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MATISSE Version 2.0

PRINCIPLE NOTE AND USER DOCUMENT

Summary: This document is the documentation for version 2.0 of Matisse. Its purpose is to list the new functions included in version 1.1, offering the user the possibility of generating regular grids. These are vital for many studies, in particular river studies (where the computational domain is longer than it is wide), as they allow the number of nodes in the final grid to be considerably reduced.

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SUMMARY

This document is the outline description and user manual for version 2.0 of the MATISSE software. Its purpose is to describe the developments and new functions added to version 1.1.

This version now offers users functions for constructing "regular" grids. These are vital for many studies, in particular river studies (where the computational domain is longer than it is wide), as they allow the number of nodes in the final grid to be considerably reduced and an anisotropic grid to be simulated.

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1. Introduction

1.1. Purpose of document

This document is the outline description and user manual for version 2.0 of the MATISSE software. Its purpose is to describe the developments and new functions added to version 1.1. It thus supplements document [1].

1.2. Purpose of version 2.0 of MATISSE

Version 2.0 of MATISSE now offers users functions for constructing "regular" grids. These are vital for many studies, in particular river studies (where the computational domain is longer than it is wide), as they allow the number of nodes in the final grid to be considerably reduced and an anisotropic grid to be simulated.

1.3. Terminology

The following terminology will be used in this document:

- a **zone** is a closed polygonal sequence that is not self-intersecting (or simple polygon),
- an **adjustable zone** is one that can be adjusted if has been validated by the software when passing into DEM mode. The user can thus select it in MESH mode in order to adjust it.
- a **regular zone** is one that can be selected by the user and adjusted in MESH mode,
- a **ridge** is a segment connecting two points. Nevertheless, this notion does not exist as such in the MATISSE interface in the BATHYMETRY and GEOMETRIC LINES modes.

2. General user procedure

In GEOMETRIC LINES mode, the user must define the geometric supports for the zones that he may wish to include in the regular grid. This stage involves building a set of polygonal sequences using the new building functions available in the software.

Adjustable zones are then built in a new mode, ZONE mode. Each zone adjoins the geometric supports defined in GEOMETRIC LINES mode.

To ensure sufficient topological consistency, the distribution of zones in the domain to be adjusted is validated by additional checking procedures before entering DEM mode (this is done automatically by the software and in a manner that is transparent to the user). In DEM mode, the step size map (criteria) is defined by the user independently of whether adjustable zones exist or not.

These zones, now referred to as "adjustable" are then proposed to the user in MESH mode so that the grid can be meshed in regular mode if he wishes. The user begins by successively meshing all or part of the adjustable zones. The adapted grid will be last stage of the grid creation process. It enables all the regular grids to be assembled with the adapted grid created for the rest of the domain in order to obtain a single grid, as in version 1.1.

The software also monitors topological and geometric consistency when switching between the various modes of the software.

3. Mode by Mode Description

3.1. BATHYMETRY mode

No modification has been made in this mode in relation to the regular grid.

3.2. GEOMETRIC LINES mode

In this mode, a set of closed polygonal sequences is built to support the zones to be used for the regular grid. Zone definition itself is done in the ZONE mode described in the following section.

The functions existing in version V1P1 of the MATISSE code did not enable the user to perform all the operations required to construct polygonal sequences interactively. New functions have been developed for this purpose, extending the possibilities offered to the user.

The purpose of these options is to provide the user with help in constructing polygons to support the zones to be adjusted, in order to ensure sufficient topological consistency of the data created in this way. This topological consistency will be checked during later zone construction in ZONE mode and when entering DEM mode.

To do this, MATISSE V2 now allows a single point to be shared by several lines.

The new functions are as follows:

- extension of the line creation function,
- a function for extending a line,
- a two-line intersection/fusion function. Depending on the situation, this function enables the user to define the points of intersection of two lines, which will then be shared by these lines, or to modify the lines to ensure that common ridges are unique.

3.2.1. Line creation/extension function

This function (Create line) is used to define a new line based on:

- points belonging to geometric lines (1),
- bathymetric points (2),
- graphically created points (3),
- points to be inserted in a ridge of an existing line (4)
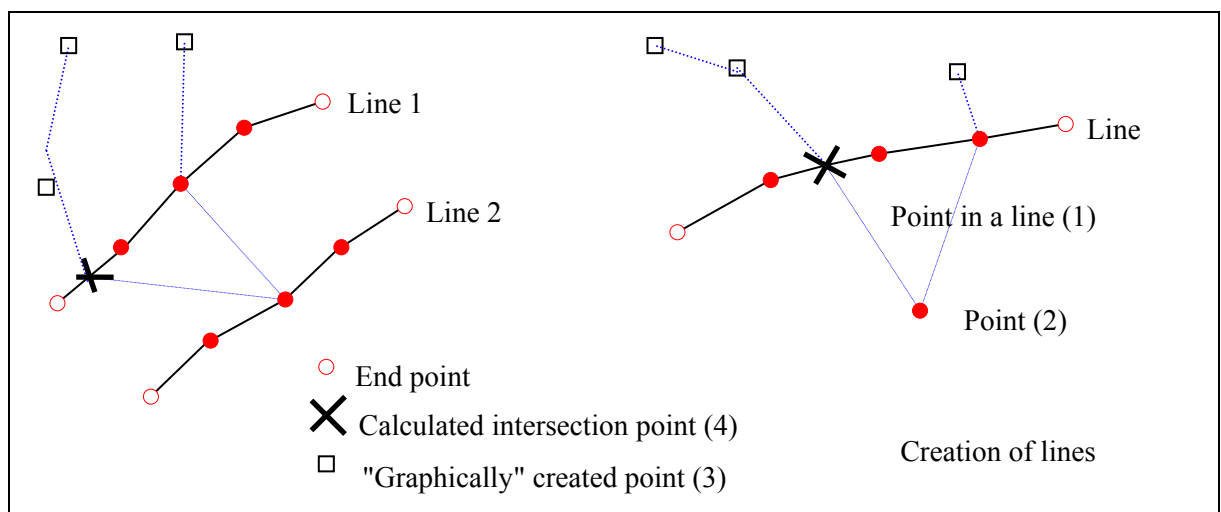
Creation of lines

In addition, in interactive mode, this line creation function detects and prevents the termination of a line based on its first point, without the line being closed. This function therefore proposes that the user should close the line automatically in this situation and, in the event of a refusal, does not keep the last point entered. In this way, the user is not led into thinking that he has created a "closed" line.

