Annex 6
Introduction to the software

Content

A6.1. Introduction to the software

The basic idea of this thesis is to explore the possibilities offered by the FRAEIJS de VEUBEKE (FdV) variational principle in the frame of the NEM.

In order to concentrate on this exploration, we decided to keep things as simple as possible, both on the theoretical aspects and the software development.

Hence, the softwares developed to test our developments are as simple as possible. They are written in Visual Fortran and we did not try to make them user friendly or to optimize their performances in terms of computation time or memory requirement.

The softwares consists of three programs listed in table A6.1.

Table A6.1. Introduction to the main programs	
Main programs	Application fields
INPUT DATA	Reads a "data file" to create the model (domain contour, number of nodes, node density) and creates a "geometry file" defining the Voronoi cells and topology data
FdV_LNLF	Reads the support conditions and the loading conditions Solves problems of 2D linear elastic, elasto-plastic and Linear Elastic Fracture Mechanics
FdV_XNEM	Reads the support conditions and the loading conditions Reads the crack geometry Solves problems of 2D Linear Elastic Fracture Mechanics with extended Natural Neighbours method

A simplified flow chart is given in figure A6.1.

After running the program **INPUT DATA**, the geometrical model, namely the Voronoi cells and the corresponding topology data, is established and all the information on this model is stored in a **geometry** file.

The 2 programs read this **geometry** file and a **boundary conditions** file defining the supports and the loading.

For the program **FdV_XNEM**, another data file **crack geometry** is read to introduce the geometry of the crack.

