

# **FEA4DICOM Userguide**

Markus Helmer

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# 1 FEA4DICOM User guide

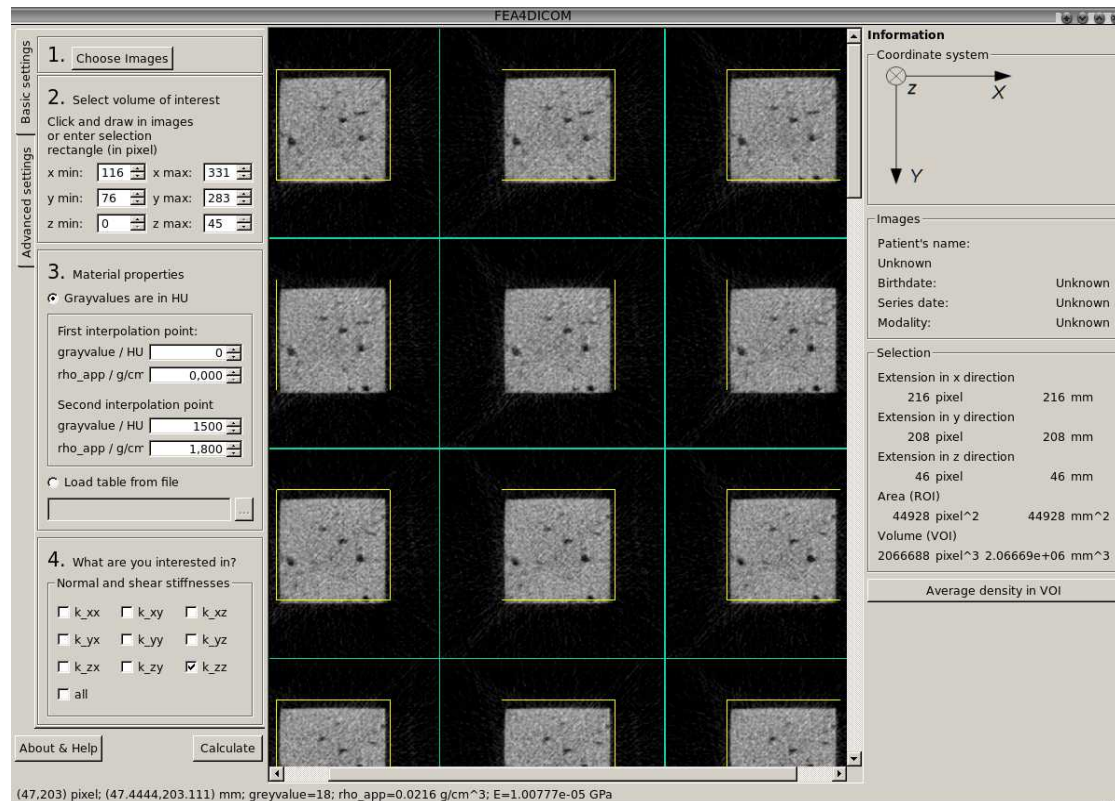


Figure 1.1: Screenshot of graphical user interface.

## 1.1 Building and installation

### 1.1.1 Binary release

The easiest way to use FEA4DICOM is to use the available binary release. Just download it to some folder and you're done—no installation is necessary.

### 1.1.2 Why should I compile FEA4DICOM myself if there is a binary release available?

- You want to make modifications to the source code

- You want to speed up the program. No kidding, if you compile the program yourself FEA4DICOM could run faster. Possibly: a lot faster. Let me explain why. FEA4DICOM depends (indirectly) on a library called BLAS (Basic Linear Algebra Subprograms). To be precise BLAS is more like a “standard” defining subroutines and what they should do. Amazingly, it turned out that most linear algebra problems can be formulated in terms of these, meaning that it is highly beneficial to tune them. And that’s what has been done. There are several implementations the most simple one being the “reference implementation” (refblas)— this is also the slowest. Other implementations are, for example, INTEL’s MKL (math kernel library), AMD’s ACML (AMD Core Math Library) and Goto BLAS. As they are only available under non-free licenses we cannot include them in FEA4DICOM. But should you possess a license it is possible to use it with FEA4DICOM.

### 1.1.3 Dependencies

FEA4DICOM depends on the following libraries. I successfully compiled it with the stated versions. Make sure you have installed and configured them correctly.

- BOOST 1.40
- QT 4.6
- dcmtk 3.5.4
- FLENS 2009-06-12
- UMFPACK 5.4.0

If your building on Windows you’ll also need

- MinGW 4.5.0

Of course you are allowed to use your preferred build environment on Windows—but I didn’t test it, so don’t blame me if it doesn’t work.

