Verto3k

1.0 **Introduction**

Verto3k allows to carry out coordinate conversion between the most commonly Geodetic Reference Systems used in Italy, namely Roma 40, ED50, ETRF89 and ETRF 2000 in all possible combinations. In addition to the geographical coordinates, this program also allows to deal with plane coordinates belonging to the Cartographic Systems normally associated with the above mentioned Geodetic Systems: **Gauss-Boaga** for ROMA40, **UTM** for ED50, and **UTM** and **Fuso Italia**, for the implementations of the Global System.

Verto 3k allows to project a point in a different time zone from the one it belongs to and allows to operate outside the selected grid, only for conversions within the same Reference System. In fact, even without having the "*.gk?" files, Verto3k can transform both the geographic and plane coordinates of the same System throughout the national territory. Moreover, in addition to UTM, "**Fuso Italia**" has been associated to the ETRF Global Systems; it consists of a new Cartographic System introduced in order to obtain seamlessly the whole national territory projection on a sole plan (see below).

As for the altimetric component, Verto3k allows to transform ellipsoid heights, referring to the geocentric ellipsoid GRS80, into geoidal ones (sea level), relating to national altimetric references, and vice versa.

Following the same logic as the other Verto, only algorithms needed to perform transformations are stored. Data must be purchased separately in grid form stored exclusively in "*** .gk?**" files, as it will be better clarified below.

Compared to Verto2k, Verto3k has additional capabilities: having an adequate number of double points, which are known in two different reference systems, Verto 3k allows the determination of geometric relations between two different reference systems in both plane and spatial roto-translation parameters form.

Once the program started, the different options to be selected are listed:

- **Generale - General**
  - I***nformazioni su*** - ***Information on ...***
  - ***Esci*** - ***Esc***
- **Conversione sistemi - Systems' conversion** (as for Verto2k)
- **Rototraslazioni spaziali - Spatial Roto-translations**
  - ***Calcolo parametri spaziali - Spatial parameters determination***
  - ***Applicazione parametri spaziali - Spatial parameters application***
- **Rototraslazioni piane - Plane Roto-translations**
  - **Calcolo parametri piani - *Plane parameters determination***
  - **Applicazione parametri piani - *Plane parameters application***

- **Esci - Esc**

IMAGE

2.0 Software installation and uninstallation

To install Verto3k, start the "**Setup_Verto3k.exe**" file downloaded from the IGMI website (www.igmi.org). The installation automatically creates a "**Verto3k**" subfolder in **"Programmi - Programs"** folder in which it stores **Verto3k.exe**, as well as a copy of the * .dll files, taken from the system on which the compilation was performed. The link to **Verto3k.exe**, in the "**Avvio - Start**" menu, will be placed in the **"IGM"** group; if this group does not exist it will be automatically created by the installation procedure.

The software is protected from illegal use. It needs its own hardware key to be connected to the system via USB port. After installing the software you need to put the hardware key into a USB port; the system will automatically detect it and you won't be asked to installed specific drivers.

The uninstallation procedure can be started from the "**Pannello di controllo - Control Panel**" using the "**Installazione applicazioni - Add or Remove Programs**" function.

3.0 Using “Conversione sistemi - Systems' Conversion” feature

The “Conversione sistemi - Systems' Conversion” feature allows to carry out coordinate conversion of both plane and altimetric coordinates between Reference Systems. The transition from geographic to plane coordinates is possible both within the same system and between different Geodetic Systems.

"*** .gk?**" files are required for switching between different systems ("* **.gk1**" and "* **.gk2**" are the currently available versions). You can select the file you want to use in the "**list box**", at the top of the "**Zona di lavoro** - **Work area**" frame, where the work area of the selected file will be shown. The approximate limits of this area are expressed both in geographic and plane coordinates, with longitudes referring to both Greenwich and Rome, according to coordinates selected in input. Reference epochs of the grids that the selected file allows you to use, are shown in the lower part of the frame. For converting coordinates within the same Reference System, throughout the national territory, you don't need the “* .gk?” files containing the grid's areas of interest. It is possible to operate in the area between 34 ° and 49 ° parallel, North latitude, and between the 5 ° and 20 ° meridian, East longitude, from Greenwich.

3.1 Geodetic and Cartographic Systems

In the upper left part of the form it is possible to select, both for input and output, the Geodetic Reference System and the type of coordinates, namely geographical and plane. In case of plane coordinates it is possible to select the Cartographic System.

The software considers 4 systems: ROMA40, ED50, ETRF89 and ETRF2000.
The Cartographic Systems are described below.

- **ROMA40** is the historical national geodetic system still in use; it adopts the Hayford ellipsoid, whose parameters are:

  a = 6378388 m, f = 1/297.

  Ellipsoid orientation is Roma Monte Mario 1940:

  ϕ = 41° 55’ 25.51’’ λ = 0° (12° 27’ 08.4’’ Est from Greenwich),

  azimut on M. Soratte: α = 6° 35’ 00.88’’.

  The software associates **ROMA40** system with orthometric heights, referring to the average sea level. For continental Italy, altimetric reference is Genoa tide gauge, whereas Catania and Cagliari tide gauges are the reference for Sicily and Sardinia.

  ROMA40 system is associated with the **Gauss-Boaga** cartographic system which uses Gauss's projection, adapting it to the national territory by means of 2 time zones of 6 °, West and East, as described below:

Gauss-Boaga Time Zone	Longitude of the central meridian from Greenwich	Longitude of the central meridian from Rome	False origin of the central meridian	Scale factor of the central meridian
Ovest	9°	-3° 27’ 08,400”	1 500 000	0.9996
Est	15°	2° 32’ 51,600”	2 520 000	0.9996

The historical national cartography was established in this System: namely the Map of Italy at scale 1:100,000 and its submultiple at 25,000 (tavolette). Most of the new Regional Technical Map at scale 1:5,000 and at 1:10,000 (numerical format) refers to the Gauss-Boaga projection, despite having a cut related to the ED50 system.

• **ED50** (European Datum 1950) is the European system also adopted in Italy since the 1950s, essentially used for cartographic purposes. It also adopts Hayford's ellipsoid but with a European medium orientation. In this system Rome M. Mario has the following coordinates:

$$\phi = 41° 55’ 31.487’’ \qquad \lambda = 12° 27’ 10.93’’.$$

The software associates the orthometric heights to the ED50 system as for ROMA40.

