Modelling of Fracture Growth in Rocks

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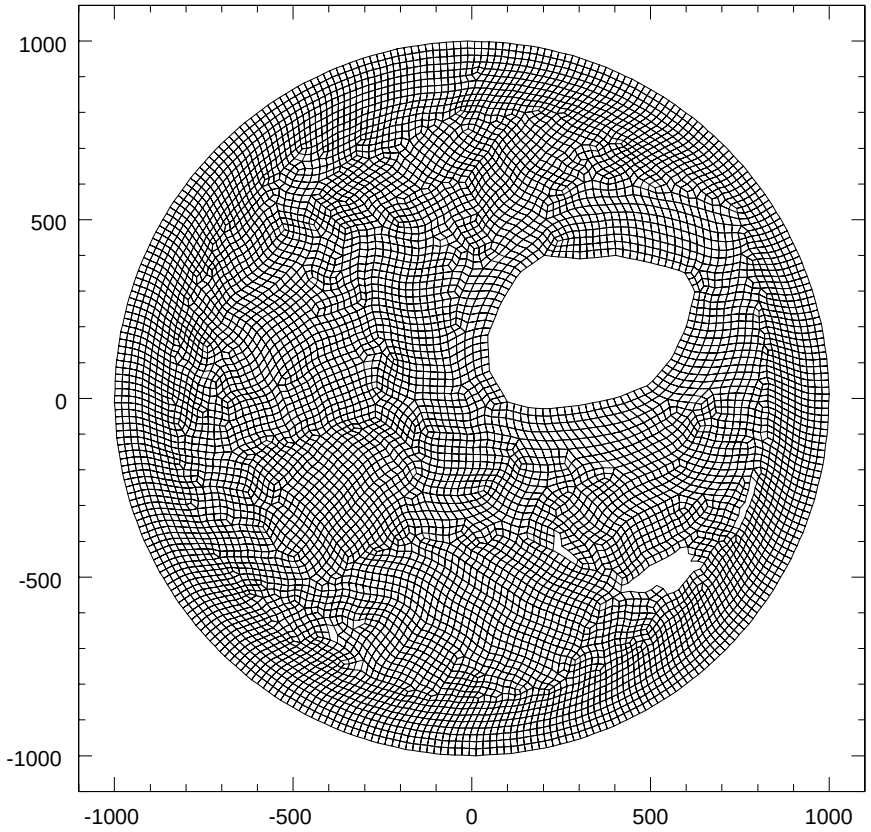
Overview

- Motivation
- Previous work
- Generating cracks
- Calculating stresses
- Future developments

Motivation

- Gain a better understanding of the mechanism of brittle rupture, crack propogation.
  - How cracks relate to each other, join together
  - Which nodes grow, which don't
- Cracks provide pathways for fluid flow, and contaminant transport
  - Water quality
  - Nuclear waste disposal
  - Oil mining in a fracture reservoir

Take a domain, sub-divide into smaller pieces, put grids on them.



