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Y-GUI: A graphical user interface and pre-processor for the combined finite-discrete element code, Y2D, incorporating material heterogeneity ☆

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ABSTRACT

Numerical modelling of a discontinuous medium has gained much popularity in recent decades. The combined finite-discrete element method (FEM/DEM) is a state-of-the-art numerical modelling technique pioneered in the mid-1990s. Y2D is a robust two-dimensional FEM/DEM research code developed by Munjiza in 2004. The major limitations of this code are (1) the lack of a graphical user interface (GUI) meaning that all pre-processing has to be made directly on an ASCII input file and (2) the inability of dealing with heterogeneous media. This contribution presents the first GUI and pre-processor, known as Y-GUI, developed for Y2D and the implementation of a new algorithm that allows for the use of heterogeneous materials. In the text all major FEM/DEM concepts are described, together with the main features available in the Y-GUI. The use of Y-GUI is presented in detail and some of its functionalities, including the heterogeneity module to be used to randomly assign materials to a mesh, are introduced. At the end of the manuscript, four case studies, including Brazilian tests of a homogeneous and a layered rock sample and a rock avalanche, are presented.

1. Introduction

Engineering materials are generally assumed to be continuous for the analysis/modelling of their behaviour. However, the validity of this idealisation is limited to only sufficiently large volumes compared to the scale of the problem. Therefore, phenomena such as progressive fracturing and fragmentation of rock (e.g. in rock blasting) cannot be easily described using the conventional continua formulation. To address this limitation, new numerical approaches have been developed over the past decades. They include the use of discrete element methods (DEM) (Cundall and Strack, 1979; Cundall, 1971; Goodman et al., 1968; Lemos et al., 1985; Mustoe et al., 1989; Williams and Mustoe, 1993), discontinua deformation analysis (DDA) (Shi and Goodman, 1988) and combined finite-discrete element method (FEM/DEM) (Munjiza et al., 1995). The latter is of particular interest for modelling highly heterogeneous materials such as rocks. The major difference between continuum and discontinuum models is that the first are based on constitutive laws while the discontinuum models are based on interaction (mechanical contact) laws (Munjiza, 1999). Contact (detection and interaction) between individual bodies, deformability and fracture of the bodies are the key processes in discontinuum methods. The particularity of the hybrid finite-discrete element method is to combine the advantages of finite elements to those of discrete elements. Each discrete element is discretized into finite elements, which means that there is a finite element mesh associated with each discrete element. Thus, continuum behaviour is modelled through finite elements while discontinuous behaviour is analysed by discrete elements (Munjiza and John, 2002).

Y2D, developed by Munjiza (2004), is a robust and efficient two-dimensional FEM/DEM research code capable of modelling continuum/discontinuum behaviour. However, the first obstacle one would face in using this code is related to the creation and verification of input files. No graphical user interface is available and the entire input file (also referred to as "Y input file") has to be typed in an ASCII text editor, an example of which is shown in Fig. 1. As this figure shows, setting up a model especially with complex geometry, numerous materials spatially distributed and various initial/boundary conditions assignments, is a time-consuming and error-prone process that could lead to significant time loss and frustration for the user. Also, it takes significant time for a novice user to get familiar with the naming conventions used for different databases and parameters of the program. Moreover, it is very difficult to trace back errors or false input data in such a file.

To overcome these problems, a graphical user interface (Y-GUI) has been developed for Y2D. Y-GUI can be conveniently used to set up models graphically, minimizing the possibility of erroneous input files. It should be noted that the time needed to set up a model using Y-GUI is a fraction of that needed when using a text editor, i.e. when