This function also manages "line extension cases". Starting from a line end point (1), it may use as a basis bathymetry points (2), points belonging to another line (3), points created graphically in the domain (4), or a point to be created on a ridge of an existing line (5, intersection). In the last case, the points created will be added to the existing lines and shared with the line being constructed.
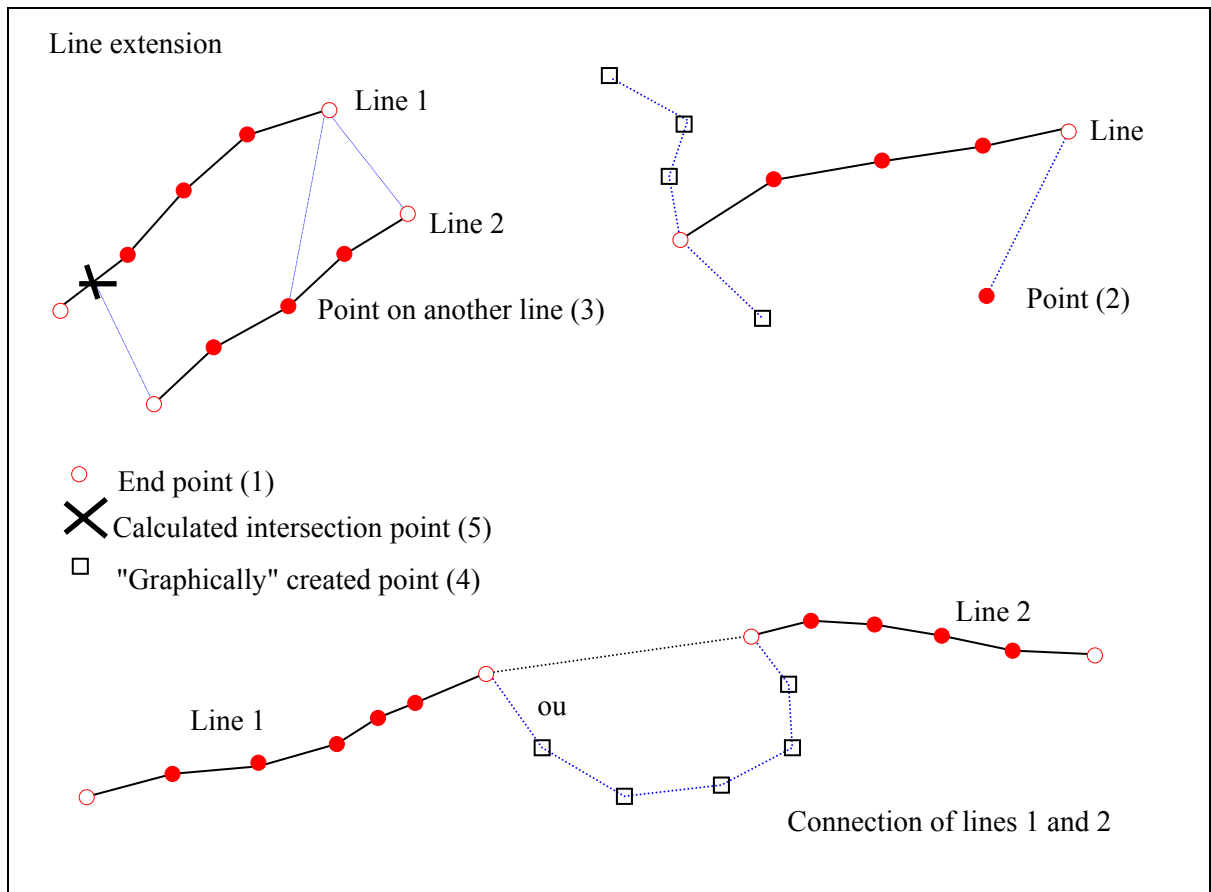
Depending on the situation, the methods for interpolating the bathymetry of created points are as follows:

- for a new point in the domain: calculated from the terrain model or fixed at a constant value defined by the user,
- for a point created on a ridge: calculated from the existing support line or fixed at a constant value defined by the user.

Remark: a created line supported at one of its ends on a point that is itself the end of another line may be connected to this second line (with the user's agreement). If both ends of the created line are ends of existing lines, the whole thing may be transformed into a single line, or a closed line may be created. This is thus an enlarged "Connect" function offering the possibility of connecting several lines while creating points between the ends of these lines.

3.2.2. *Intersection/fusion function*

This function is used to modify data of geometric line type in order to eliminate any line superimposition. Zone contours must not intersect or be superimposed.

The changes proposed in the line creation (and extension) function enable the user to construct lines and zones in compliance with this topological consistency. Nevertheless, the user may be faced with this type of problem in the case of imported geometries or geometric objects (circles, rectangles) transformed into lines.

To do this, the intersection/fusion function transforms two selected lines into two new lines modified to comply with this minimum topology:

- by inserting points at proper intersections, which will be shared by the two parent lines,
- by eliminating common ridges in the case of improper intersections. The line designated as having priority by the user will continue to be supported on these ridges, while the one with lower priority will be modified by having the ridges eliminated.

The order of selection determines a priority between the objects and defines which one may be cut and which will remain "whole". The first one selected has priority over the second. Introducing this semantic choice enables the user to control the results of his operations more effectively. These same rules are used in the altimetric interpolation of intersection points: the altimetry will be calculated by linear interpolation between the points on the priority line.