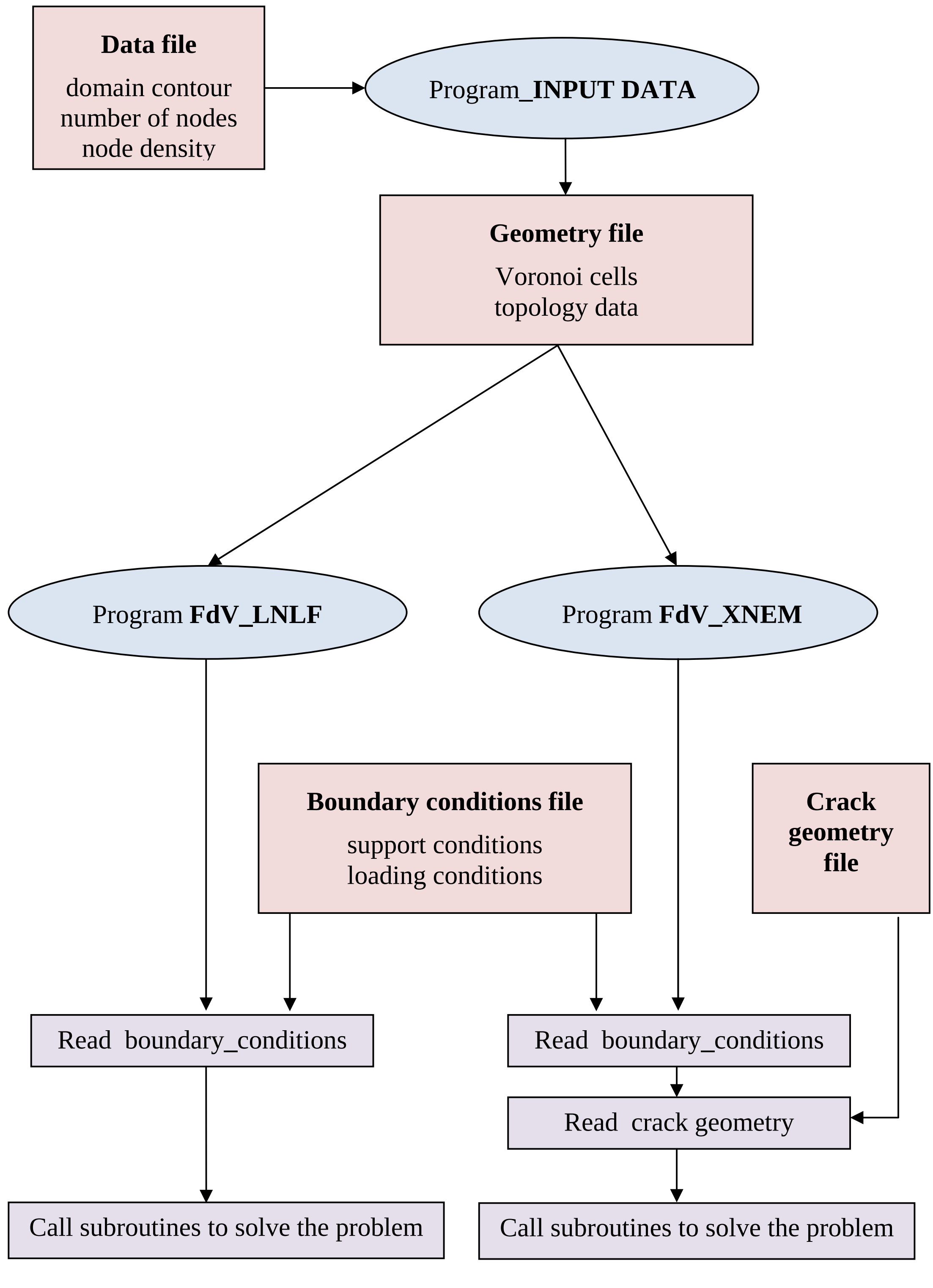

Figure A6.1. Flow chat of the programs

A6.2. Introduction to the subroutines

The flow chats of the software FdV_LNLF and FdV_XNEM are given in figures A6.2 and A6.3 respectively.

The details of the subroutines are collected in tables A6.2 and A6.3.