The ED50 system is associated with the UTM Cartographic System designed to map the whole Earth using Gauss's conformal representation. The UTM system therefore considers 60 time zones of 6° numbered from West to East starting from the Greenwich anti meridian; Italy falls in 3 time zones: 32, 33 and 34, which have the following characteristics:

UTM Time Zone	Longitude of the central meridian from Greenwich	False origin of the central meridian	Scale factor of the central meridian
32	9°	500 000	0.9996
33	15°	500 000	0.9996
34	21°	500 000	0.9996

The new Map of Italy at scale 1: 50,000 and its submultiple, the new 25,000 are realized in this system.

• **ETRF89** and **ETRF2000** (European Terrestrial Reference Frame) are two realizations of the Global Earth-centred/Earth-fixed System adopted in Europe to which the GRS80 ellipsoid (Geodetic Reference System 1980), still Earth-centred/Earth-fixed, is associated; it has the following parameters:

$$a = 6378137 \text{ m}, \qquad f = 1/298{,}257222101.$$

The software associates the ellipsoidal heights referring to the GRS80 and the UTM Cartographic System to the ETRF systems, as described above.

Moreover, the new "Fuso Italia" has been associated to the ETRF Systems; it is a new Cartographic System, introduced in order to obtain, seamlessly, the projection of the whole national territory on a sole plan.

This system, designed to minimize deformations over large areas, is particularly suitable for georeferencing the information systems covering the whole national territory

“Fuso Italia”	Longitude of the central meridian from Greenwich	False origin of the central meridian	Scale factor of the central meridian
	12°	7 000 000	0.9985

Different heights are indicated in each of the 2 frames located under the respective selected systems. When different heights are associated to 2 selected systems in input and output (ellipsoidal in input and orthometric at sea level in output, or vice versa) the software automatically activates the button allowing also to perform the altimetric transformation.
In case of keyboard input, as a result of activating this button, the text boxes allowing the input and output of the heights become available.

Warning

The software allows point projection also in time zones other than that of belonging, offering the possibility of extending the Gauss-Boaga and UTM systems zones, beyond their real dimension of 6 °(for example in UTM a point at 10 ° East, falling in zone 32, can be projected in time zone 33 or 34). However, this option must be used carefully because it provides coordinates that, strictly speaking, no longer belong to the selected cartographic system (for example Gauss-Boaga coordinates time zone East with the first digit of the East coordinate 1 instead of 2). Furthermore, it should be considered that by extending the time zone, deformations grow exponentially. Except for "Fuso Italia", if there is no particular need, it is advisable to use time zones, in their original size, by selecting the "fuso automatico/automatic time zone".

3.2 Grid's release forms

Grid's areas are released separately. They are available in the two formats described below.

- *Data covering about 10 km around each IGM95 point. These data are useful for those who work on the ground and carry out determinations by GPS measurements. These ones allow to obtain ETRS89 coordinates of points by connecting them to an IGM95 point, ellipsoid height included*. Files consist of a 6 alphanumeric characters name (the same that identify the IGM95 point to which they refer), they can be purchased separately from the point's monograph. In this way the user, who has already the monograph, can acquire only the section related to the transition between Systems with "??????.gk?" file. The approximately 4500 files are the same number as the IGM95 points. It should be noted, however, that if you purchase several of these files, associated to close IGM95 points, you could get the same data for several times. On the other hand, due to the way files are made of, you are not guaranteed to completely cover a zone.
- *Data corresponding to the area of each sheet of Italy's map at scale 1:50,000.* Files consist of a 3 or more alphanumeric characters name corresponding to the cartographic element number. These files are perfectly "modular" one next to the other in order to cover the entire national territory. There are 676 files having the following characteristics:

- 654 files numbered as the corresponding sheets at scale 1: 50,000, (including the 2 sheets 577bis and 580bis);

- 3 files with double specification: 588sicilia, 601sicilia, 614sicilia, to be used for the Sicilian territory of the aforementioned sheets, along with 588calabria, 601calabria, 614calabria, to be used for the Calabrian territory;

- 2 files corresponding to 2 particular sheets, identified with the following names:

  - **Elba -** covering the entire surface of the island corresponding to the areas falling on sheets 316, 328 and 329 (printed in a single element called "Elba Island");

  - **PianosaN -** corresponding to 328 and 341 sheets areas (printed in a single element called "Pianosa and Montecristo Island") covering an area in the Tuscan Archipelago where Pianosa Island is located.

- 17 files relating to one or more islands whose surfaces are represented in boxes of other sheets of the Italian map at scale 1: 50,000, as detailed in the table below.

File name	territory covered
Montecristo	Montecristo island described in a box, on sheet no. 328 - 341
Scoglio	"Rock of Africa or Formica di Montecristo" island described in a box, on sheet no. 328 - 341
Capraia	Capraia island described in a box, on sheet no. 317
Gorgona	Gorgona island described in a box , on sheet no. 283
Giglio	Giglio island described in a box, on sheet no. 352
Formiche	“Formiche di Grosseto” islands described in a box, on sheet no. 331
Tremiti	Tremiti islands described in a box, on sheet no. 383
PianosaS	Pianosa island described in a box, on sheet no. 384
Ponziane	Ponziane islands described in a box, on sheet no. 413
Ventotene	Ventotene island described in a box, on sheet no. 414
Ventre	“Mal di Ventre” island described in a box, on sheet no. 528
Stromboli	Stromboli island described in a box, on sheet no. 577Bis
Ustica	Ustica island described in a box, on sheet no. 585
Pantelleria	Pantelleria island described in a box, on sheet no. 626
Lampedusa	Lampedusa island described in a box, on sheet no. 635
Linosa	Linosa island described in a box, on sheet no. 635
Lampione	Lampione island described in a box, on sheet no. 635

Each line of the following table shows the “two for the price of one” files sold together, as specified in the last column.