The contour also has priority over any other entity, irrespective of the order of selection. Two contours cannot intersect, therefore.

This notion of priority is also used to designate the line that must remain complete regardless of the geometric situation:

- in the case of proper intersections, the information relating to both lines is retained and the calculated point(s) will be inserted on these two lines,
- in the case of fusion (improper intersection), the priority line is kept intact, possibly with one or two proper intersection points being added. The non-priority line is cut by eliminating the common ridges with the priority line, and will thus be transformed into one or more polygonal sequences. The diagrams below show the results expected in the case of two simple examples.

Examples of the results of fusion and intersection calculations for two polygonal sequences.
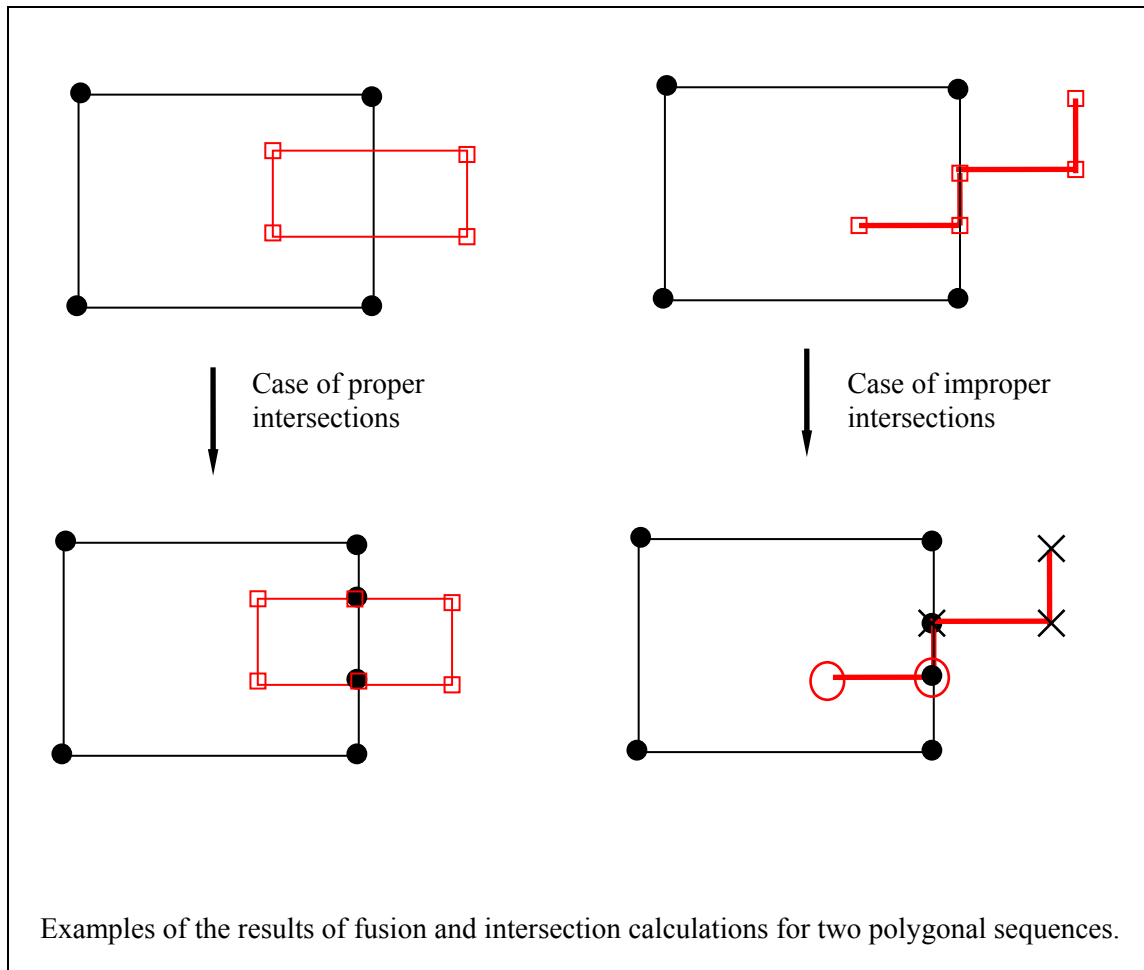
Remark: zones adjoining lines that have been cut (lines with less priority in the case of improper intersections) will be eliminated for reasons of consistency.

3.3. ZONE mode

A new working mode has been created in MATISSE Version 2.0. This "ZONE" mode combines the various handling options connected with adjustable zones.

It is used:

- to define zone contours on the basis of geometric lines derived from the GEOMETRIC LINES mode,
- to offer tools for handling these zones (editing, deletion, auditing, etc.),
- to check the consistency of defined zones before going into DEM mode.

3.3.1. Notion of zone

A zone is a closed set of lines adjoining sub-sequences derived from geometric lines. Any manipulation of shared data in GEOMETRIC LINES mode (eliminating peaks, shifting peaks, adding peaks, etc.) will have an effect on zone definition. It should be noted that zone validity (non-intersection) may be thrown into question if it has been validated previously.

In addition, 4 corner points are associated, 2 at the entrance and 2 at the exit, to divide this set of lines into four sides: an entrance, an exit and two edges. These sides are oriented, and define a transverse direction and longitudinal direction.
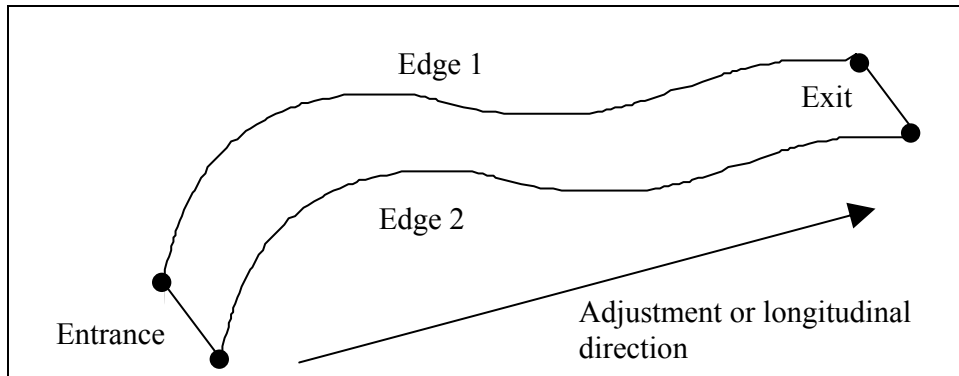
3.3.2. Zone construction function

The user constructs a zone (Create zone menu) by successively indicating sub-sequences of geometric lines defining a closed polygon.