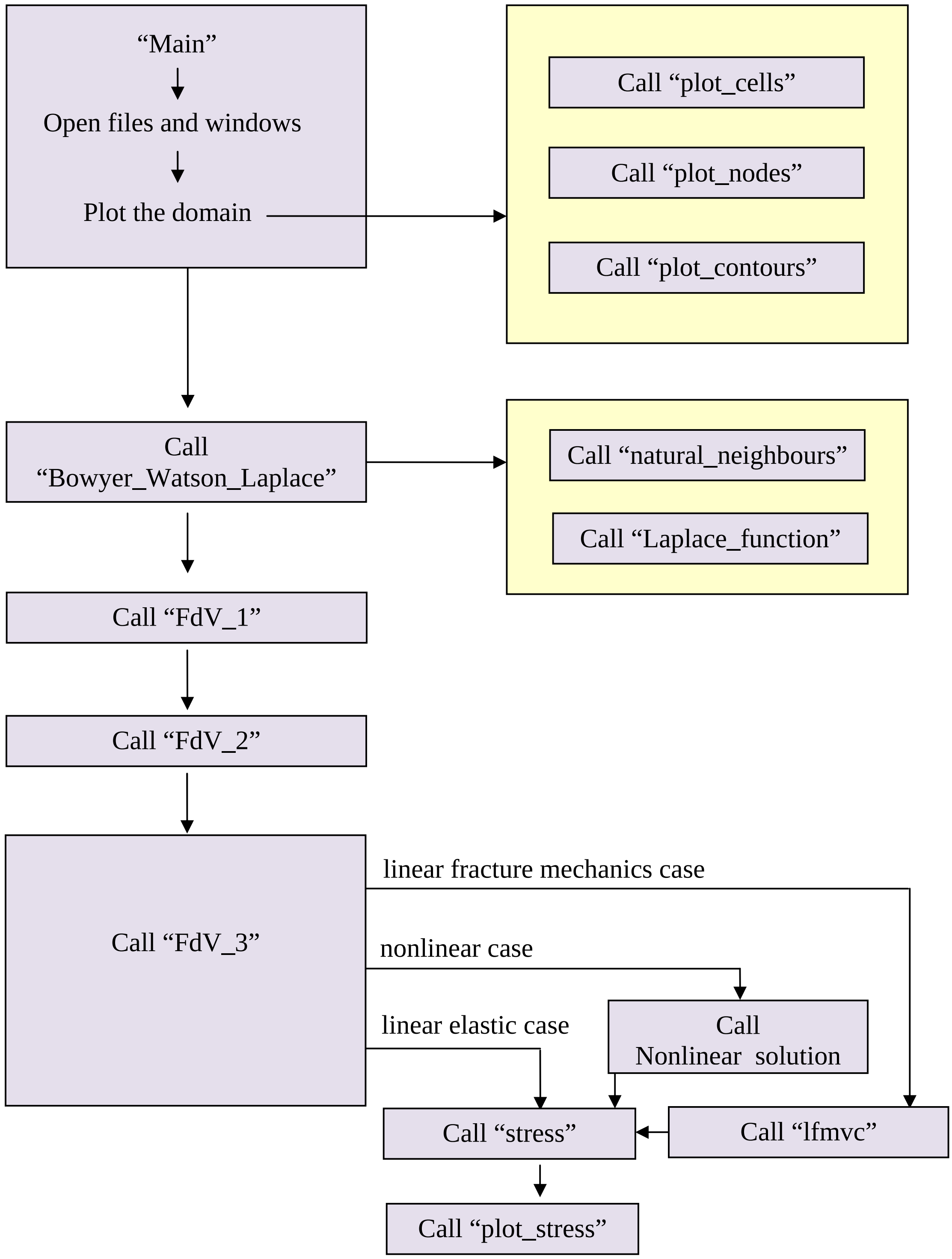

Figure A6.2. Flowchart of the software **FdV_LNLF**

Table A6.2. Introduction to the subroutines of **FdV_LNLF**	
Main	Open all data files, call all the subroutines
Module_main_variables	Define variables, scalars, vectors and matrices
read_main_variables	Read information of the mechanical model stored in the “geometry” file
read_boundary_conditions	Read the “boundary conditions” file
read_main_variables_Nonlinear	Read information of the mechanical model for linear elasto-plastic problems
plot_nodes	Plot the nodes
plot_cells	Plot the Voronoi cells
plot_contours	Plot the contours of the domain
natural_neighbours	Find the natural neighbours of a given point
Bower_watson_Laplace	Compute the value of the Laplace interpolant at a given point
Laplace_function	Compute the value of the Laplace interpolant if the given point is located at a node
FdV_1	Calculation of all the useful integrals on all the edges of cells
FdV_2	Select the edges belonging to each cell and calculate the integrals on the contours of these cells
FdV_3	Compute the stiffness matrix
Gauss	Solution of a linear system of equations by Gauss elimination
stress	Calculate the strains and stresses of each Voronoi cell for linear elastic problems
nonlinear_solution	Solution to elasto-plastic problems: Newton-Raphson iterations are used at the level of different time steps to solve the equations
lfmvc	Solution to the linear fracture mechanics: solve the linear equation system by Gauss elimination
plot_stress	Plot the cells filled with different colours according to the stress level