1	**7**				sheet 1 is only an out-of-margin printed on the sheet 7
2	**8**				sheet 2 is only an out-of-margin printed on the sheet 8
19	**20**				sheet 19 is only an out-of-margin printed on the sheet 20
111	**112**				sheet 111 is only an out-of-margin printed on the sheet 112
130	**131**	**150**	**151**		sheets 130, 150 and 151 are printed on sheet 131
132	**152**	**153**			Sheets 132 and 152 are only out-of-margin printed on the sheet 153
148	**149**				sheet 149 is only an out-of-margin printed on the sheet 148
188	**206**				sheet 206 is only an out-of-margin printed on the sheet 188
213	**230**				sheet 230 is only an out-of-margin printed on the sheet 213
229	**246**				sheet 246 is only an out-of-margin printed on the sheet 229
258	**271**				sheet 271 is only an out-of-margin printed on the sheet 258
283	**Gorgona**				Gorgona is a frame inside sheet 283
316	**328**	**329**	**Elba**		parts of sheets 316, 328 and 329 are inside the Elba sheet
317	**Capraia**				Capraia is a frame inside sheet 317
328	**341**	**PianosaN**	**Montecristo**	**Scoglio**	parts of sheets 328 and 341 are inside the sheet "Isola di Pianosa e di Montecristo" in which there are the 3 islands in boxes.
331	**Formiche**				Formiche is a frame inside sheet 331
352	**Giglio**				Giglio is a frame inside sheet 352
383	**Tremiti**				Tremiti is a frame inside sheet 383

384	**PianosaS**				Pianosa is a frame inside sheet 384
413	**Ponziane**				Ponziane is a frame inside sheet 413
414	**Ventotene**				Ventotene is a frame inside sheet 414
577bis	**Stromboli**				Stromboli is a frame inside sheet 577bis
446	**447**				sheet 446 is only an out-of-margin printed on the sheet 447
476	**477**				sheet 477 is only an out-of-margin printed on the sheet 476
528	**Ventre**				Ventre is a frame inside sheet 528
581	**586**				sheet 581 is only an out-of-margin printed on the sheet 586
585	**Ustica**				Ustica is a frame inside sheet 585
626	**Pantelleria**				Pantelleria is a frame inside sheet 626
635	**Lampedusa**	**Linosa**	**Lampione**		Lampedusa, Linosa and Lampione are frames inside sheet 635
588calabria	**588sicilia**				To be used each for its own territory
601calabria	**601sicilia**				To be used each for its own territory
614calabria	**614sicilia**				To be used each for its own territory

Remarks:

- collect all the files purchased in a subfolder (e.g. "DATA") specially created in the subfolder "Verto3k" (where Verto3k.exe is stored) which is in the "software" folder.
- use the mouse while working with the software; it is however possible to exit the software by pressing the Alt+F4 keys.

3.3 Keyboard Input and Output

IMAGE

(Keyboard Input and Output example)

Keyboard input provides results directly on the monitor and it is useful when there is a small number of points to convert. In this case you cannot print the results. To enter input coordinates, click on the corresponding text boxes. By clicking on **"Invio** - **Enter**" it is possible to switch from one field to another according to a logic that is normally useful. "**Tab**" key is not operating.
This software accepts both geographic coordinates, expressed in sexagesimal degrees (which must be entered in dd.ppssdddd format), and plane coordinates expressed in meters. Heights are expressed in meters.
When you point your mouse over the input text boxes, you can see an image similar to the input format. Decimal separator can be either a dot or a comma, according to what is selected in the Windows "*Pannello di controllo - Control Panel*". This software does not perform conversions of a point falling outside the area of interest. A *message box* will warn the user.

3.4 Input and Output from file

By using input / output from a file, up to a maximum of 50,000 points can be processed simultaneously. After performing a conversion, the **"ESEGUI** - **RUN**" button remains shut off; it will be automatically reactivated by selecting a new output file or switching to keyboard input. Once the conversion completed, a message-box will inform the user about the procedure outcome and will provide the number of points both processed by the program and not processed because outside the area of interest.

IMAGE

Input and Output from Microsoft Excel® file
This software supports data input from *.xls files (Excel); in this case results will also be made available in the same format file. In the "**file list box**" related to the input and output the software proposes only files with the extension ".**xls**"; if the output file's name is not selected but entered from the keyboard without extension, the software will automatically add ".**xls**" extension.

The input file must be organized with the following criteria:

- each line collects all and only the information related to a point;
- first line is ignored by the software and can be used for headers;
- in column "A" the identifying number of the point (also alphanumeric) must be entered;
- in column "B" either the latitude of the point expressed in sexagesimal degrees in the format gg.ppssdddd or the North coordinate expressed in meters shall be entered;
- in column 'C' either the longitude of the point expressed in sexagesimal degrees in the format gg.ppssdddd or the East coordinate expressed in meters shall be inserted;
- in column "D" point's height expressed in meters shall be entered (only if you want to obtain its conversion);
- no blank lines must be left between the data (blank line means the end of the data);
- the decimal separator may be either a dot or a comma.

All coordinates in a file must be of the same type: either geographic or plane.

A	**B**	**C**	**D**	**E**
1	***number***	***latitude***	***longitude***	***height***
2	101	42.21324014	10.58202417	918.238
3	102	42.31254169	11.18174101	1872.455
4	111A	42.35117451	11.01020047	777.952
5	Point 3	42.36191455	12.09478582	3567.921
6				

Or

A	**B**	**C**	**D**	**E**
1	***number***	***North***	***East***	***height***
2	10215	5030214.251	2309747.184	918.238
3	102114	5041247.254	2321417.294	1872.455
4	111A12	5038954.978	2318941.399	945.231
5	Point113	5047618.001	2352147.817	1547.2
6				

An example of an input file is available while running the software by clicking the "***Esempio file di input - Input file Example***" button.

