PROMISE – Prostate Meshes for Isogeometric Analysis

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Introduction

This program aims at generating meshes for isogeometric analysis of prostate cancer growth. The inputs of the program are a surface model of the prostate including the urethra (*.ply*) or its corresponding volumetric NURBS model (nurbs file), together with a series of properties for its execution. These properties are intended to refine the mesh globally and perform mesh partition for parallel computations.

If you run the program with a *.ply* file as input, it will generate a *.csv* file with the control points of the volumetric NURBS model and then it will make the nurbs file.

Then there are two ways of execution to refine the mesh, PetIGA and General. The first option provides a mesh that can be directly used in the context of PetIGA, while the second provides a general file with the key information of the volumetric nurbs. The program will run one, none or both depending on the selection of the user.

If PetIGA is selected, a *.dat* file for the final mesh will be generated leveraging the *igakit* library together with a *.vtk* associated with it for visualization.

If General is selected, the program will generate a G_prostate_X folder including the final mesh and the *.vtu* files of the mesh for visualization.

If you provide a nurbs file directly, the program will jump directly to PetIGA and General processes.

Installation

Uncompress file and run the installer (*sudo sh install.sh*).

If it works correctly, you don't need to do anything else. Should an error occur, then you have to install manually the dependences.

NOTE: If you run it without administrator permission it may fail.

Dependences

NOTE: This will only have to be done if the automatic installation fails.

- Install **SuiteParse**. Uncompress and use *make* to install. Copy content of <SuiteSparse folder>/lib to /usr/lib/ and the content of <SuiteSparse folder>/include to /usr/include/

NOTE: It may be necessary to install Openblas and Lapack (*apt-get install libopenblas-dev liblapack-dev*)

- Install **cmake.** (a*pt-get install cmake)*

- InstallPython 2.7.x (*apt-get install python-dev)*

Dependences: *sudo apt-get install python-gi python-numpy*

- Install **igakit**. Go to igakit folder and execute *python setup.py install*

- Install fortran and mpi *apt-get install libopenmpi-dev gfortran* and then execute *mpif90 -O3 *f* on directory *automesh/postproc1/interfaz_postproc/*

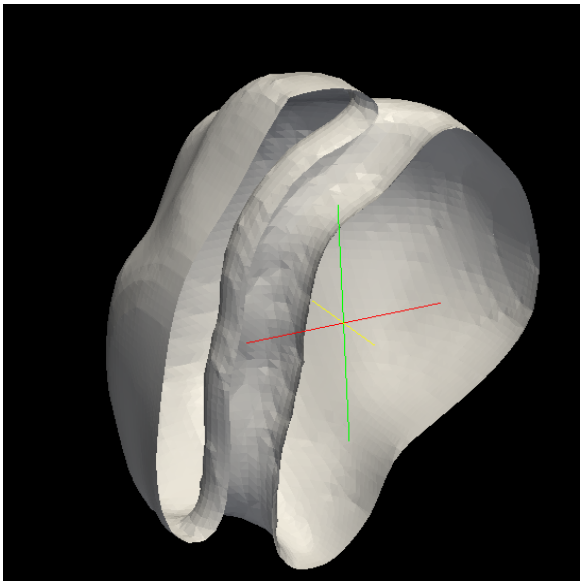
Execution

- Remember to execute *install.sh* file first. Should it fail, install manually the dependences. This process needs to be done only once.

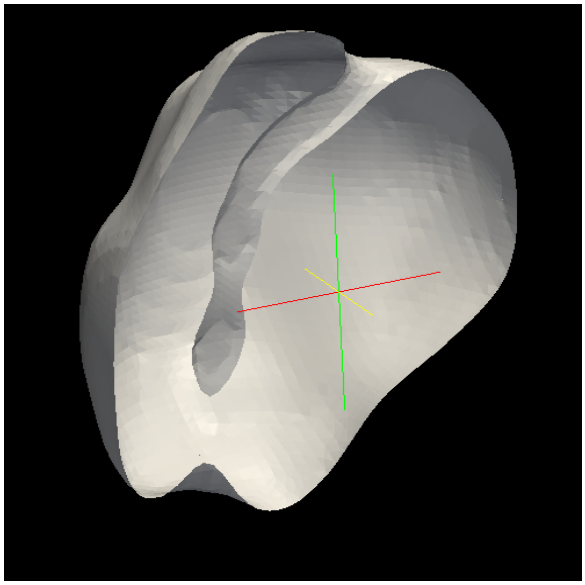
- Execute *init.sh file.* This will launch the application with default values.

Prerequisites

The triangulated mesh *.ply* must be formed by simple triangles. There must not exist holes in the mesh or faces with area value of 0. The mesh must be oriented so that there is an XZ plane containing the urethra, i.e. that the intersection of such plane with the prostate provides two closed non-concentric curves. The same applies for the XY plane, but in this case we expect to find two closed concentric curves.



Valid XZ plane



Invalid XZ plane

The nurbs file name must start with *"nurbs-"* to be found by the program. It should be a plain text file.

