HAL
archives-ouvertes.fr

Grid Generation for Fusion Applications

Hervé Guillard, Jalal Lakhlili, Adrien Loseille, Alexis Loyer, Ahmed Ratnani

► To cite this version:

Hervé Guillard, Jalal Lakhlili, Adrien Loseille, Alexis Loyer, Ahmed Ratnani. Grid Generation for Fusion Applications. EFTC 2017 - 17th European Fusion Theory Conference, Oct 2017, Athens, Greece. pp.1. hal-01644309

HAL Id: hal-01644309
https://hal.inria.fr/hal-01644309

Submitted on 22 Nov 2017

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Grid Generation for Fusion Applications

H. Guillard[1], J. Lakhlili[2], A. Loseille[3], A. Loyer[1], A.Ratnani[2]

[1] Inria Sophia Antipolis Méditerranée and Côte d'Azur University, LJAD, CNRS , France
[2] Max-Planck-Institut für Plasmaphysik, Garching, Germany
[3] Inria Saclay Île-de-France, France

Magnetized plasma

- An extremely anisotropic medium :
  - Transport coefficients in the parallel (to the magnetic field) and perpendicular directions differ by several order of magnitude : $k_{//}/k_{\perp} \sim 10^9$
  - Dynamics is completely different in the parallel and perpendicular direction : incompressible in the perp direction, compressible (and supersonic in the SOL) in the parallel direction : plasma slides along the magnetic field lines
- Plasma - wall interaction (Bohm's boundary condition) : Plasma enter into the wall at supersonic velocity :

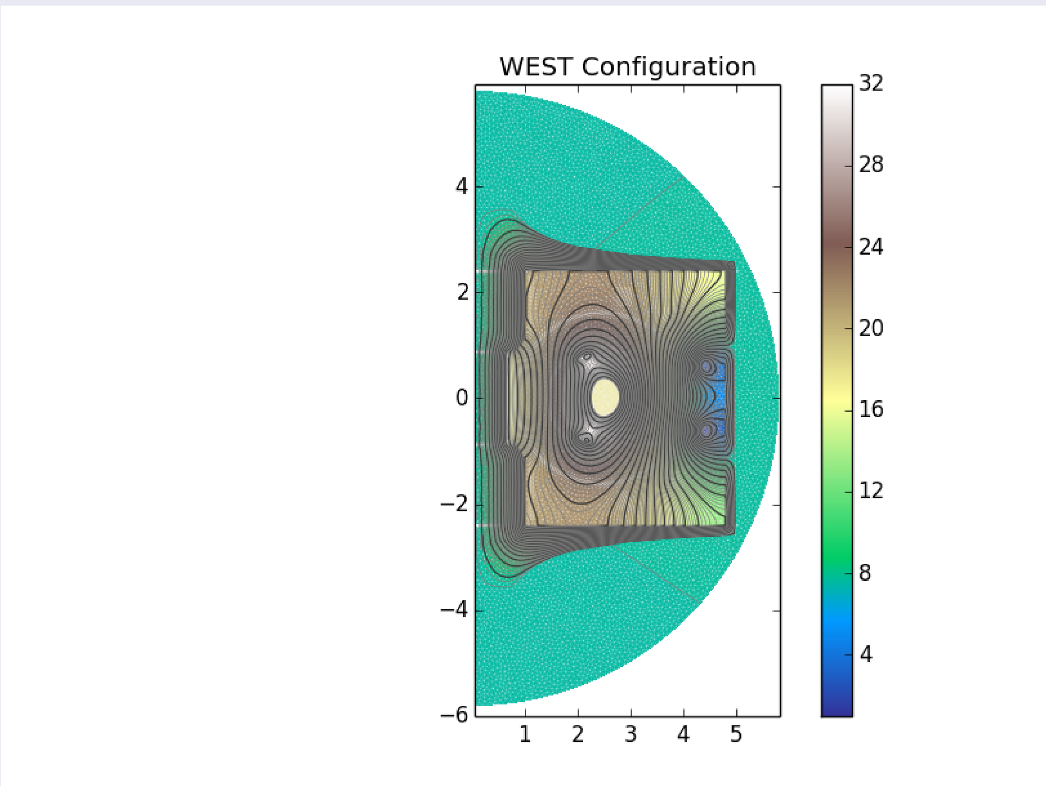
In magnetized plasma, plasma flows along the magnetic field lines