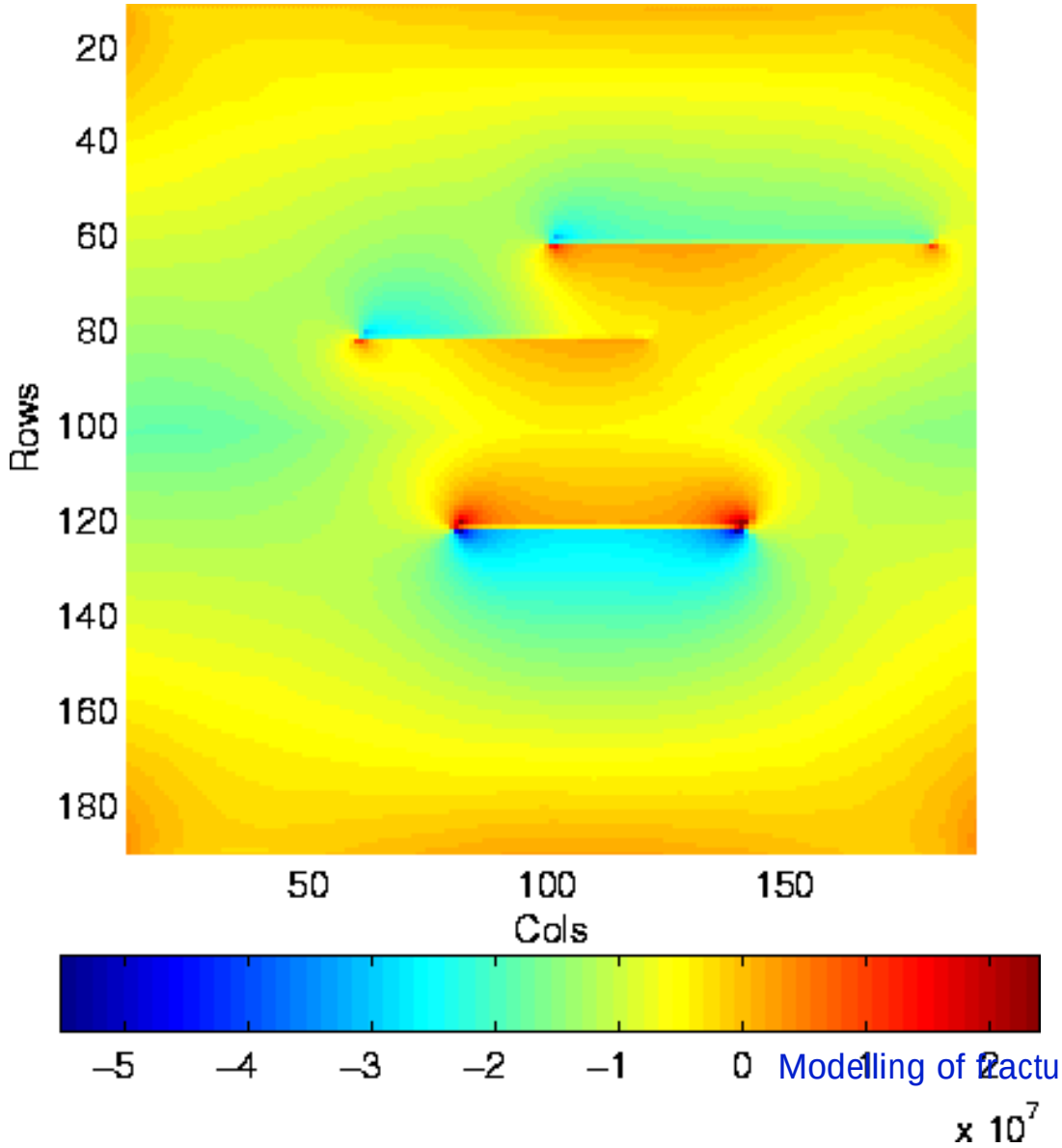
Computing cracks

- Apply forces and boundary conditions, calculate the stresses at each point using finite element method.
- Cracks are failed elements.
- Cracks can be propogated if the stress at surrounding points are greater than the local strength of the material.

Previous Work

- Javier did extensive work using serial code
  - Applies Dirichlet boundary conditions (forces displacements to be zero)
  - Applies forces
  - Allows inputs of fractured nodes
  - Displays stresses