Properties prerrequisites:

- The size set in PetIGA and General must be multiples of the initial mesh size.

- The number of elements in the General properties must be multiple of the processor partitions.

- The coordinates Y and Z must be correct to define XZ and XY planes that segment the mesh at an appropriate point.

- The default properties are correct, but they could be changed if needed.

- All the properties are integers, except for the coordinates and the angle, which are real numbers.

Running

The application consists of a small form with some predefined data.

The first text box is the name of simulation, which will create the directory structure. It only accepts letters, numbers, hyphen (-) or underscore (_). It cannot be repeated to not overwrite possible existent folders.

The selector *ply/nurbs* set the application configuration for each input mode.

The second text box ask for *.ply* or nurbs files.

The following text boxes, as well as those within the options are the properties of each simulation. They need to fulfil the abovementioned prerrequisites to complete the execution without problems.

At the end, the application lets you select which output you prefer and set the properties of each one.

When you click on the *execute* button, it will create a folder with the selected name, and it will start to work until the simulation ends or crashes. At the end it will provide information about how the simulation ended.

Results

Once the execution ends, the program will create a folder with the selected name on the provided root of application. This folder contains all the results from initial steps, the PetIGA results, and a G*_prostate_x* folder including all the result files from General processing.

Test

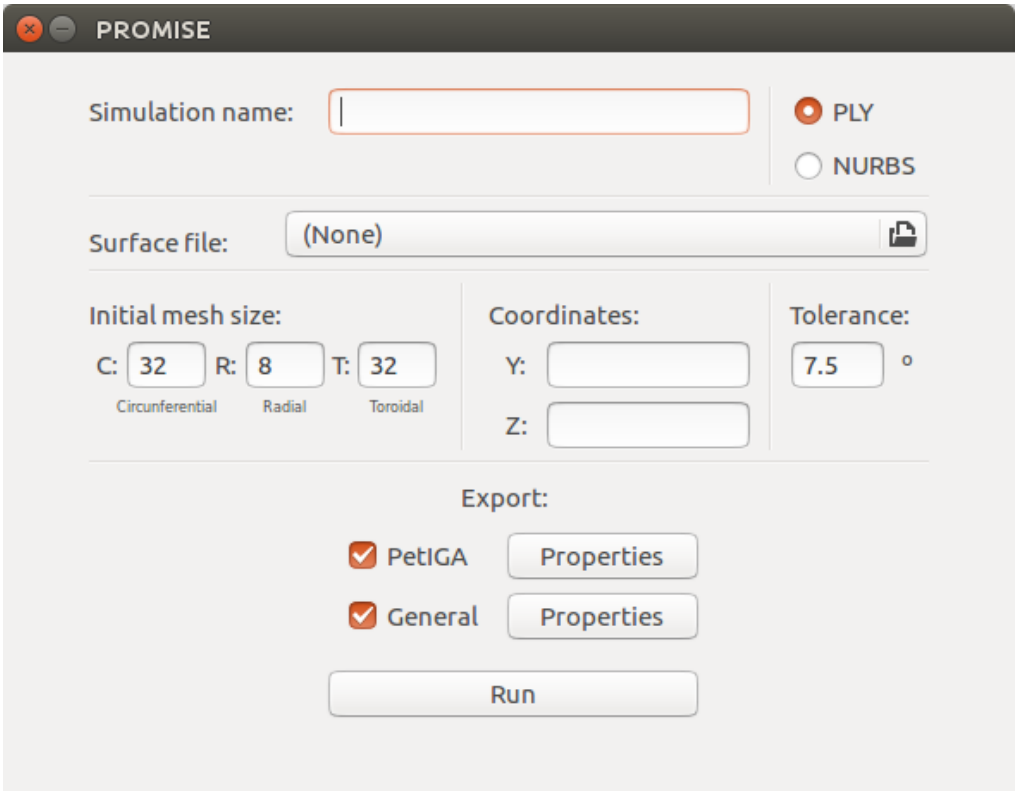
If you want to test the program, it has a folder caller *"Examples"* inside *"HowToInstall"* that contains ply and a nurbs files that you can use for this purpose. There is an auxilliary file called *"properties"* that provides the properties to run the simulation correctly. It may take a little time to complete.

Notes

If you want to launch the application without the *init.sh*, remember you need to set *ulimit -s 527680* to increase the stack and prevent segmentation errors.

This guide was created on Ubuntu 16.04 and the application was tested on it, it may need a bit of changes to work properly in other systems.

Data Dictionary



- **Simulation name:** It defines the name of the container folder to place the project. It accept letters (lowercase and uppercase), numbers, hyphen (-) or underscore (_).