☆ Code available from server at: http://www.geogroup.utoronto.ca/Y-GUI/
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```
/* Control Database */
/YD/YDC/MCSTEP 1500 /YD/YDC/NCSTEP 10
/YD/YDC/DCGRAY 10.0
/YD/YDC/DCSIZC 2.0 /YD/YDC/DCSIZF 0.5e+08
/YD/YDC/DCSIZS 0.40e+08 /YD/YDC/DCSIZV 100.0
/YD/YDC/DCSTEC 0.25e-4
/YD/YDC/DCTIME 0.0
/YD/YDC/ICOUTF 3
/YD/YDC/ICOUTI 0
/YD/YDC/ICOUTP 2
/* Elements Database */
/YD/YDE/MELEM 4048 /YD/YDE/NELEM 2
/YD/YDE/MELST 2 /YD/YDE/NELST 2
/YD/YDE/MELNO 4 /YD/YDE/NELNO 3
/YD/YDE/D2ELST 21 2 0
/YD/YDE/I1ELCF 2
-1 -1
/YD/YDE/I1ELPR 2
0 0
/YD/YDE/I2ELTO 12 3 2
0 1 2 3 4 5
/* Interaction Database */
/YD/YDI/MICOUP   150000            /YD/YDI/NICOUP 0
/YD/YDI/IIECFF  -2
/YD/YDI/DIEDI 200.0
/YD/YDI/DIEZON 0.01
/YD/YDI/D1IESL 0
/YD/YDI/I1IECN 0
/YD/YDI/I1IECT 0
/* Nodes Database */
/YD/YDN/MNODIM 2 /YD/YDN/NNODIM 2
/YD/YDN/MNOPO 2000 /YD/YDN/NNOPO 6
/YD/YDN/D2NCC 12 2 6
1.25 0.0 0.25 1.0 0.25 -1.0 -1.25 0.0-0.25 -1.0 -0.25 1.0
/YD/YDN/D2NVC  12  2 6
-30 0 -30 0 -30 0 30 0 30 0 30 0
/YD/YDN/I1NOBF 6
1 1 1 1 1 1
/YD/YDN/I1NOPR 6
 1 1 1  1  1  1
/* Properties Database */
/YD/YDP/MPROP 2 /YD/YDP/NPROP 2
/YD/YDP/MFACT 1 /YD/YDP/NFACT 1
/YD/YDP/D3PFAC 231 2 2 1
/YD/YDP/D1PEFS 2
3.15e+08 3.15e+08
/YD/YDP/D1PEFT 2
3.15e+08 3.15e+08
```

Fig. 1. Example of a sample Y2D input file. For more details about databases of this figure refer to Table 1.

directly working on the input file. The same holds for tracing errors in the model and modifying them. Y-GUI not only simplifies the use of Y2D, but also adds new functionalities to it, such as the possibility to randomly assign material properties.

This contribution presents a brief overview of the Y2D data structure, followed by the description of the Y-GUI interface and its main features. The verification and compatibility of the Y-GUI program are also addressed. Finally, four different case studies are produced using Y-GUI and its new heterogeneity function and the modelling results are presented.

2. Y-GUI

Y-GUI, coded in Microsoft Visual C# 2005, is a Graphical User Interface (GUI) for the Y2D code (Munjiza, 2004). It can significantly simplify the process of building and manipulating a Y2D model. At the same time it greatly reduces the possibility of erroneous model setup thanks to the visualisation tools implemented.

The GUI can be used to conveniently input the data required in the Y2D code such as time step size, interaction buffer zone, material properties and boundary conditions, as well as interactively work on the mesh; e.g., assigning material properties to the mesh elements and boundary/initial conditions to the nodes. Simple mesh manipulation tools are also available. These include, moving a node of a mesh or translating selected nodes, dynamically drawing mesh elements and nodes, and merging two separate meshes. A full list of the features will be given in the coming section.

For the ease of use, the interface is divided into several sections mainly using tab-pages for different data input and graphics. In principle, these pages are based on the Y2D data structure that will be addressed in Section 2.2.

2.1. Y-GUI features

Various features have been implemented in Y-GUI V2.0. These would greatly simplify the process of setting up input files in the standard format permitted in the Y2D Code. The main features are listed below:

- Easy data input for control database, interaction database, material properties and boundary conditions (see the next section for more information about these databases).
- Mesh import from Phase[2] (Rocscience, 2004) as well as Y2D mesh format.
- Y2D file import allows importing the whole data of a Y2D input file including all its databases, mesh, property sets and assignments, etc.
- Mesh manipulation tools for moving a mesh node, translating selected nodes of a mesh, drawing a mesh and merging two meshes. Note that the mesh nodes should be inserted in a counter-clockwise fashion.
- Graphical assignment of material properties and boundary/initial conditions to selected elements and selected nodes of a mesh, respectively. Each property set or boundary condition set has a colour associated with it which makes it easy to visually check the assignments.
- Save screenshot; saving the contents shown in the Graphics page as an image in Bitmap, GIF, or JPEG format.
- Zoom and pan tools available through the toolbar buttons and middle-mouse click and drag. These include zooming in, zooming out, zooming to extents and refreshing a view through the toolbar on the right hand side of the canvas, panning to east, west, north and south through the provided buttons, dynamic zooming in/out by scrolling the middle button of the mouse and dynamic panning by pressing and dragging the middle-mouse button.
- Graphically define output history points through the context menu of the Graphics tab-page (activated by right-clicking). The relevant data of the inserted points are shown in a table in the output history tab-page.
- Heterogeneity: material properties can be randomly assigned to each individual finite element using a user defined normal distribution. The percentage of each set of material property is defined in the Heterogeneity tab-page. This tool helps count for the natural inhomogeneity of rock masses.
- Keyboard and mouse shortcuts make the program more user-friendly while speeding up processes (for a list of them refer to the website of Y-GUI).