A zone is created in the interface by selecting an initial point and then a ridge attached to this point, thus determining a direction of movement. If a point of intersection is encountered during this selection process, the user then indicates the path to be followed ("right" or "left") in order to remove any ambiguity and continue choosing ridges until a closed curve is obtained (see figure 1 below). To facilitate this selection, the Backspace key is used to go back one or more stages in the selection (returning to the intersection where the previous choice was made – following diagram – figure 2).

Figure 1   Figure 2
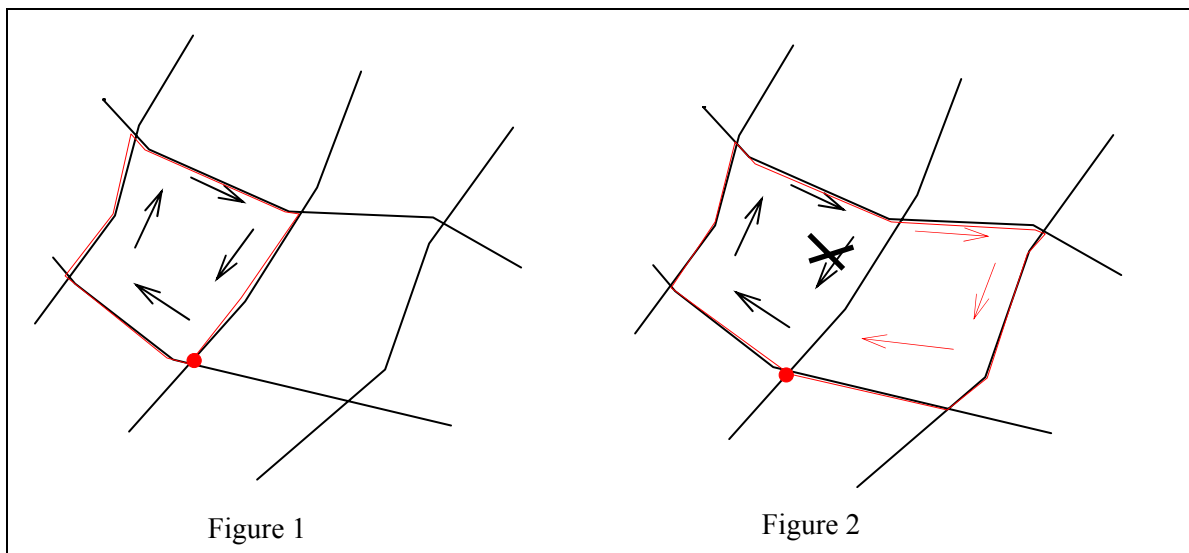
During these operations, any entity clicked on is highlighted to confirm the selection. The user validates the construction with the middle button of the mouse.

Zones can be named (using a character chain) by the user. The name must be unique. By default, zones are numbered implicitly (with a strictly positive, unique number).

The user must then indicate the four corner points (define corners button) in trigonometric order and may assign a colour. These attributes may be modified by the zone edition function. Corner points can also be modified in the MESH mode.

Zone construction ends with automatic verification that the set of lines by which it is defined do not intersect. In the event of intersection, the construction process is cancelled and an error message is displayed on the screen.

The user may also use a zone audit function (cf. section 3.3.4).

3.3.3.   Zone edition and manipulation functions

These functions enable the user to:

- select one or more zones. A zone is selected by choosing its name, clicking with the mouse on the zone or foreground/background selection,
- probe a zone: the name of the zone where the mouse cursor is situated is displayed,
- move a zone to the foreground/background,
- select everything,
- destroy one or more zone(s),
- edit a zone, i.e. modify zone attributes (names, corner points).

3.3.4.   Geometric audit function

Checking operations are carried out at various stages of the process:

- whenever a zone is created, a non-intersection test is carried out automatically,
- when entering ZONE mode, the software checks that none of the zones are self-intersecting. The user may indeed have modified the geometric lines adjoining the zones, and the set of lines defining this zone may thus be self-intersecting. Zones that do not pass this test are destroyed,
- in ZONE mode, the user may select a zone and ask for a first-level audit to be carried out. This prepares the transition into DEM mode, during which a number of geometric verification operations are carried out.

The first-level geometric audit function checks only intersections between the selected zone and the other zones, as well as with lines defined as "contours". Inclusions are not checked, as the contours (inside and/or outside) have not all necessarily been defined.

If an intersection problem is detected, the software displays the segments concerned in red.

3.4.   DEM mode

3.4.1.   Topological tests

Zone validity is also checked on entering DEM mode. However, these checks are more thorough (second-level) than those performed or proposed at present in ZONE mode (first-level). They can be used to validate completely the definition of zones to be adjusted in the domain.

If the verification fails, access to DEM mode (and consequently to grid construction functions in MES mode) is not denied. The user can choose to return to the ZONE or GEOMETRIC LINES modes (and possibly modify the zones concerned) or continue working. In the second case, non-validated zones will not be proposed later for a regular grid.

Zones that pass these tests will be considered to be adjustable but will not necessarily be adjusted (meshed) (this is a final choice made by the user in MESH mode).