The output file will have the characteristics as listed below:

- in the first line there are the reference epochs of the grids used in the transformation, both for the planimetric and the altimetric part (RO-ED refers to ROMA40-ED50grid, RO-E89 refers to ROMA40-ETRF89 grid,E89-E2000 refers to the Global System realizations in-between grid);
- the second line shows the information relating to the coordinates introduced in input: Geodetic system, unit of measurement; if the coordinates are plane, the time zone to which the coordinates belong;
- the third line shows the information related to the output coordinates: Geodetic System, unit of measurement; if the coordinates are plane, the time zone in which the coordinates have been requested;
- the fourth line shows the unit of measurement of the heights and, in the case of altimetric conversions in particular areas, the indication of the geoid model used (*see paragraph "Accuracy/ Precision"*);
- the fifth line is for headings indicating the contents of columns;
- in the first 4 columns there are input data;
- in the next 3 columns there are the results of the conversion;
- in the eighth column, in case of output in plane coordinates, information is given of the time zone: no information for Fuso Italia; indication of the time zone if it was requested as 'automatic'; if a specific time zone has been requested, 'true' or "false" are shown referring to whether or not the point belongs to the requested time zone;
-for points falling outside the area that can be treated with the selected grid file, the columns of results will be marked as "**fuori griglia** - **out grid**."

A	**B**	**C**	**D**	**E**	**F**	**G**	**H**
1	Gr. Epoch	RO-ED:2002	RO-E89:2002	E89-E2000:	2008	Geoid:	2005
2	Coordinate	Input:	ETRF89	degrees	sexag.		
3	Coordinate	Output:	ROMA40	meter	T. Zone requ.	Automatic	
4	Heights:	meters					
5	Number	Lat. ETRF89	Lon. ETRF89	h ellis.	North ROMA40	East ROMA40	H geoid. T. Zone
6	51801	45.26021357	12.20162263	918.238	5034623.904	2311775.935	874.650 East
7	51901	45.26123378	12.21347072	1872.455	5034882.499	2313491.457	1828.880 East
8	52701	45.35329184	12.28255414	945.231	Fuori griglia	Fuori griglia	Fuori griglia
9							

Input and Output from ASCII file
This software supports data input from ASCII files; in this case results will also be made available in the same format file. The input file extension can be anything. In the "**file list box**" related to the output the software proposes only files with the extension **"txt";** if the output file's name is not selected but entered from the keyboard without extension, the software will add **".txt"** automatically.
The input file must be organized with the following criteria:

- lines having as first significant character the bar (/) or the apex (') are considered as comments and ignored by the software;
- each line collects all and only the information related to a point; they must be inserted in the following sequence:
- the point's identifying number, also alphanumeric, without spaces (maximum 8 characters);
- the latitude of the point expressed in sexagesimal degrees in the format gg.ppssdddd or the North coordinate expressed in meters;
- the longitude of the point expressed in sexagesimal degrees in the format gg.ppssdddd or the East coordinate expressed in meters;
- the height of the point expressed in meters (only if you want to get the conversion);
- fields must be separated by spaces (as many as you like), or by tabulation;
- the decimal separator may be either a dot or a comma.

All coordinates in a file must be of the same type: either geographic or plane.
For example:

/ number	Latitude	Longitude	Height
101	42.21324014	10.58202417	918.238
102	42.31254169	11.18174101	1872.455

work area B			
111A	42.35117451	11.01020047	777.952
Point 3	42.36191455	12.09478582	3567.921

Or

/ number	Nord	East	Height
10	5030214.251	2309747.184	18.238
102	5041247.254	2321417.294	872.455
work area B			
111A	5038954.978	2318941.399	7.952
Point_3	5047618.001	2352147.817	567.921

An example of an input file is available while running the software by clicking the "**Esempio file di input - Example input file**" button.

The output file will have the characteristics as listed below:

- in the first line there are the reference epochs of the grids used in the transformation, both for the planimetric and the altimetric part;
- the second line shows the information relating to the coordinates introduced in input: Geodetic system, unit of measurement; if the coordinates are plane, the time zone to which the coordinates belong;
- the third line shows the information related to the output coordinates: Geodetic System, unit of measurement; if the coordinates are plane, the time zone in which the coordinates have been requested;
- the fourth line shows the unit of measurement of the heights and, in case of altimetric conversions in particular areas, the indication of the geoid model used (*see paragraph "accuracy"*);
- the fifth line is for headings indicating the contents of columns;
- in the first 4 columns the input data are rewritten;
- in the next 3 columns there are the results of the conversion;
- in the eighth column, in case of output in plane coordinates, information is given of the time zone: no information for Fuso Italia; indication of the time zone if it was requested as 'automatic'; if a specific time zone has been requested, 'true' or "false" are shown referring to whether or not the point belongs to the requested time zone;
- for points falling outside the area that can be treated with the selected grid file, the columns of results will be marked as "**fuori grig. (out grid)**"

For example:

Grids epoch: RO-ED 2002; RO-E89 2002; E89-E2000 2008; Geoid 2005
Input coordinates: ETRF89; sexagesimal degrees
Output coordinates: ROMA40; meters; requested time zone : Automatic
Heights expressed in meters

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/Number	Lat. ETRF89	Lon. ETRF89	h ellis.	Nord ROMA40	Est ROMA40	H geoid.	Time zone
51801	45.26021357	12.20162263	918.238	5034623.904	2311775.935	874.650	East
51901	45.26123378	12.21347072	1872.455	5034882.499	2313491.457	1828.880	East
52701	45.35329184	12.28255414	945.231	5051895.456	2322961.795	901.369	East

4.0 Using "*Rototraslazioni spaziali* - Spatial Roto-translation" feature

The "Rototraslazioni spaziali - Spatial Roto-translation" feature allows the determination of geometric relations between two different reference systems in spatial roto-translation parameters

form, i.e. referring to the origin of the Cartesian geocentric system which, for global reference systems, corresponds to the Earth's centre of mass. Keyboard input and output are not possible: both data input and output are done through files that can be either in Microsoft Excel or ASCII format. Microsoft Excel format is simpler as for text formatting but considerably slower; when large amounts of data have to be processed, it is advisable to use ASCII format.

4.1 Spatial parameters determination

IMAGE

Number of parameters, for expressing the geometric relations between the two Reference Systems, can be chosen among the following options:

· 3 parameters - 3 translations along the X, Y and Z axes (Tx, Ty, Tz - rigid transformation);
· 4 parameters - 3 translations and 1 scale factor (Tx, Ty, Tz, S – conformal transformation);
· 5 parameters - 3 translations, rotation around the Z axis and 1 scale factor (Tx, Ty, Tz, Rz, S - conformal transformation);
· 6 parameters - 3 translations and 3 rotations around X, Y and Z axes (Tx, Ty, Tz, Rx, Ry, Rz - rigid transformation);
· 7 parameters - he same 3 translations and 3 rotations around the X, Y and Z axes, and 1 scale factor (Tx, Ty, Tz, Rx, Ry, Rz, S - conformal transformation).