Serial Code Output



Beginnings of the Parallel code

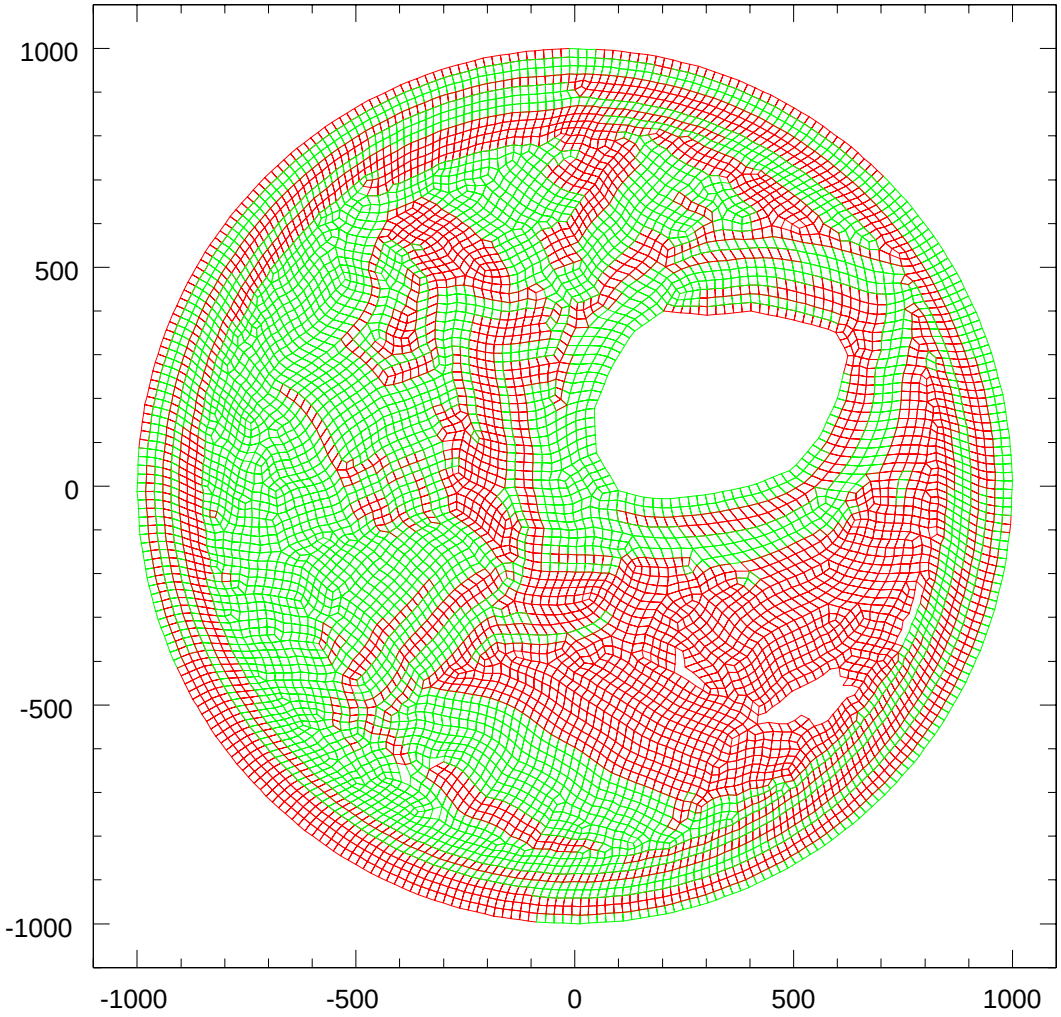
- Javier then began on a parallel code.
- Models the elasticity of a rock