These tests check in succession that:

- each adjustable zone is not self-intersecting. As it is compulsory to pass through the ZONE mode, modifications in GEOMETRIC LINES mode may have been made since the last check,
- there is no intersection between the various zones or between these zones and the domain contours, all of which have now been identified,
- no contour line (and hence an inner contour) is included inside a zone; if this is the case, the zone is deactivated and a warning given, but this anomaly is not considered to be critical,
- the zones are included in the domain.

Any zones that do not pass these tests are not adopted. Zones that successfully pass all these tests are validated and will become adjustable zones.

These tests also detect:

- whether part of the domain is not covered by an adjustable zone. In this case, there will necessarily be an adapted zone, and a step size map will have to be defined. In contrast, if the entire domain is covered by adjustable zones that have actually been adjusted, there will be no adapted part and the user will not have to define a step size map,
- the inclusion of adjustable zones. Indeed, it is not possible to mesh all types of zone, and in particular zones containing inner contours or other zones that have already been meshed.

The various possible case of inclusion and the expected result (in terms of zone validation or invalidation) are represented in the following figure.
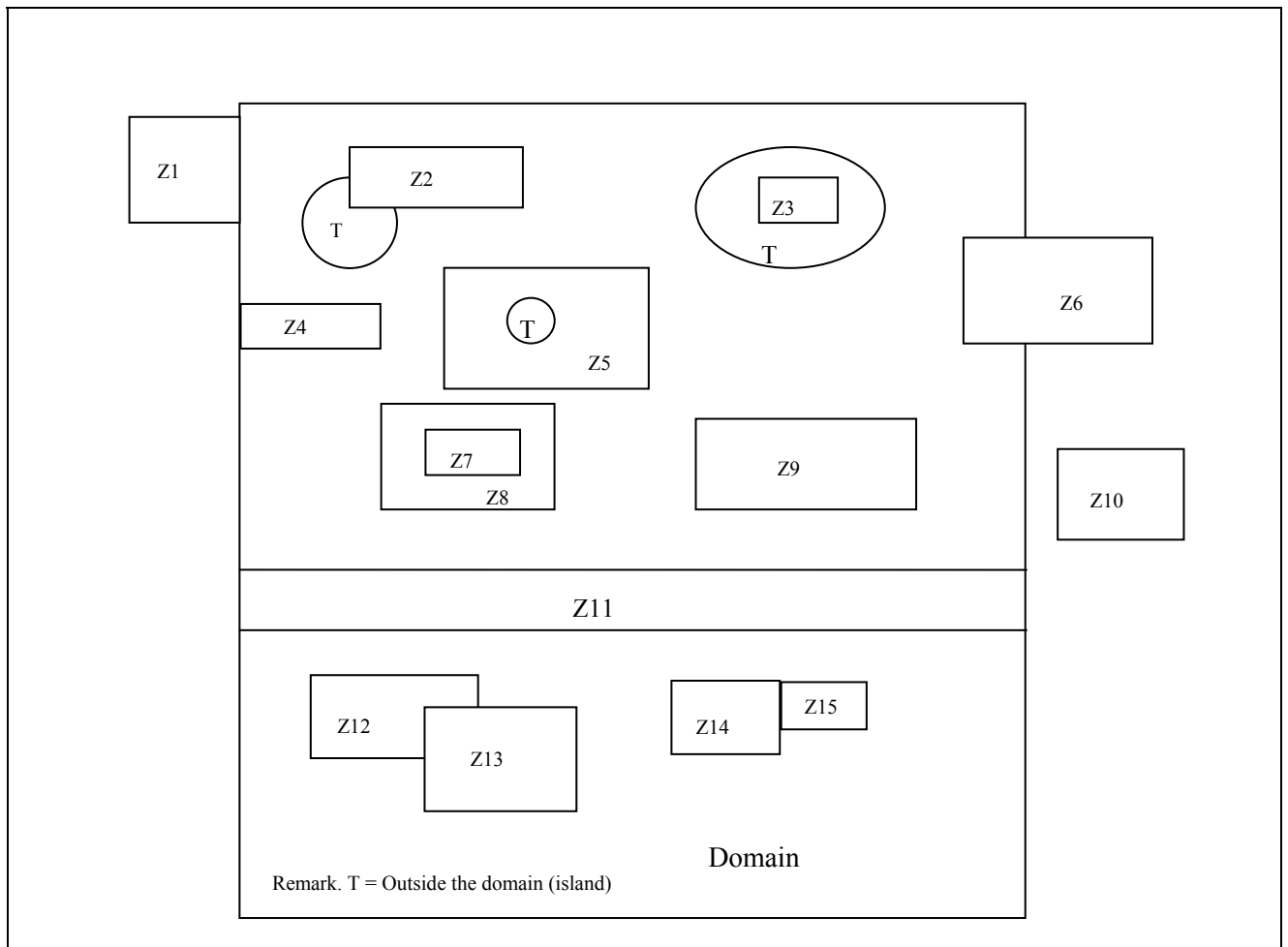
In the examples presented above, the following zones will be invalidated:

- Z1, Z10 (outside the domain),
- Z2, Z6, Z12, Z13 (intersections),
- Z5 (contains a hole),
- Z3 (is contained in a hole),

while the following will be validated:

- Z4, Z9, Z11, Z14, Z15

Remark: Z7 (or Z8) if Z8 (or Z7) is not chosen by the user in MESH mode. At this stage of the operations the two zones will be considered to be valid.

It will be noted that, in DEM mode, the adjustable zones are displayed (in a semi-transparent colour) but they cannot be modified.

3.4.2. *Other functions*

The DEM mode is not changed for the other actions and the functions available in the previous version of MATISSE (V1P1) are still possible for all data. As the zones are simply "adjustable" at this stage, the possibility of defining criteria for peaks and lines that may be inside or outside these zones is kept.

The user must ensure that the discretisation step on the boundaries of the regular zones (obtained when choosing the adjustment method and its parameters) is consistent with the step size map.

Remark: points defined as being prescribed in this mode and which will be included in the regular zones are transferred to the final grid. However, in this case, the regular grid will be modified locally.