It is also required to indicate the reference ellipsoid for the geographic coordinates of points for both the "first" and the "second" system. The software proposes some of the ellipsoids of the most common Reference Systems:

Bessel_1841, derived in 1841; used in Italy for the first National Geodetic Reference System and still used by the National Cadastre;
- a = 6 377 397.155;
- 1/f = 299.1528128.

· **Clarke_1880 (Fr)**, derived in 1880; used by France for local Geodetic Reference Systems;
- a = 6 378 249.145;
- 1/f = 293.465.

· **Krassovsky_1940**, derived in 1940; used by Russia and East countries;
- a = 6 378 245.0;
- 1/f = 298.3.

· **Hayford**, used by ROMA40 and ED50 European System;
- a = 6 378 388.0;
- 1/f = 297.0.

· **WGS84**, Earth-centred/Earth-fixed ellipsoid for all Global Systems;
- a = 6 378 137.0;
- 1/f = 298.257223563.

· **GRS80**, associated to ETRS89 Geodetic System and used in Europe;
- a = 6 378 137.0;
- 1/f = 298.257222101.

It is possible to use coordinates referring to any other ellipsoid by selecting the "**definito dall'utente - user-defined**" box and entering the specific geometric parameters:
- a (semi-major axis);
- 1/f (inverse flattening).

Warning

It should be remembered that the geographic coordinates of the IGM95 geodetic network, covering uniformly all Italy and entirely determined by GPS measurements, are referred to the ETRS89 European System and are therefore calculated on the ellipsoid GRS80.

The software calculates the required parameters applying the Helmert transformation and Molodensky formulas, allowing to treat planimetry and altimetry separately. By means of these formulas, shown below, it is possible to get the solution without performing coordinate transformation into geocentric Cartesian coordinates, strictly speaking impossible and in any case source of error in Local Systems for which the ellipsoidal heights are generally unknown.

EXAMPLE OF MOLODENSKY FORMULAS

The use of Molodensky's formulas allows, by indicating each line of the input file, to use only the planimetric or altimetric determination of each double points compared.

3 files are required to perform this process:

· **data file** concerning double points;
· **report file** of parameters determination;
· **parameter file,** useful for the next parameters application.

If the *.xls (Excel) format is selected in the "**file list box**" related to the 3 files, the software proposes only files with the extension ".**xls**"; if the report file's name is not selected but entered from the keyboard without extension, the software will automatically add ".**xls**" extension.
If the ASCII format is chosen, the file extension can be anything. In the "**file list box**" related to report and parameters, the software proposes only files with the extension ".**txt**"; if the report file's name is not selected but entered from the keyboard without extension, the software will automatically add the ".**txt**" extension. Each file can contain up to a maximum of 10,000 double points. After performing a conversion, the **"ESEGUI - RUN**" button remains shut off. It will be automatically reactivated by selecting a new report or parameters file. Once the process completed, a *message-box* will inform the user about the procedure outcome providing the number of the determined parameters and other useful information.

IMAGE

4.1.1 Data file

Data must be organized so that each line contains all and only the information about a double point. It is useful in order to arrive at an optimal solution, the possibility of excluding and reinserting one or more double points in the calculation, or even just the planimetric or altimetric values of some points. This is possible by changing the number indicated in "**Valori in calcolo – Computation values"** at the end of the line. For the values excluded from the computation the software also calculates the residual values of the relevant equations, allowing a quick and

effective analysis of the results.

Example of Excel data file

	A	B	C	D	E	F	G	H
1	*Num.*	*Lat. IN*	*Long. IN*	*Height IN*	*Lat. OUT*	*Long. OUT*	*Height OUT*	*Values*
2	66801	44.56314009	6.45320170	1758.990	44.56290340	6.45336900	1758.890	3
3	00024M	44.56209372	6.44484842	1846.830	44.56185603	6.44501411	1846.310	3
4	0024ZC	44.56168889	6.45151428	1767.020	44.56145126	6.45167958	1766.860	3
5	0024ZI	44.55506550	6.45149940	2061.890	44.55482773	6.45166498	2062.040	3
6	29	44.54097827	6.46039043	2401.390	44.54074141	6.46055465	2400.870	3
7	313	44.53376364	6.46557569	2197.400	44.53352697	6.46573993	2197.240	3
8	37	44.53061497	6.47592293	2216.190	44.53037925	6.48009009	2214.240	3

- first line is ignored by the software and can be used for headers;
- in column "A" the INPUT point's identifying number (also alphanumeric) must be entered;
- in column “B” the INPUT point's latitude, expressed in sexagesimal degrees, in the format gg.ppssdddd, must be entered;
- in column “C” the INPUT point's longitude, expressed in sexagesimal degrees, in the format gg.ppssdddd, shall be entered;
- in column "D" INPUT point's height expressed in meters, shall be entered;
- in column “E” the OUTPUT point's latitude, expressed in sexagesimal degrees, in the format gg.ppssdddd, must be entered;
- in column “F” the OUTPUT point's longitude, expressed in sexagesimal degrees, in the format gg.ppssdddd, must be entered;
- in column "G" OUTPUT pointìs height expressed in meters, shall be entered;
- in column “H” (**Valori in calcolo** - **Computation Values**) any of the following coefficient shall be entered:

  3 = all point's coordinates are used for the computation;
  2 = only planimetry is used for the computation;
  1 = only height is used for the computation;
  0 = point is not used for the computation.
- the decimal separator may be either a dot or a comma according to according to what is selected in the *Windows "Pannello di controllo - Control Panel"*.

