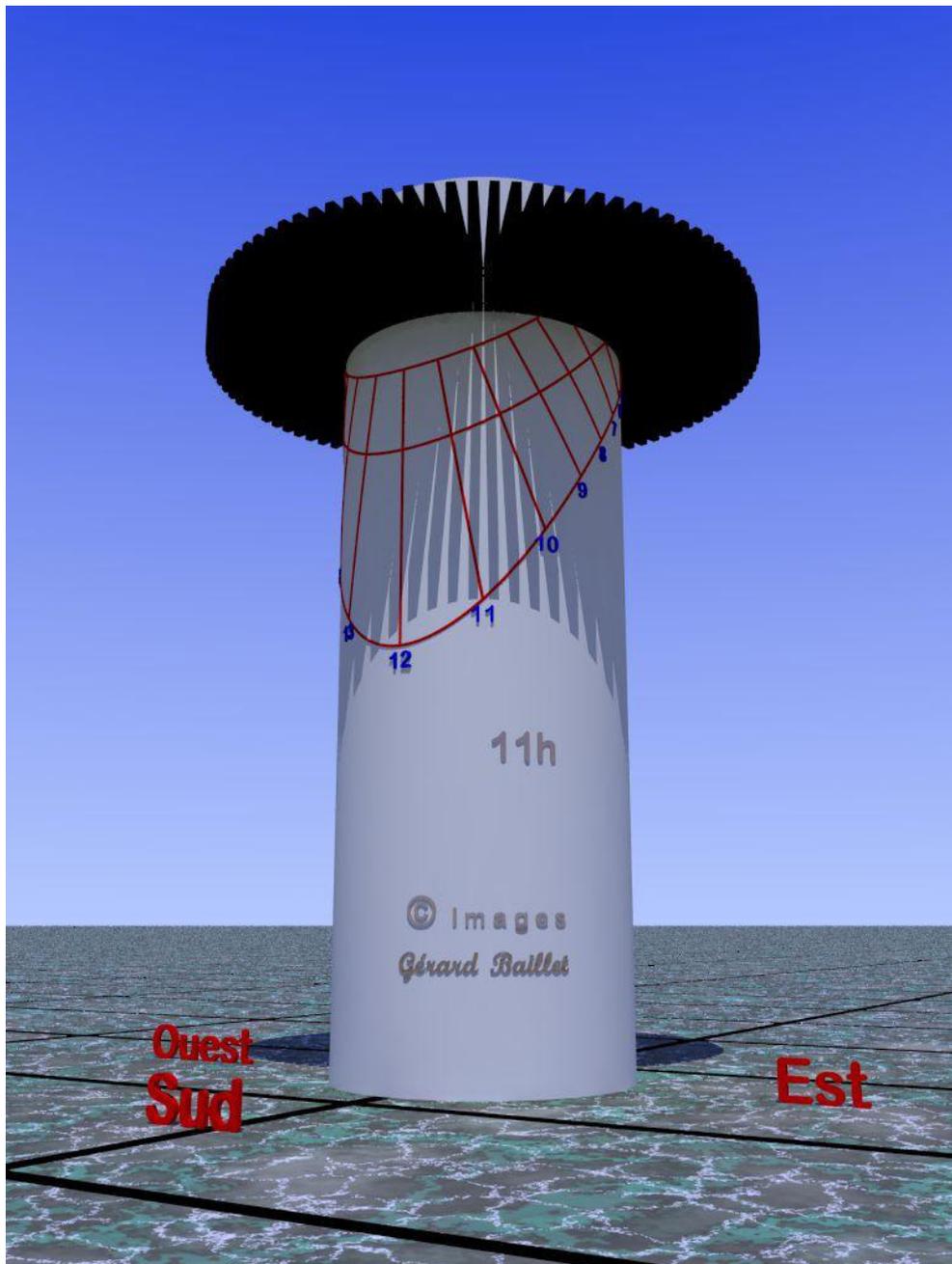
In the photo the conical sundial built in 2006 has been realised by cabinet-maker wood
It is suggested the reading of the article published on Gnomonica Italiana n° 3 in 2007 available (in Italian only) on the link www.sundialatlas.eu/atlas.php?so=IT1577
“RUN”.



The speed of execution depends on the program selected, the number of functions employed and the computer used. Programs that use spherical trigonometry are the slowest because of the complexity of the calculations carried out, followed by those that use the parametric method, then the projective method and then 3D analytical geometry. The fastest is probably no. 5 because it mainly uses LINE functions. **Cartesius.01**, the anthology that brings

these programs together, has scroll and zoom functions. It is also possible to move the axes and widen the screen.

With **Cartesius.01**, the values for latitude and longitude can be entered in both sexagesimal and decimal form. Click on **Tools** and open the **Utility Board** to convert figures from one format to the other. You can also calculate the declination of a sundial in the same window. There are illustrated instructions to make it easier to understand and use the method whereby sun's southern azimuth is used for the northern hemisphere and vice versa. It is even possible to obtain the current figures for the time equation and other interesting data such as when the sun crosses the meridian and sunrise and sunset times that take into account the effect of light refraction. The bibliography contains a list