3.5. MESH mode

3.5.1. *Meshing procedure*

It is in this mode that the user chooses the meshing methods and zones to be adjusted. Not all adjustable zones defined in ZONE mode will need to be adjusted. This is an interactive choice left to the user in the same way as he chooses a step size map for adaptation from among all those he has defined in DEM mode.

Regular zones will always be meshed successively before the adaptation part. The final grid is obtained after assembling the grids of regular zones and the adapted grid. The adapted grid is calculated at the end of the process using what is left in addition to the domain of the zones actually adjusted. It will be noted that even in the particular case where the domain is entirely covered by a regular zone, the user must choose the Calculate grid option before obtaining the final assembled grid.

3.5.2. *Management of regular zones*

One or more zones are selected by clicking with the mouse or choosing the name. Problems of selecting adjustable zones that are included in one another can thus be overcome by:

- selecting the name,
- using the foreground/background display function.

By selecting a zone, two main types of operation can be performed:

- Zone meshing. A zone can be meshed if it is valid and if it does not contain a zone that has already been adjusted.

Zone 1 regular grid

Zone 2 invalidated by the meshing of zone 1
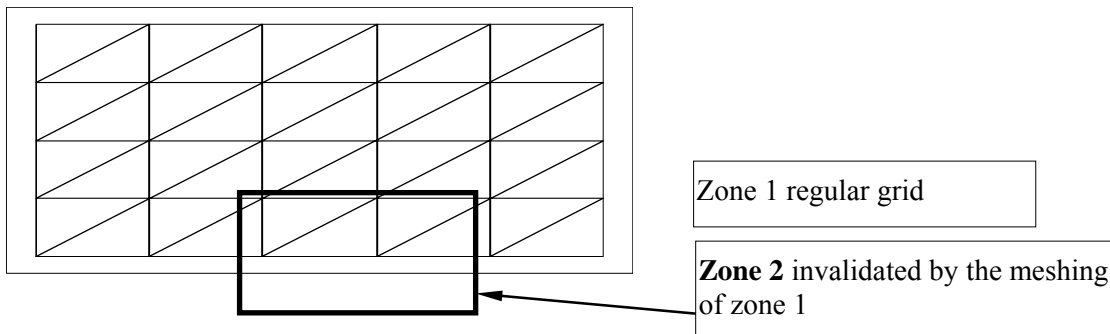
- <u>Modifying and editing a zone</u>. If the adjustable zone selected is already meshed, the grid can be either deleted or re-meshed. In any event, the user can modify the adjustment parameters associated with this zone (including the corner points – "Mesh Zone" window).

3.5.3. *Regular grid options*

Several regular grid options are offered to the user in Meshing/Mesh Zone mode. At this stage, certain checks are performed via the interface in order to make a coherent request to the regular grid calculation module.

Grids are chosen on each side (entrance, exit and edges).

A zone is thus defined by an association of method and parameters for the (entrance/exit) pair and another for the two edges.

To date, the types of regular grid are as follows:

- <u>Mathematical discretisations</u> (linear distributions, with arithmetic or geometric progressions) They are particularly suited for entrances/exits and for fairly simple edges. These mathematical discretisations may be accompanied by parameters (bias, number of meshes) and type of justification (centred, inverted centred, left, right).
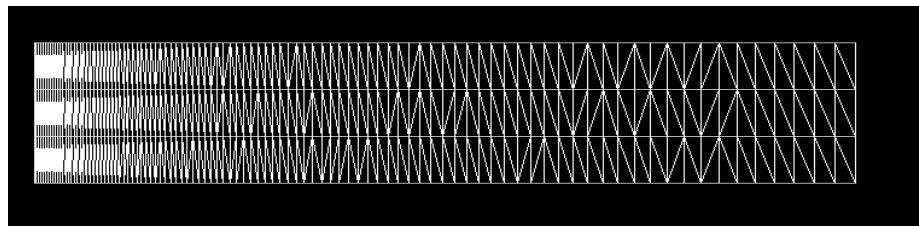
- <u>"Free" discretisation</u>, i.e. by trying to place discretisation points as well as possible depending on the geometry. It is not the number of points that is chosen but the progression step for placing the meshes. This must be reserved for the edges, which must have a direction of propagation and shape similitude (case of river banks).
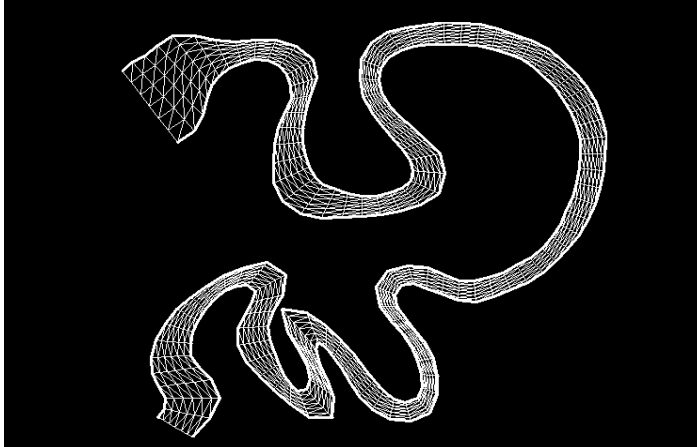
- Discretisation into a number of meshes, by prescribing hard points and constraint ridges. Points to be added to prescribed peaks are placed on non-constrained ridges. This is recommended for entrances/exits.

The choices are not completely free and are quickly constrained during construction of the grid. Below is a description of the possibilities of the various methods depending on the objects, possible parameters, constraints on these parameters, etc.

The options chosen by the user are stored and associated with the zones and then proposed again by default if the user asks to re-mesh the zone later.