Example of ASCII data file

```
1  Num.      Lat. IN      Long. IN     Height IN   Lat. OUT     Long. OUT    Height OUT  Values

66801  44.56314009  6.45320170 1758.990  44.56290340 6.45336900 1758.890       3
00024M 44.56209372  6.44484842 1846.830  44.56185603 6.44501411 1846.310       3
0024ZC 44.56168889  6.45151428 1767.020  44.56145126 6.45167958 1766.860       3
0024ZI 44.55506550  6.45149940 2061.890  44.55482773 6.45166498 2062.040       3
work area B
29     44.54097827  6.46039043 2401.390  44.54074141 6.46055465 2400.870       3
313    44.53376364  6.46557569 2197.400  44.53352697 6.46573993 2197.240       3
37     44.53061497  6.47592293 2216.190  44.53037925 6.48009009 2214.240       3
```

• lines having as first significant character the bar (/) or the apex (') are considered as comments and ignored by the software;
• each line collects the information inserted in the following sequence:
• the point's identifying number, also alphanumeric, without spaces (maximum 8 characters);
• the INPUT point's latitude expressed in sexagesimal degrees in the format gg.ppssdddd; • the INPUT point's longitude expressed in sexagesimal degrees in the format gg.ppssdddd;
• the INPUT point's height expressed in meters;
• the OUTPUT point's latitude, expressed in sexagesimal degrees, in the format gg.ppssdddd;
• the OUTPUT point's longitude, expressed in sexagesimal degrees, in the format gg.ppssdddd;
• the OUTPUT point's height expressed in meters;
• the following coefficient (**Valori in calcolo** - **Computation Values)**:

3 = all point's coordinates are used for the computation;
2 = only planimetry is used for the computation;
1 = only height is used for the computation;
0 = point is not used for the computation.

• fields must be separated by spaces (as many as you like), or by tabulation;
• the decimal separator may be either a dot or a comma according to according to what is selected in the *Windows "Pannello di controllo - Control Panel"*.

4.1.2 Report file

Data and results are summarized in the report file. When evaluating the reliability of the result it should be remembered that MSE and the residuals of the equations take on greater importance than the MSE of the parameters which can be negatively influenced by geometry.

Example of Excel report file
See the Italian version of this document

Example of ASCII report file
See the Italian version of this document

4.1.3 Parameters file

Needed values for next parameters application are collected in a file (**parameters file**). This file has been specially created for the “Spatial parameters application” feature. In addition to parameters' number and values, this file contains names and geometric constants of input and output ellipsoids, which are used in the determination. Parameters' signs are written accordingly to data conversion from input to output systems.

Example of Excel Parameters file

	A	B	C	D
1	**Input**	GRS80	6378137	0.003352811
2	**Output**	Hayford	6378388	0.003367003
3	**Parameters**	7		
4	Tx	33.91488548	m	
5	Ty	-1.26785405	m	
6	Tz	-152.6490949	m	
7	Rx	- 3.01322E-06	radianti	
8	Ry	6.11205E-06	radianti	
9	Rz	-3.42747E-06	radianti	
10	S	4.54738E-05		
11				

Example of ASCII Parameters file

```
Input:      GRS80
            6378137
            3.35281068118232E-03
Output:     Hayford
            6378388
            3.36700336700337E-03
Parameters: 7
Tx=         33.9573160551907
Ty=         -1.26034750462173
Tz=         -152.58289894746
Rx=         -3.01884492131433E-06
Ry=         6.10877077222254E-06
Rz=         -3.43293828413119E-06
S =         4.54616654858093E-05
```

4.2 Spatial parameters application

The "Applicazione parametri spaziali - Spatial parameters application" feature allows the application of a parameters set (obtained as described above and stored in a **parameters file**) to a set of points of which the input coordinates of the first system are known to obtain those in the second system. Once selected the format of the file you want to work with (Excel or ASCII), and in which data and parameter files are available, the procedure requires the selection of 3 files:

· **file of parameters**, previously determined;
· **file of data**, concerning the points to be converted from the first to the second system;
· **results/output file** of parameters application.

If you select the ***.xls files (Excel)** format in the 3 "***file list box***", the software proposes only files with the extension ".**xls**"; if the output file's name is not selected but entered from the keyboard without extension, the software will automatically add ".**xls**" extension. In case you select the ASCII format, the data file extension can be anything. In the "***file list box***" of parameters and results, the software proposes only files with the extension ".**txt**"; if the output file's name is not selected but entered from the keyboard without extension, the software will automatically add ".**txt**" extension.

IMAGE OF SPATIAL PARAMETERS APPLICATION

During execution, the software reports the parameters in use and the constants of the input and output ellipsoids on the monitor. The output coordinates are calculated applying Molodensky's formulas, previously described. Each file can contain up to a maximum of 50,000 double points. After performing a conversion, the "**ESEGUI - RUN**" button remains shut off; it will be automatically reactivated by selecting a new output file. Once the conversion completed, a message-box will inform the user about the procedure outcome and will provide the number of parameters and points to which the parameters have been applied.

IMAGE

4.2.1 Data file

Each line must contain all and only the information related to the point the parameters are to be applied to.

Example of Excel data file

	A	B	C	D	E
1	***Num.***	***Lat. IN.***	***Long. IN.***	***Height IN***	
2	66801	44.56314009	6.45320170	1758.990	
3	00024M	44.56209372	6.44484842	1846.830	
4	0024ZC	44.56168889	6.45151428	1767.020	
5	0024ZI	44.55506550	6.45149940	2061.890	
6	29	44.54097827	6.46039043	2401.390	
7	313	44.53376364	6.46557569	2197.400	
8	37	44.53061497	6.47592293	2216.190	
9					

- first line is ignored by the software and can be used for headers;
- in column "A" the point''s identifying number (also alphanumeric) must be entered;
- in column “B” the INPUT point's latitude, expressed in sexagesimal degrees, in the format gg.ppssdddd, must be entered;
- in column “C” the INPUT point's longitude, expressed in sexagesimal degrees, in the format gg.ppssdddd, shall be entered;
- in column "D" INPUT point's height expressed in meters, shall be entered.

Example of ASCII data file

```
/ Num.            Lat. IN.          Long. IN.         Height IN.
66801             44.56314009       6.45320170        1758.990
00024M            44.56209372       6.44484842        1846.830
0024ZC            44.56168889       6.45151428        1767.020
0024ZI            44.55506550       6.45149940        2061.890
Work area B
29                44.54097827       6.46039043        2401.390
313               44.53376364       6.46557569        2197.400
37                44.53061497       6.47592293        2216.190
```

- lines having as first significant character the bar (/) or the apex (') are considered as comments and ignored by the software;
- each line collects the information inserted in the following sequence:

- the point's identifying number, also alphanumeric, without spaces (maximum 8 characters);
  - the INPUT point's latitude expressed in sexagesimal degrees in the format gg.ppssdddd;
  - the INPUT point's longitude expressed in sexagesimal degrees in the format gg.ppssdddd;
- the INPUT point's height expressed in meters;

- fields must be separated by spaces (as many as you like), or by tabulation;
- the decimal separator may be either a dot or a comma according to according to what is selected in the *Windows "Control Panel"*.