  displays the displacements under an applied force

- Partitions the grid using Metis

  a set of programs for partitioning finite element meshes, available on the web

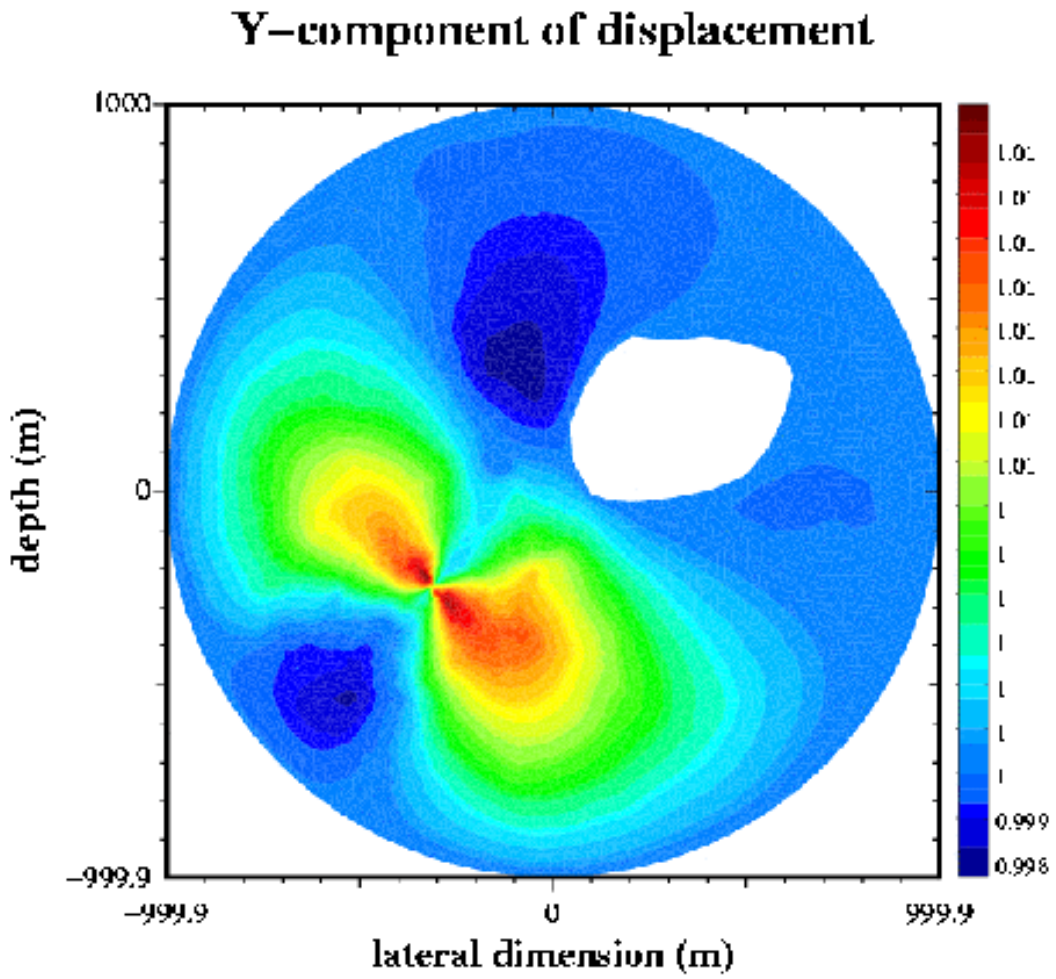
Partitioned with Metis



Beginnings of the Parallel code

- Parallelised using MPI
- Uses the AZTEC library

  an iterative solver library that simplifies the parallelization process when solving linear systems of equations.


Y–component of displacement
1000
0
–999.9
depth (m)
–999.9
0
999.9
lateral dimension (m)
0.999
0.998