Meshes adapted to magnetic flux surfaces

Grad-Shafranov solvers

For realistic geometries, magnetic field has to be computed by numerical Grad-Shafranov solvers

$$-\nabla\left(\frac{1}{\mu r}\nabla\psi\right)=\begin{cases} J(x,\psi) & \text{plasma}\\ J(\text{voltage},\partial_t\psi) & \text{coils}\\ 0 & \text{elsewhere}\end{cases}$$



Block-structured grid

1. Block-structured meshes :
   - Identify the sub-domains (blocks–patches) Ω_n
   - Construct the mappings between logical grid $[0,1]x[0,1]$ and physical Ω_n
2. How many blocks and definition of the patches ?
   This is a **segmentation problem :**
   Given a domain Ω : Find a number n and n patches Ω_n such that :
   $$\Omega = \cup\Omega_n \text{ with } \overset{\circ}{\Omega}_n \cap \overset{\circ}{\Omega}_m = \emptyset$$
   and there exists a one to one mapping between Ω_n and the the unit square :
   $$\exists\phi_n : [0,1]x[0,1] \leftrightarrow \Omega_n$$
3. for flux surface aligned grid, the segmentation problem can be solved by **Morse theory**

Segmentation Problem and Morse Function

f is a Morse function if all its critical points are regular.

Critical points

Let C^r be the space of $r \geq 2$ differentiable scalar field defined on Ω. $\mathbf{p} \in \Omega$ is a critical point of f if $\nabla f(\mathbf{p}) = 0$.

Regular Critical points

A critical point is regular if the Hessian of f at $\mathbf{p}$ is invertible.

In 2-D

the only possible critical points of a Morse function are :

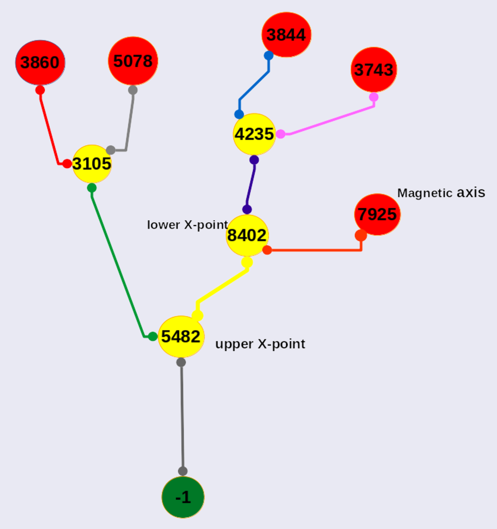
Maxima index = 2 Minima index = 0
Saddles index = 1

Topology of a Morse function : The topological set of the iso-contours of f consists of connected components that are either

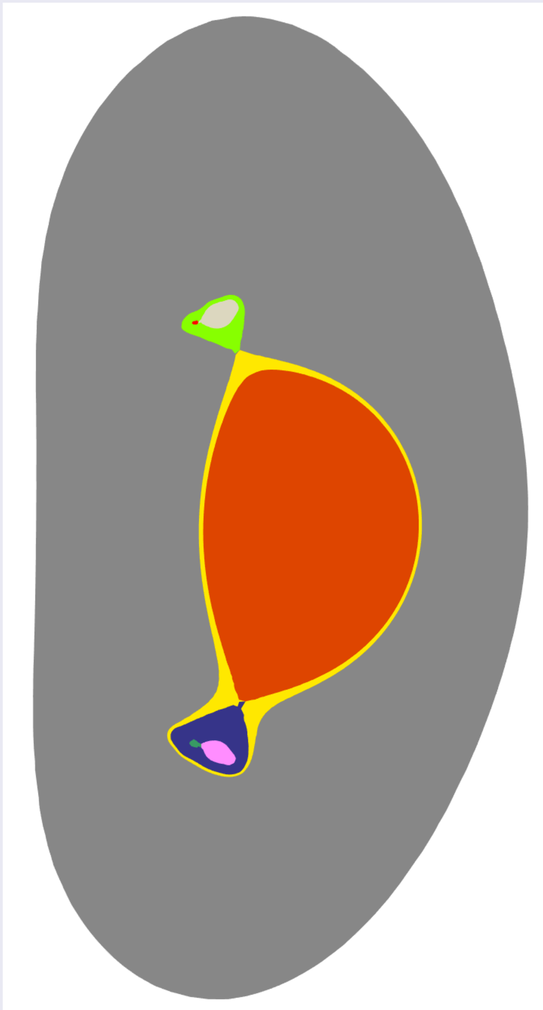
- Circle cells which are homeomorphic to open disks
- Circle bands which are homeomorphic to open annulus