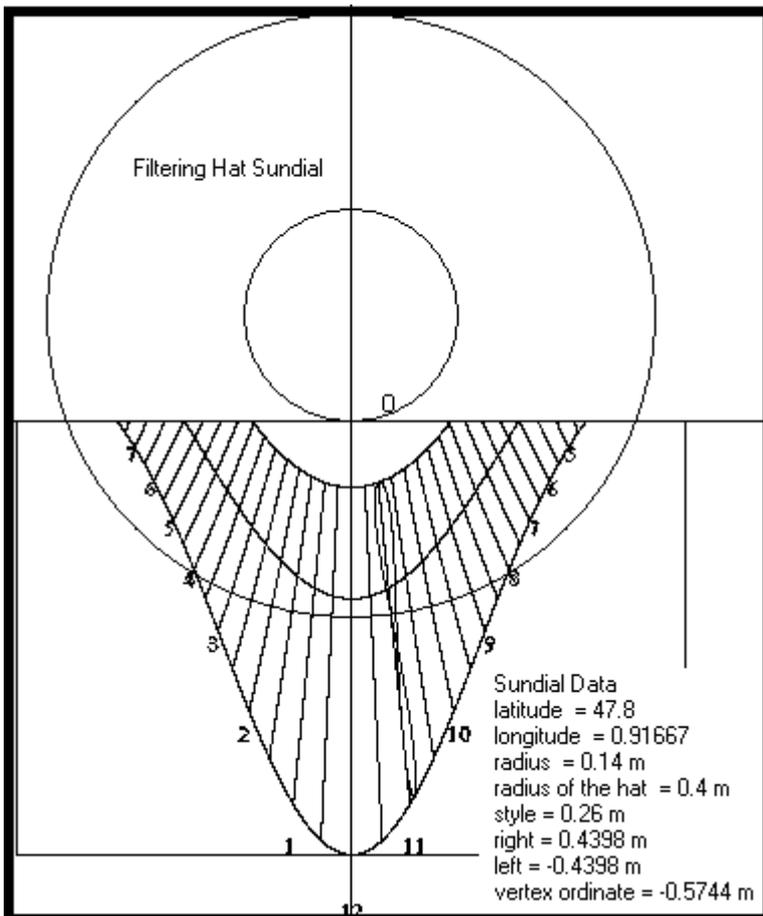
of the books I consulted in devising these calculations. The sun's azimuth for the northern hemisphere is positive when measured anticlockwise from north. Likewise, the declination and the inclination of zenith-type sundials take the opposite sign in the southern hemisphere to those in the northern hemisphere.

The algorithm that generates the values in the time equations was taken from "Astronomia Sferica e Teorica" a book by Francesco Zagar, published by Zanichelli, 1988. I would like to express particular thanks to my son, Andrea William, analytical programmer, without whose help this project would never have been possible.

It would be very much appreciated if users would signal any problem with the programs to the authors as it would help us to produce improved versions. Versions prior to n°91 contained flaws, and problems ensued when attempting to draw limit sundials. Since then, subsequent versions have been significantly improved to reduce the risk of such problems arising to a minimum.

Filtering hat sundial

This time-telling quadrant is composed of a circular sectioned cylindrical column and a disk whose diameter is bigger than the column one, positioned horizontally as it were a hat. The shadow of the cylinder casts on the cylinder: the vertex of this curvilinear shadow is the indicator of the sundial. The software Cartesius 2013 traces the graph for the direct print on a A4 sheet, or using AutoCad. The graph is to be reported on the surface of the column. Originally, the circle generator of shadow was formed by a close radius structure that eased the reading of the hour along the vertical shadow of a radius. On the screen graph, the yellow circle is related to the section of the column, the blue one, instead, the disc of the hat that can be shifted up and down by varying the coordinate V1, before “Run”.



Let me propose the filtering hat sundial known as Sundial of La Baumette (France). The latitude is $47^{\circ} 48'$, the longitude $0^{\circ} 55''$ west, radius of the column 0.14 (metres) to be inserted as “RADIUS”, radius of the hat 0.4 to write under the voice “R_2”. By Cartesius 2013 it is possible to trace the analemma on the 12 o’clock mean time or on any other hour simply varying properly the longitude. The graph can also show Italian hours, Babylonian hours, Temporary hours and astronomical hours corrected in longitude so to make them indicate the apparent time of the Standard Time Zone (-15° east of Greenwich) of the dial. The key “F” limits the zodiacal lines from seven to three. There are available complete analemmas, half six – month analemmas, single or for each hour. In order to obtain some combinations, it is necessary the use of the key “L” and of the key “S”. If you click on **Analemma** with L ad S off you get a sole complete analemma

depending on the value of the longitude, after Run. If you click on L you obtain, after Run; a single semi analemma, whose period covered, depends on the options 22 D – 21 J or on 22 J – 21 D. By clicking on S too, you’ll get Analemma or semi Analemma on each hour.

The DXF graph is available on the disc C after clicking on the key DXF on the upper side of the screen.

Conditions of use

Cartesius is the demo version of a freeware program. It is made available to users in its current form and with no guarantees as to its functioning. Use of the product is freely permitted but any sale thereof is strictly forbidden by law. The authors own the intellectual property rights to the program.

They take no responsibility for any malfunctions or any consequences arising from improper use of the same.

Riccardo Anselmi, December 2013

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Photo of the bifilar vertical sundial indicating italic and astronomical hours by Roberto Finozzi in 2007 a Thiene. He is also the author of the sundial (Cartesius)

Virtual image of the double catenary by Luigi Ghia (2010)

Photo of the doble catenaria (Joseph Theubet 2009)

Photo of the cornice conical dial by Riccardo Anselmi (2010)

Photo of the cornice sundial using a CD by Riccardo Anselmi (also author 2010)

Photo of the ancient conical sundial by Riccardo Anselmi (also author 2006)

Virtual image of the filtering hat sundial by Gérard Baillet