- **Ply/NURBS selector:** It changes the aspect and functionality of application depending on whether it runs with a ply or a nurbs file

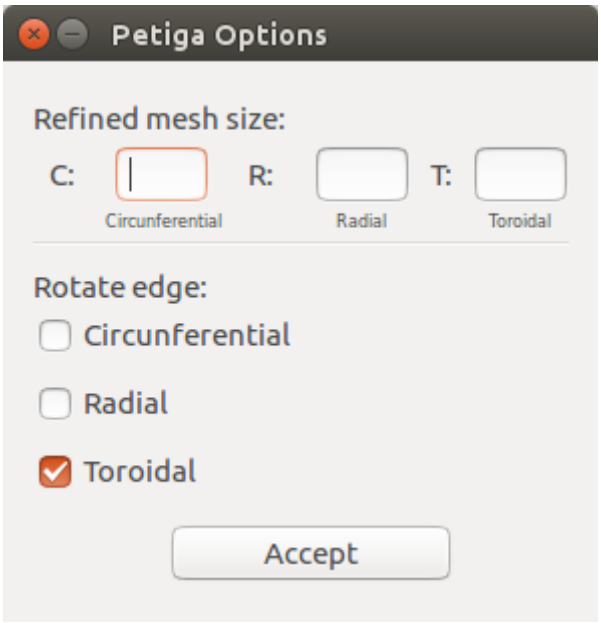
- **Surface file/NURBS file:** File inserted to run the simulation. It accepts "*.ply" files (if ply is selected) or "nurbs*" (if Nurbs is selected). In case of Nurbs its name must start with the string "nurbs"

- **Initial mesh size:** It starts with a default values (32x8x32) but it is possible to change them. These values are integers that define the size of the initial mesh created from the *ply or inserted from the nurbs* file.

- **Coordinates:** They define the XZ and XY planes required to cut the *ply as a prerequisite to build the NURBS model. The required values must be real. Some decimals are recommend to obtain better prostate meshes.

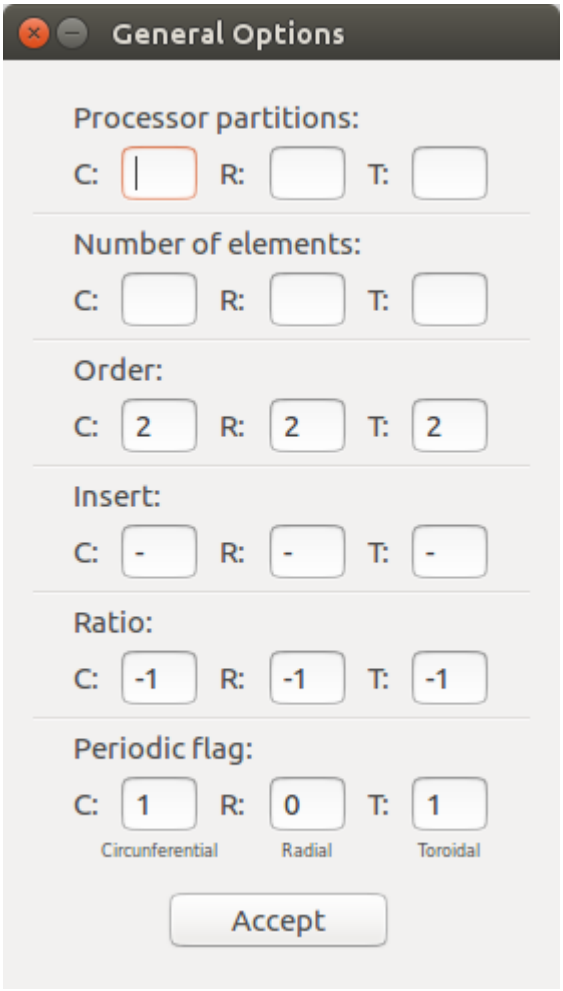
- **Tolerance:** Angle corrector to adjust the section of the mesh. The required value is real.

- **PetIGA/General checks:** Select this to run these modes. If they are left unchecked the program will only provide the nurbs file.



- **Refined mesh size:** It defines the desired size of refined mesh. These values must be a multiple of their analogues in the *initial mesh size* to work property. You need to introduce integer numbers.

- **Rotate edge:** It inverts the direction of an axis. It will only invert the direction selected. By default only toroidal is selected. These options might be used to orient the parametric coordinates of the mesh appropriately for its use in PetIGA.



- **Processor partitions:** Select the processor partitions in each direction. These values are integers.

- **Number of elements:** Select the number of elements in each direction of the refined mesh. It accepts integers. Each value must be a multiple of *processor partitions* in the same direction and a multiple of the analogous value in the initial mesh.

- **Order:** Select polynomial order in each direction. A default value of 2 is set. Order elevation is performed before knot insertion to refine the mesh. This option should not be changed unless necessary.

- **Insert:** Select knot file to insert knots in each direction, if it is none, set “-”. It accepts integer numbers and hyphen “-”. The default value is hyphen “-”. This option should not be changed unless necessary.

- **Ratio:** Select element ratio in each direction to insert new knots. It accepts integer numbers (-1 (No ratio), <-1 (Asymmetric ratio), >0 (Symmetryc ratio)). This option should not be changed unless necessary.

- **Periodic flag:** It determines if the direction is periodic. It accepts integer numbers (0(No periodic BC), 1 (Periodic BC)). It has a set of default values. This option should not be changed unless necessary.