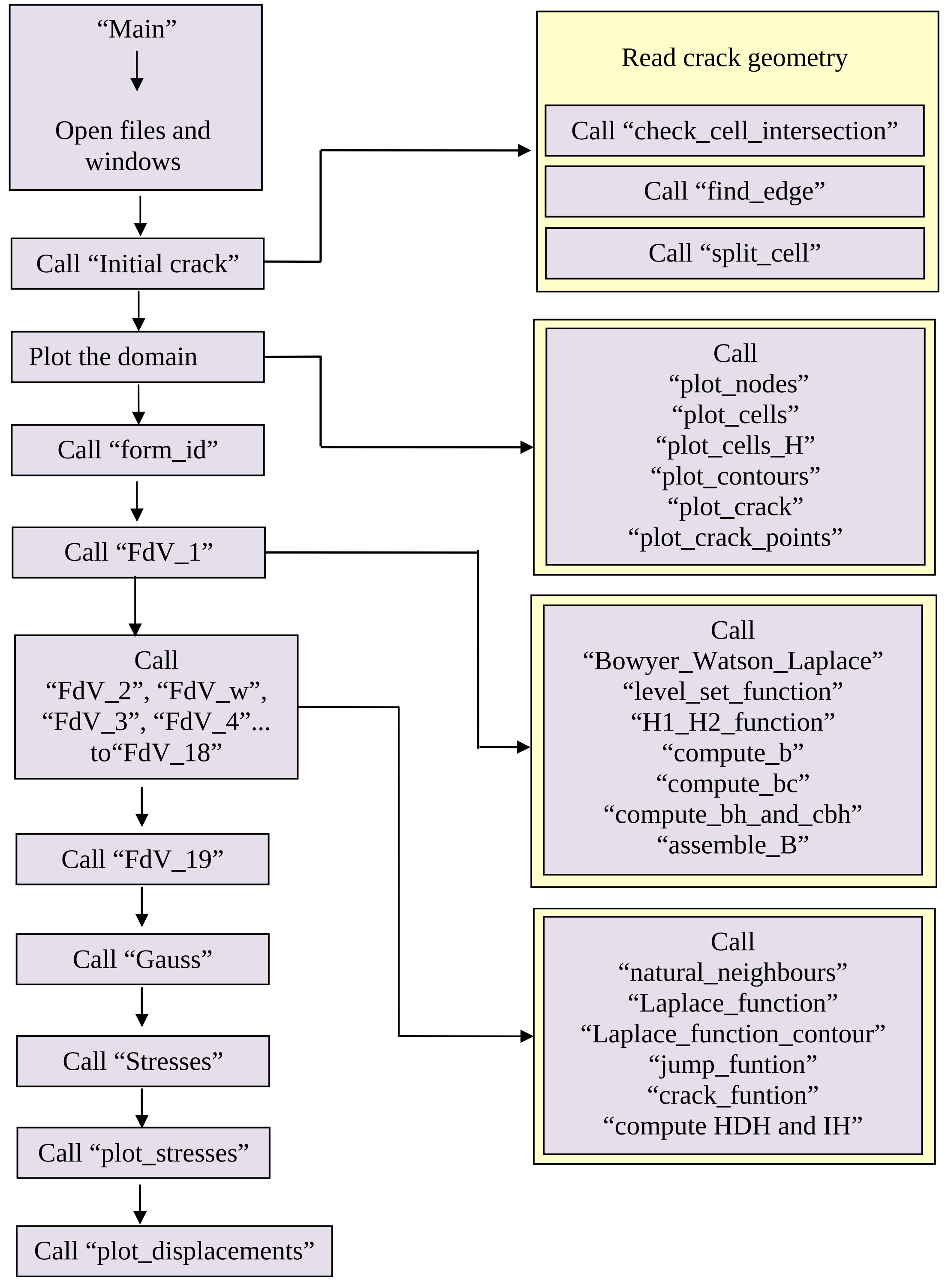

Figure A6.3. Flowchart of the software **FdV_XNEM**

Table A6.3. Introduction to the subroutines of **FdV_XNEM**	
Main	Open all data files, call all the subroutines
Module_main_variables	Define variables, scalars, vectors and matrices
read_main_variables	Read information of the mechanical model stored in the "geometry" file
read_boundary_conditions	Read the "boundary conditions" file
initial_crack	Read the "crack geometry" file
check_cell_intersection	Determine the cells intersected by the crack
split_cell	Split the cells of type H into 2 parts *A* and *B*
form_id	Determine the characteristics of the equation system, form the matrix that indicates the numbering of the equations
plot_nodes	Plot the nodes
plot_cells	Plot the Voronoi cells
plot_cells_H	Plot the cells of type H
plot_contours	Plot the contours of the domain
plot_crack	Plot the crack
plot_crack_points	Plot the crack points
natural_neighbours	Find the natural neighbours of a given point
Bower_watson_Laplace	Compute the value of the Laplace interpolant at a given point
Laplace_function	Compute the value of the Laplace interpolant if the given point is located at a node
Laplace_function_contour	Compute Laplace functions of the points located on a contour edge
level_set_function	Compute the jump function at a given point
locate_crack_tip	Find the cells in which the crack tips are located
crack_function	Calculate the crack function *C(X)*
FdV_1	Calculation of all the useful integrals on all the edges of cells including the edges of the split cells
FdV_2	Select the edges belonging to each cell and calculate the integrals on the contours of these cells

FdV_3 to FdV_18, FdV_w, H1_H2_functions, compute HDH and IH, compute_B, compute_Bh	Calculation of all the terms of the stiffness matrix
FdV 19	Final solution to the equation system, computes the displacements and the stress intensity factors
Gauss	Solution of a linear system of equations by Gauss elimination
Stresses	Calculate the strains and stresses of each Voronoi cell
Plot_stress	Plot the cells filled with different colours according to the stress level
Plot_displacements	Plot the deformed solid according to the displacement of each node