3.5.3.1. Parameters for each method

The parameters linked with the choice of methods are as follows, for each entrance/exit and edge1/edge2 pair:

Method/parameters	No. meshes	Step	Bias	Justification
Regular distribution	x			
Arithmetic progression	x			x
Geometric progression	x		x	x
Number of meshes	x			
Free method		x		

- The step is the progression step for the so-called free method, in which the user tries to place a transverse every metre "step". In this case, the number of meshes obtained is not known exactly beforehand. It depends to a great extent on the geometry.
- The bias is the ratio between the largest and smallest meshes for the geometric progression method (the number of meshes is insufficient in this case).
- The justification (centred, inverted centred, left and right) indicates the point of refinement of the geometric and arithmetic progression methods. Centred and inverted centred geometries are symmetrical with respect to the centre of the line, progressing in an increasing or decreasing manner towards the edges.

Lastly, there is another parameter, this time linked to the zone. It is therefore unique and independent of the edge meshing methods. It is the type of breakdown of the quadrilaterals created by the adjustment module, which leads to the creation of triangular meshes:

- Alternating 1
- Alternating 2
- Non-Alternating 1

- Non-Alternating 2
- Smallest length
- Greatest length
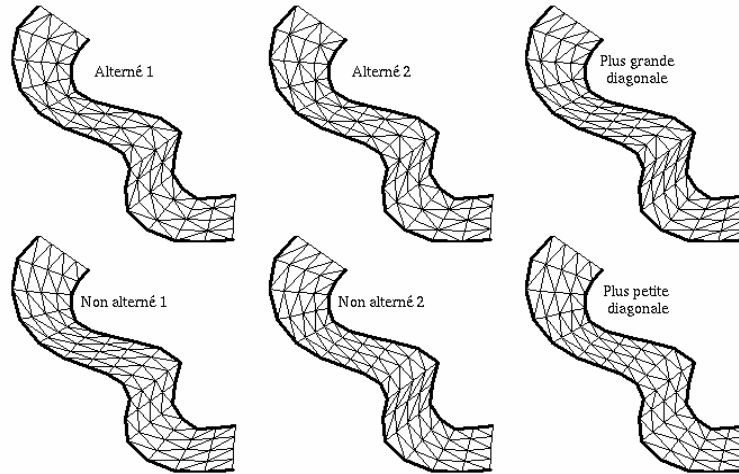
3.5.3.2. *Method and parameter acceptance conditions*

There are several types of condition:

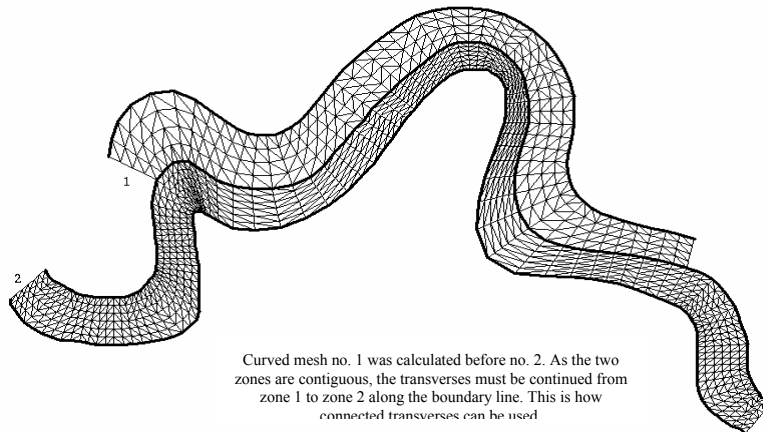The <u>conditions concerning the types of line</u> to be discretised are given in the table below:

Method/parameters	Entrance/exit	Edges
Regular distribution	x	x
Arithmetic progression	x	x
Geometric progression	x	x
Number of meshes	x	x
Free method		x

In brief, it is not possible to mesh entrances/exits freely as geometric similitude is required, and this does not necessarily exist.

Method/parameters	Free	Prescribed points	Prescribed ridges
Regular distribution	x		
Arithmetic progression	x		
Geometric progression	x		
Number of meshes	x	x	x
Free method	x	x	x

It is clear that purely geometric meshing (regular distribution, arithmetic or geometric progressions) is not possible if points or edges are prescribed (adjacent zones) unless such peaks are corner points.

The two non-geometric methods can accept prescribed points or ridges, which is particularly useful in the case of adjacent zones.

Curved mesh no. 1 was calculated before no. 2. As the two zones are contiguous, the transverses must be continued from zone 1 to zone 2 along the boundary line. This is how connected transverses can be used

The <u>conditions concerning the parameters</u> are as follows:

Method/parameters	No. meshes	Step	Bias
Regular distribution	> 0		
Arithmetic progression	> 0		
Geometric progression	> 0		> 0
Number of meshes	≥ f (no. constrained ridges + no. hard points) > 0		
Free method	0 < step < min. length (edge1,edge2)		

- In the case of the so-called free method, the progression step must be less than the length of the edge (in fact than the length of the shorter edge).

These constraints are managed via the interface, which allows or prohibits the various options and prescribes certain conditions on the adjustment parameters.

3.5.4. *Dependence between regular zones/re-discretisation*

Because of the construction method, regular zones may be adjacent, i.e. they may have shared ridges or contour lines.

The meshing of an adjustable zone may thus re-discretise its contour, and the modification will extend to neighbouring zones that share the modified contour. This propagation effect will also affect contours that may share information of geometric line type (as in the case of regular zones adjoining the exterior boundary, for example).