The Reeb graph

- Compute the connected components by computing the Reeb Graph



- Obtain the associated domain segmentation

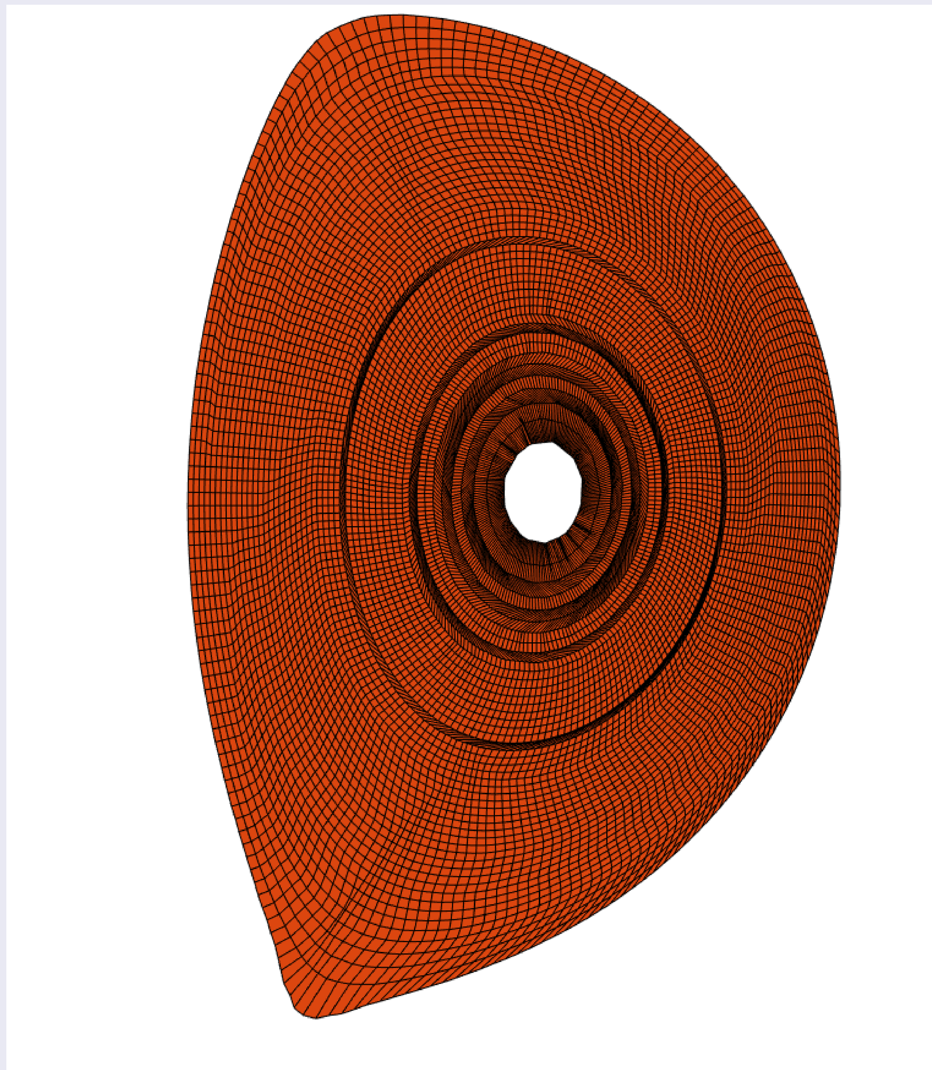


each subdomain correspond to an edge of the Reeb graph and in each subdomain, the function is monotone