4.2.2 Results/output file

In the results/output file the following information are listed:

- Roto-translation parameters used;
- Ellipsoid constants of input and output systems;

• Number of points, which have been processed together with input and output systems coordinates.

Parameters file example in Excel format
See the Italian version of this document

Parameters file example in ASCII format
See the Italian version of this document

5.0 Using "*Rototraslazioni piane* - Plane Roto-translation" feature

The "*Rototraslazioni piane* - Plane Roto-translation" feature allows the determination of geometric relations between two different reference systems in plane roto-translation parameters form. Keyboard input and output are not possible: both data input and output are done through files that can be either in Microsoft Excel or ASCII format. Microsoft Excel format is simpler as for text formatting but considerably slower; when large amounts of data have to be processed, it is advisable to use ASCII format.

5.1 Plane parameters determination

IMAGE

Number of parameters, for expressing the geometric relations between the two Reference Systems, can be chosen among the following options:

· 1 parameter – 1 rotation (R - rigid transformation);
· 2 parameters – 2 translations (Tn Te – rigid transformation);
· 3 parameters – 2 translations and 1 scale factor (Tn, Te, S - conformal transformation);
· 3 parameters – 2 translations and 1 rotation (Tn, Te, R – rigid transformation);
· 4 parameters – 2 translations, 1 rotation and 1 scale factor (Tn, Te, R, S – conformal transformation).
. 5 parameters – 2 translations, 1 rotation and 2 scale factors (Tn, Te, R, Sn, Se – affine transformation);

Warning

The transformation by means of the single rotation is very particular. It should only be used when it is certain that the two systems only differentiate by one rotation, except for accidental errors.

The software elaborates the required parameters by the method of least squares, setting each generating equation, after referring the two sets of coordinates, at its barycentre (except for the case of the single rotation for which the original coordinates are used). This methodology is advantageous because it allows to have an optimal solution, since it reduces the dependence of the translations from the rotations.

3 files are required to perform this process:

· **data file** concerning double points;
· **report file** of parameters determination;
· **parameter file,** useful for the next parameters application.

If the *.xls (Excel) format is selected in the "**file list box**" related to the 3 files, the software proposes only files with the extension ".**xls**"; if the report file's name is not selected but entered from the keyboard without extension, the software will automatically add ".**xls**" extension.
If the ASCII format is chosen, the file extension can be anything. In the "**file list box**" related to report and parameters, the software proposes only files with the extension ".**txt**"; if the report file's name is not selected but entered from the keyboard without extension, the software will automatically add the ".**txt**" extension. Each file can contain up to a maximum of 10,000 double points. After performing a conversion, the **"ESEGUI** - **RUN**" button remains shut off. It will be automatically reactivated by selecting a new report or parameters file. Once the process completed, a *message-box* will inform the user about the procedure outcome providing the number of the determined parameters and other useful information.

IMAGE

5.1.1 Data file

Data must be organized so that each line contains all and only the information about a double point. It is useful in order to arrive at an optimal solution, the possibility of excluding and reinserting one or more double points in the calculation. This is possible by changing the number indicated in "**Valori in calcolo - Computation Values**" at the end of the line. For the points excluded from the computation the software also calculates the residual values of the relevant equations, allowing a quick and effective analysis of the results.

Example of Excel data file

	A	B	C	D	E	F	G
1	*Point*	*North*	*East*	*Y*	*X*	*Valori in cal.*	
2	3	4840421.199	671386.879	42103.29	-16540.58	1	
3	35	4840764.814	671408.628	42446.06	-16508.92	1	
4	39	4840947.293	670917.988	42642.45	-16994.30	1	
5	43	4839837.741	671527.993	41516.04	-16416.02	1	
6	47	4840314.194	672171.429	41973.84	-15759.25	1	
7							
8							

- first line is ignored by the software and can be used for headers;
- in column "A" the point identifying number (also alphanumeric) must be entered;
- in column "B" the North coordinate (ordinate) of the INPUT point must be entered;
- in column "C" the East coordinate (abscissa) of the INPUT point shall be entered;
- in column "D" the North coordinate (ordinate) of the OUTPUT point must be entered;
- in column "E" the East coordinate (abscissa) of the OUTPUT point shall be entered;
- in column "F" (**Valori in calcolo** - **Computation Values**) one of the following coefficient shall be entered:

  1 = point is used for the computation;
  0 = point is not used for the computation.

- the decimal separator may be either a dot or a comma according to according to what is selected in the *Windows "Pannello di controllo - Control Panel"*.

Example of ASCII data file

```
/Point       North        East         Y              X     Valori in cal.
   3        4840421.199  671386.879  42103.29   -16540.58         1
   35       4840764.814  671408.628  42446.06   -16508.92         1
   39       4840947.293  670917.988  42642.45   -16994.30         1
   43       4839837.741  671527.993  41516.04  -16416.02          1
   47       4840314.194  672171.429  41973.84  -15759.25          1
```

- lines having as first significant character the bar (/) or the apex (') are considered as comments and ignored by the software;
- each line collects the information inserted in the following sequence:
- the point identifying number, also alphanumeric, without spaces (maximum 8 characters);
    - the North coordinate (ordinate) of the INPUT point;
    - the East coordinate (abscissa) of the INPUT point;
    - the North coordinate (ordinate) of the OUTPUT point;
    - the East coordinate (abscissa) of the OUTPUT point;
    - one of the following coefficients (**Valori in calcolo** - **Computation Values**):

        1 = point is used for the computation;
        0 = point is not used for the computation.
    - fields must be separated by spaces (as many as you like), or by tabulation;
- the decimal separator may be either a dot or a comma according to according to what is selected in the *Windows "Pannello di controllo - Control Panel"*.