The description of
zone 2 is
modified
by the grid
of zone 1

Zone 1

Zone 2
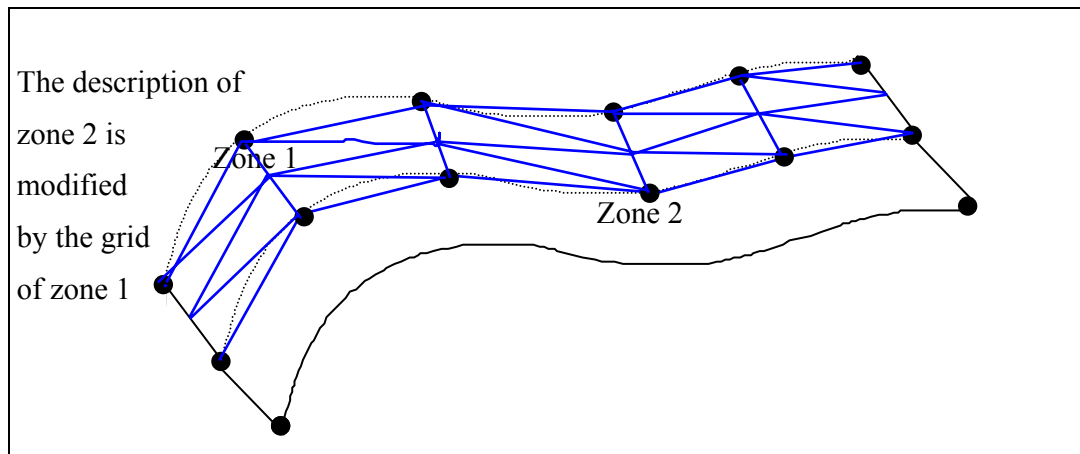
As the topology is modified, certain zones may no longer be compliant (their description will no longer correspond to the validation criteria at the entrance to the DEM): self-intersection, intersection with another side or with a contour, inclusion rules not obeyed. Thus, if the user is not careful, it is possible that regular grid generation for one zone may render another zone or adjacent entity inconsistent. A message is sent to the user in the event of a serious problem. He must then modify the adjustment parameters in order to solve the problem (section 3.5.3.1).

3.5.5. *Case of prescribed points and constraint lines*

If the user selects constraint lines crossing part or all of the regular zones, the mesher locally modifies the grid that has already been constructed in the regular zones, in order to add the peaks defined by the intersection of the re-discretised constraint lines and the ridges of the regular grids. So the grids will no longer be adjusted in certain places. The user may avoid this situation by cutting the constraint line so that it does not pass over a regular zone.

Similarly, if prescribed points have been defined in DEM mode (chosen by the user) and are included in a regular zone, then the regular grid will be locally modified during assembly in order to integrate the said point.

3.5.6. *Interactive modification of the grid*

Once the final grid has been completed, access to the grid manipulation and display functions is proposed, as in MATISSE Version 1.

It will be recalled that, when a new grid is calculated (with a different step size map, for example), manual modifications of points in the regular zones or adapted part will be forgotten.

3.5.7. *Altimetric interpolations*

Interpolations are made at the time of assembling the final grid. The user has the possibility of modifying the bathymetry of certain points, for example those belonging to zone support lines, which does not throw into question the geometric validity of the regular grid associated with this zone.

This choice means that it is possible to ensure consistency between the altitudes of all points in the final grid. The bathymetry is therefore inaccessible until the grid has been assembled.

Regular grid points inside zones are interpolated as in the previous version (MATISSE Version 1). All points inside the adapted grid (2D type interpolation after location in the DEM grid) are interpolated normally.

In contrast, 1D type linear interpolation is carried out for the peaks of regular grid edges, depending on the position of these points in relation to the points of the original lines. In the graph below, this means finding where the points of the regular grid (red dots) fit between the DEM data points (circles).
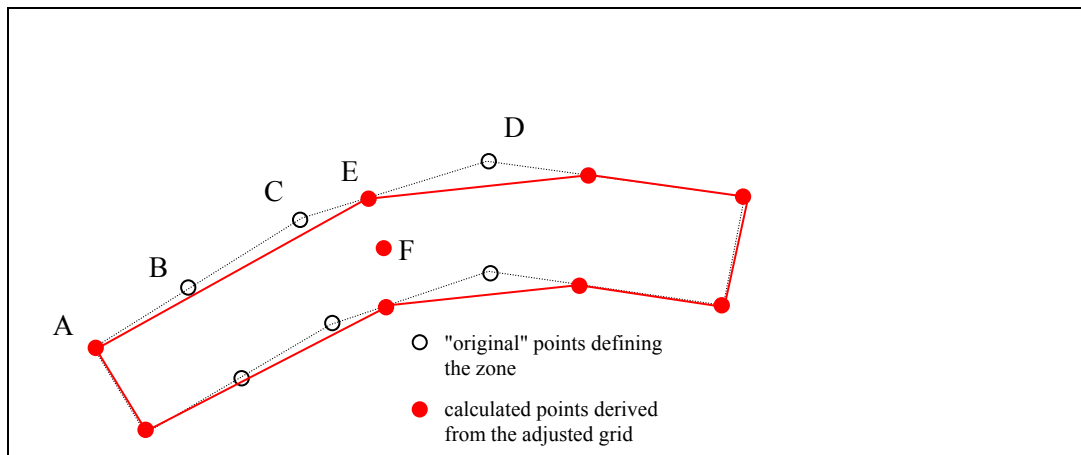
- point F is inside the zone and will therefore be interpolated from the points of the DEM mesh that contain it,
- point E is between points C and D and will therefore be interpolated linearly between these points.

3.5.8. Remeshing

After deletion (Delete mesh of zone option), the user may remesh regular zones that have already been meshed (modifying the adjustment parameters) and, if he wishes, remesh only the adapted part of the grid with another criterion.

If the user wishes to modify the grid of a regular zone (Zone edition/selection option), the adapted part will be deleted and the user may select the regular zone to be deleted and remeshed. The adapted part must therefore be reconstructed. In all events, it is up to the user to trigger the adaptation (Compute mesh option), which will create the final assembled grid.

3.6. BOUNDARY CONDITIONS mode

The BOUNDARY CONDITIONS mode is not modified. The grid on which these characteristics are defined is the final assembled grid, constructed from the regular zones and the adapted part.

4. Conclusion

This document is the documentation for version 2.0 of Matisse. Its aim is to list the new functions integrated into version 1.1 enabling users to generate regular grids.

REFERENCES

[1] P. PRYGODA

"MAILLEUR MATISSE – User manual version 1.0"

EDF report HE-45/22.

Avril 1997