### 1.1.4 Compiling

In the `src` directory edit the `config` file to your needs. It should be self-explanatory. In essence

- state if you want to compile for windows (`OSTYPE=win`) or linux (`OSTYPE=linux`). At the moment this only determines if additional system dependent libraries have to be linked to the program. It does (unfortunately) not yet influence the compiler options (cf. next item)
- change the compiler options if necessary — or you wish to do so. It is well possible that you have to specify the compiler name on Windows.
- specify where to find header files and the library file for the dependencies.

On the command line change to the `src` directory, type

```
1 | make all
```

wait... and that's it.

## 1.2 How to use FEA4DICOM

### 1.2.1 Quick start

1. Click on “Choose images” and select the images.
2. To select the VOI click with the mouse on a point of some slice, drag the mouse to another point and release it.
3. Input two correspondences between a gray-value and an apparent density.
4. Choose which stiffnesses you want to be calculated
5. Click on “Calculate”

### 1.2.2 Detailed feature description

**Image selection.** Select the images each of which contains one slice of the image. All images must have the same format: either DICOM or BMP. If you use DICOMs you don't have to worry about the order of the images; it will be calculated from the information contained in the files. However, you have to make sure all selected DICOM images belong to the same series and contain images of the same size. In addition take care that no slice of the series is missing.

If bitmaps are selected a window will pop up and query the distance between pixel and slices. Furthermore the order of the images is determined from the selection (first file name in selection becomes first slice and so on).

**Volume of interest.** Currently only rectangular selections—parallel to the coordinate axes—are supported. Note that the orientation of the coordinate axes is shown on the right. You have two possibilities to choose the VOI:

- Point with the mouse on a point you want to become the top-left corner. It doesn't matter on which of the slices you do that. Then click with the left mouse button on that point, draw the mouse to the point you want to become to bottom right corner of your selection and release the mouse.
- Specify it in the boxes labeled “xmin”, “xmax”, “ymin”, “ymax”, “zmin” and “zmax”.

In the image view area all slices lying in the range `zmin...zmax` will show a yellow selection rectangle indicating the ranges `xmin...xmax` and `ymin...ymax`. On the right some information about the selection is shown. Of particular interest is the “volume” (in  $\text{pixel}^3$  units) information as the time needed for the calculation grows with this number.

**Conversion formula.** State, how the information in the images (the gray-values) should be converted to elastic properties. Again, you have currently two options:

- Use the default settings. In this case the conversion is done in two steps. The first is to convert gray-values to apparent densities. It is assumed that the relation is linear and hence you must specify two pairs of points from which the parameters for the linear function are determined. In the second step the apparent densities are converted to Young’s moduli. The formula is

$$E/\text{GPa} = a(\rho_{\text{app}}/\text{g}/\text{cm}^3)^b + c$$

and by default  $a = 8.92$ ,  $b = 1.83$  and  $c = 0$  (Morgan et al. [2003]) and  $\nu = 0.3$ . To change this click on the button “Elasticity-density relationship”. The raw data for the table is read from the file `eldensrel.csv` in the program folder. It is a text file that can be edited and extended with an editor or a spreadsheet program.

- Load a table from a file. Isotropic material properties are assumed where Poisson’s ration  $\nu = 0.36$ . Young’s modulus is drawn from the file. The file shall have the following format:
  - The first line contains the number of interpolation points, i.e. the number of lines in the file following the first one.
  - each other line contains a gray-value, followed by white-space, followed by the Young’s modulus you wish to attribute to the gray-value at the beginning of the line.
  - The gray-values must be strictly growing.

The gray-values found in the images are then assigned to a Young’s modulus in the following way. A gray-value which is smaller than the one of the first interpolation point is assigned the Young’s modulus of the smallest interpolation point, i.e. the Young’s modulus is assumed to be a constant function of the gray-value in this case. A gray-value greater than that of the last interpolation point is treated analogously. Finally, between interpolation points a linear interpolation is used.

**Information view on the right.** On the right some information is shown. The tags in the “Images box” can only be shown if DICOMs are used as bitmaps don’t contain that information. The tags in the “Selection” box refer to the VOI and are updated if it is changed. In particular the volume information give the number of voxels in the VOI and not the number of “supervoxels” (elements, cf. “Advanced settings tab”).

Furthermore the button “Average density in VOI” calculates (surprise!) the average density in the VOI. This is useful if you have scans of phantoms which you want to use to determine the linear relation between gray-values and apparent density. In that case load the corresponding images, select the phantom part, set the first pair to `grayvalue=0` and `rho_app=0` and the second pair to `grayvalue=1` and `rho_app=1`. Then the average density is equal to the average gray-value.