5.1.2 Report file

Data and results are summarized in the report file. When evaluating the reliability of the result it should be remembered that the MSE and the residuals of the equations take on greater importance than the MSE of the parameters which can be negatively influenced by geometry.

Example of Excel report file
See the Italian version of this document

Example of ASCII report file
See the Italian version of this document

5.1.3 Parameters file

Needed values for next parameters application are collected in a file (**parameters file**). This file has been specially created for the “Plane parameters application” feature. In addition to parameters' number and values, this file contains names and geometric constants of input and output ellipsoids, which are used in the determination. Parameters' signs are written accordingly to data conversion from input to output systems.

Example of Excel Parameters file

	A	B	C	D
1	Parameters	4		
2	Type	4		
3	Parameters	7		
4	TN	158.1887	m	
5	TE	5.738967	m	
6	R	0.100006	radianti	
7	S	0.999968		

Example of ASCII Parameters file

```
Parameters:      4
Typo:            4
```

```
TN= 1             58,188665081708   m
TE=               5,73896698390101  m
R=                0,10000647728161  radianti
S=                0,999968252729419
```

5.2 Plane parameters application

The “Applicazione parametri piani - Plane parameters application” feature allows the application of a parameters set (obtained as described above and stored in a **parameters file**) to a set of points of which the input coordinates of the first system are known to obtain those in the second system. Once selected the format of the file you want to work with (Excel or ASCII), and in which data and parameter files are available, the procedure requires the selection of 3 files:

· **file of parameters**, previously determined;
· **file of data**, concerning the points to be converted from the first to the second system;
· **results/output file** of parameters application.

If you select the ***.xls files (Excel)** format in the 3 “***file list box***”, the software proposes only files with the extension "**.xls**"; if the output file’s name is not selected but entered from the keyboard without extension, the software will automatically add "**.xls**" extension.

IMAGE

In case you select the ASCII format, the data file extension can be anything. In the “***file list box***” of parameters and results, the software proposes only files with the extension "**.txt**"; if the output file’s name is not selected but entered from the keyboard without extension, the software will automatically add "**.txt**" extension.
During the *.par file reading, parameters which have been read, are displayed on the monitor. Each file can contain up to a maximum of 50,000 double points. After performing a conversion, the "**ESEGUI - RUN**" button remains shut off. It will be automatically reactivated by selecting a new output file. Once the process completed, a *message-box* will inform the user about the procedure outcome and provides both the number of parameters and points at which the parameters were applied.

IMAGE

5.2.1 Data file

Each line must collect all and only the information related to the point the parameters have to be applied to.

Example of Excel data file

	A	B	C	D
1	Point	North	East	
2	3	4840421.199	671386.879	
3	35	4840764.814	671408.628	
4	39	4840947.293	670917.988	
5	43	4839837.741	671527.993	
6	47	4840314.194	672171.429	
7				
8				

- first line is ignored by the software and can be used for headers;

- in column "A" the point's identifying number (also alphanumeric) must be entered;
- in column “B” the North coordinate (ordinate) of the INPUT point must be entered;
- in column “C” the East coordinate (abscissa) of the INPUT point shall be entered.

Example of ASCII data file

```
/ Point           North              East
      3           4840421.199       671386.879
      35          4840764.814       671408.628
      39          4840947.293       670917.988
      43          4839837.741       671527.993
      47          4840314.194       672171.429
```

- lines having as first significant character the bar (/) or the apex (') are considered as comments and ignored by the software;
- each line collects the information inserted in the following sequence:
- the point's identifying number, also alphanumeric, without spaces (maximum 8 characters);
    - the North coordinate (ordinate) of the INPUT point;
    - the East coordinate (abscissa) of the INPUT point;
- fields must be separated by spaces (as many as you like), or by tabulation;
- the decimal separator may be either a dot or a comma according to according to what is selected in the *Windows "Pannello di controllo - Control Panel"*.

5.2.2 Results/output file

In the results/output file the following information are listed:

- Roto-translation parameters used;
- Number of points, which have been processed together with input and output systems coordinates.

Results/output file example in Excel format
See the Italian version of this document

Results/output file example in ASCII format
See the Italian version of this document

6.0 Accuracy/Precision

Conversions’ accuracy between different Reference Systems is not related to the software in use but it depends on the grids used and implemented by the software.
Grids files have ***.gk?** extension and, once selected, can be identified per year of realization. At the moment two grids extensions are available: **gk1** and **gk2**; grids are the same for plane coordinates and they give the same results as the ones used by IGMI. Geographic coordinates are expressed in sexagesimal format (about 3 mm), plane coordinates are expressed in mm. Accuracy is within millimetre thanks to the formulas developed by Prof Bonifacino.
ITALGEO99 is the geoidic model in use for heights and implemented in **gk1** grids (it was created thanks to the cooperation between IGMI and the Polytechnic of Milan). This geoidic model has a mean deviation (1σ) from GEOTRAV network (part of IGM95 network) of:

- $\pm$ 0.15 m for continental Italy (Genoa tide gauge);
- $\pm$ 0.04 m for Sicily (Catania tide gauge);
- $\pm$ 0.07 m for Sardinia (Cagliari tide gauge).

At 3σ (confidence level of 99%) values are $\pm$ 0.45 m, $\pm$ 0.12 m, and $\pm$ 0.21 m respectively.

For Pelagie islands and Pantelleria island, separation values were estimated using Wenzel global model and they not referred to the national geoidic models normally used. A message-box will inform the user about the geoidic model used for these areas.
ITALGEO2005 (also created thanks to the cooperation between IGMI and the Polytechnic of Milan) is the geoidic model implemented in **gk2** grids with a mean deviation (1σ) from GEOTRAV network (part of IGM95 network) of:

- ± 0.035 m for the whole of Italy

At 3σ (confidence level of 99%) value is ± 0.10 m.
For Pelagie islands and Pantelleria island, separation values were estimated using EGM2008 global model, whose accuracy should not be lesser than 0.5 m. A message-box will inform the user about the geoidic model used for these areas
Both for spatial and plane roto-translations the reliability of the result concerning the parameters' estimation is expressed by the MSE of residuals of the equations, while the MSE of the parameters which can be negatively influenced by geometry, are of poor reliability.

The IGMI Geodetic Service will be grateful to anyone who would like to contribute with observations and suggestions for improving the software.