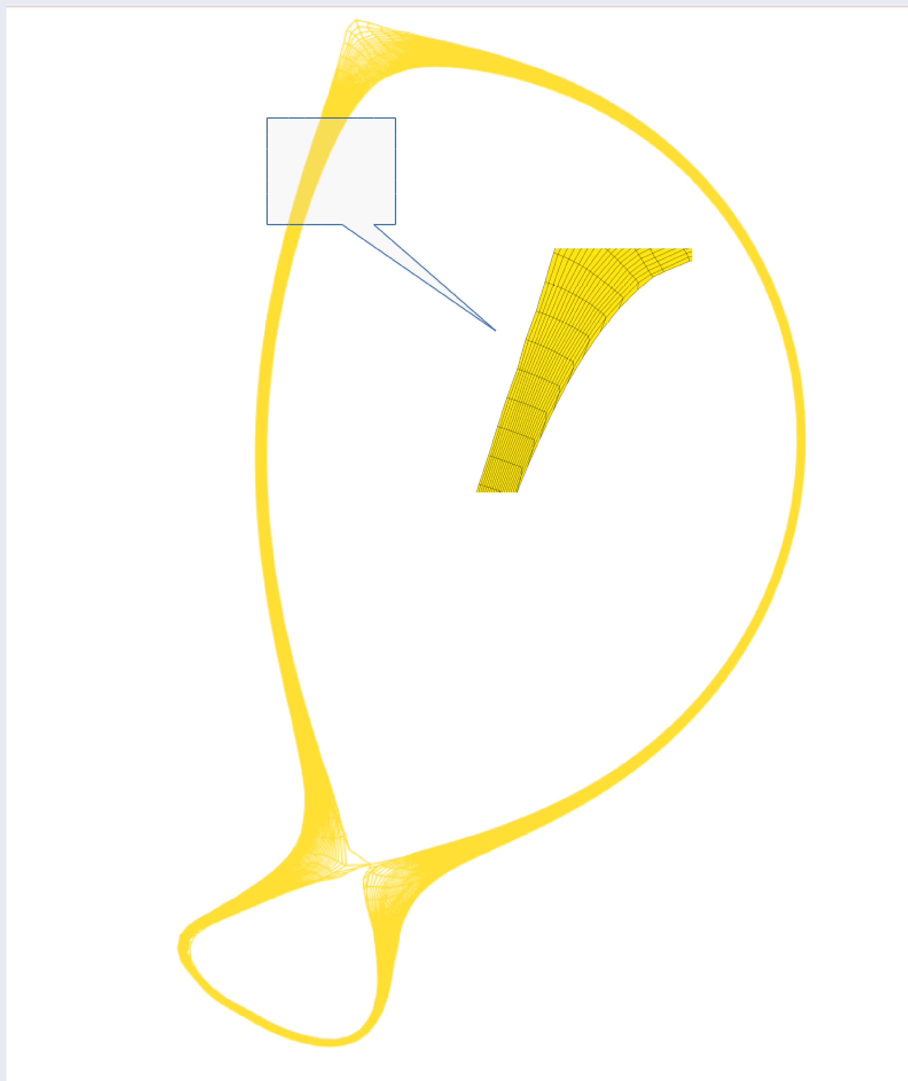
Construction of the mapping of Ω_n

Orthogonal mesh constructed by intersecting
–The isolines
–Streamline integration of $\frac{dx}{ds} = \nabla\psi$

- Leaf of the Reeb Graph : homeomorphic to a disk
  Example : Reeb Graph edge : [7925-8402]



- Internal edge of the Reeb graph : homeomorphic to annulus
  Example : Reeb Graph edge : [7925-8402]



Future works

- More accurate and smooth GS solvers
- Add additional mapping techniques : Elliptic solvers + equidistribution
- Topological simplification of the Reeb-Graph
- Construction of $\mathcal{C}^1$ mappings
- Take into account the vacuum chamber boundary