**Image view area.** If you point with the mouse on an image a toolbox will appear showing the file name of the corresponding image. Furthermore the status bar on the bottom will show position information of the pixel your mouse is momentarily pointing on. Using the mouse wheel when the mouse is pointing on an image will zoom the images, using it on the greenish area besides the images will scroll to other images if you have selected more images than fit on the screen.

**Advanced settings tab.** Apart from the aforementioned elasticity-density relation ship two options are available. The “Supervoxel feature” is used to combine several voxel into one element (or “supervoxel”). The “scaling factors” must be input. They determine the factor by which the pixel number in each space direction is scaled. For example, if your VOI contains  $10 \times 20 \times 30$  voxel and you use the scaling factors 0.1, 0.2 and 0.3 you will get a VOI with  $1 \times 4 \times 9$  voxel. The effective gray-value assigned to an element is currently the average gray-value of all voxel that are completely contained in the element.

The export options allow you to export the mesh including material properties to Ansys or to export the linear system  $K\vec{z} = \vec{F}$  to text files that can be read by, for instance, Matlab.

### 1.2.3 Scripting

FEA4DICOM supports a very simple script format; an example is given in listing 1.

Listing 1: Example of the script format that FEA4DICOM understands

```
# Images
dir=path/to/images/
basename=imagename
4 suffix=.dcm
  firstimgnum=0
  lastimgnum=49
# VOI
  colmin=0
9  colmax=1
  rowmin=2
  rowmax=3
  slicemin=4
  slicemax=5
14 # Material properties
  grayvalue1=0
  rho1=0.0
  grayvalue2=1500
  rho2=1.8
19 a=1.0
  b=2.0
  c=3.0
  nu=0.30
```

```

24 # Experiments
   experiments=kxx,kxy,kzx,kzz,kyy
   # Export. Allowed values: no,ansys,linsys
   export=no
   # Scaling. Allowed values: no,[approx. number of elements]
   scaling=no
29 # Run FEA4DICOM
   run

```

Lines that have a “#” in the first column are interpreted as comments and ignored. All other lines are treated as relevant (in particular no empty lines are allowed not even as last line!). All keywords (i.e. strings before the “=” signs) must be present but the order of lines is irrelevant. In addition, no white-space is allowed at the beginning of lines and before and after the “=” sign. The file names of the images are constructed from the strings assigned to `dir`, `basename` and `suffix` as well as the integers `firstimgnum` and `lastimgnum` such that `filename = [dir][basename][image number][suffix]` and image number takes the values `firstimgnum ≤ [image number] ≤ lastimgnum`. Note that `dir` is a path relative to the current working directory, that `dir` has to end with a path delimiter (“\” or “/” ) and that `suffix` is either “.dcm” for images in the DICOM format or “.bmp” for bitmaps. In case bitmaps are used the additional keywords `colspacing`, `rowspacing`, `slicespacing` must be present. If DICOM images are used these keywords are ignored because this information is contained in and read from the images.

While the definition of the volume of interest should be self-explanatory the conversion formula from gray-values to Young’s moduli is such that in a first step a linear relation between gray-values and apparent densities is assumed and specified by given two points on that straight line, that is by the values of (`grayvalue1,rho1`) and (`grayvalue2,rho2`). Then the Young’s modulus is calculated according to

$$E/\text{GPa} = a(\rho_{\text{app}}/\text{g/cm}^3)^b + c.$$

The stiffnesses to be calculated are specified in a comma separated list and assigned to the keyword `experiments`. Take care that the list does *not* end with a comma and that no white space is used before and after commas!

If `export` is set to `linsys` then the linear system  $K\vec{z} = \vec{F}$  is exported to text files that can, for instance, be read with Matlab. `export=ansys` causes FEA4DICOM to act only as preprocessor and export a mesh including material properties to a `.cdb` file that can be imported into Ansys.

A number assigned to the `scaling` keyword instructs FEA4DICOM to combine several voxel into one element such that the total number of elements equals approximately the specified number.

Finally, the `run` keyword will start the calculation.

To use the script invoke FEA4DICOM with the parameters `-s scriptname`, for example

```
gui -s testscript.f4d
```



### 1.3 Possible future extensions

- Improve that after zooming sometimes the region of interest isn't shown correctly any more
- Polygonal region of interest
- Ability to calculate other stiffnesses, e. g. torsional or bending stiffnesses
- Thresholding
- Export mesh to ANSYS<sup>®</sup> Workbench

## Bibliography

Elise F. Morgan, Harun H. Bayraktar, and Tony M. Keaveny. Trabecular bone modulus–density relationships depend on anatomic site. *Journal of Biomechanics*, 36(7): 897–904, 2003.