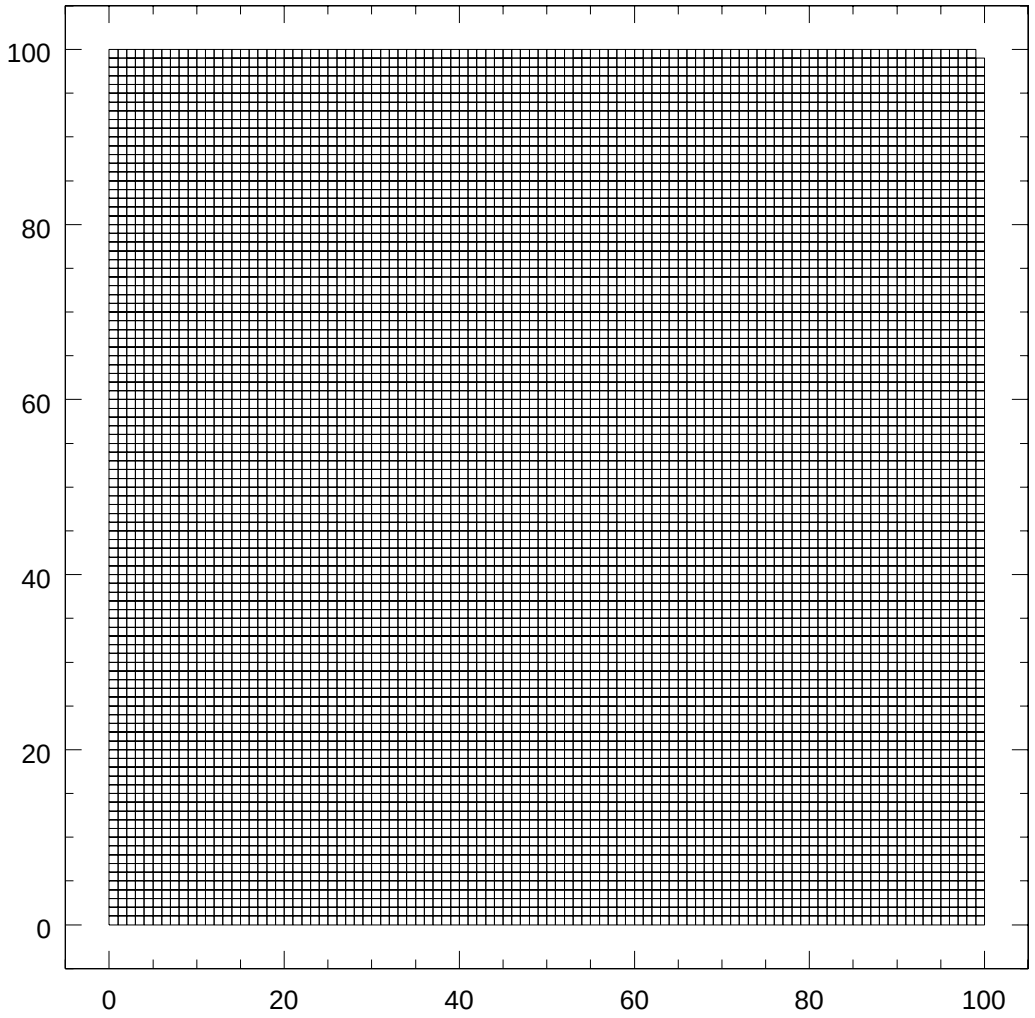
Initial Difficulties

- Did not run on the suns
- Aztec library portablility
- Works on Linux

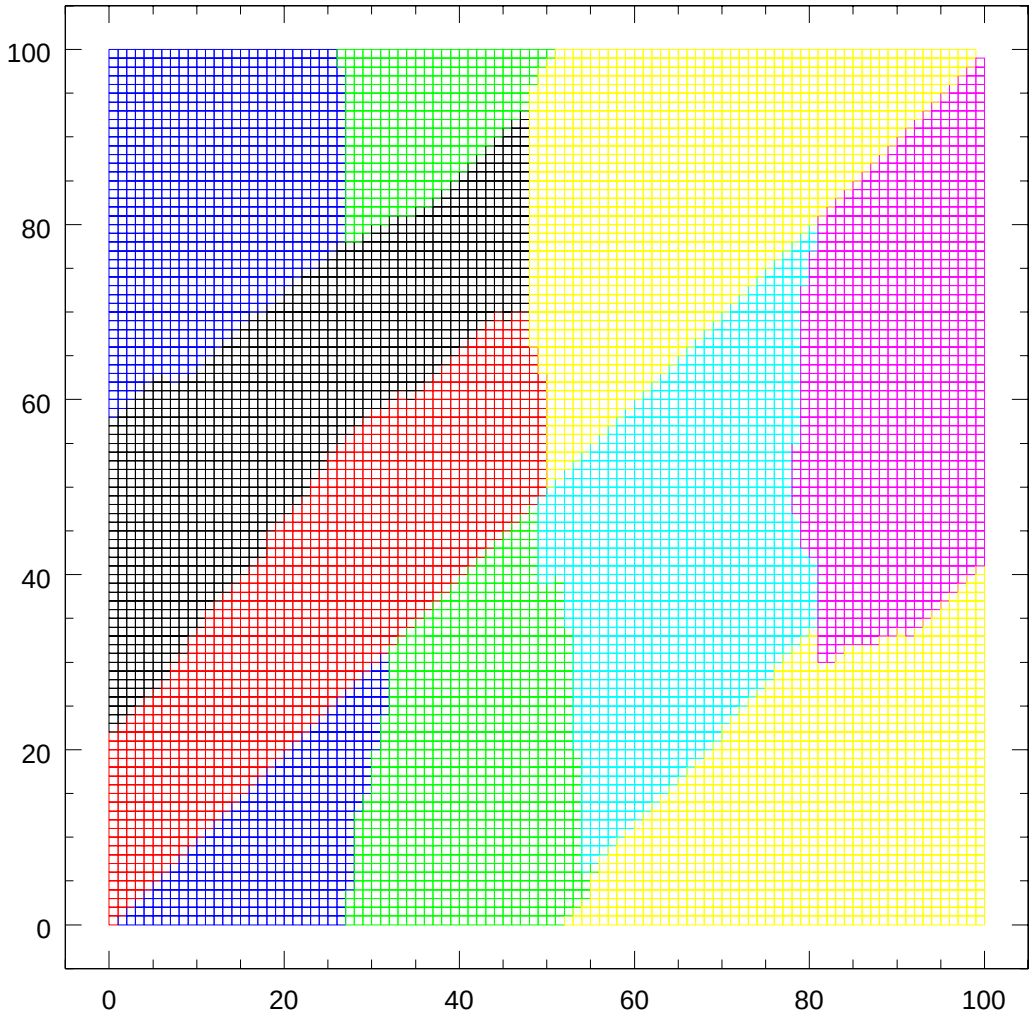
Input File

- The input file includes:
  - The co-ordinates for each gridpoint
  - The gridpoints in each element
  - Specification of Dirichlet boundary conditions, nodal forces and materials.
- My mesh generator creates a similar input file
  - Square
  - Dirichlet boundary conditions, corners, edges
  - Forces along edges

My grid



My grid



Generating Cracks

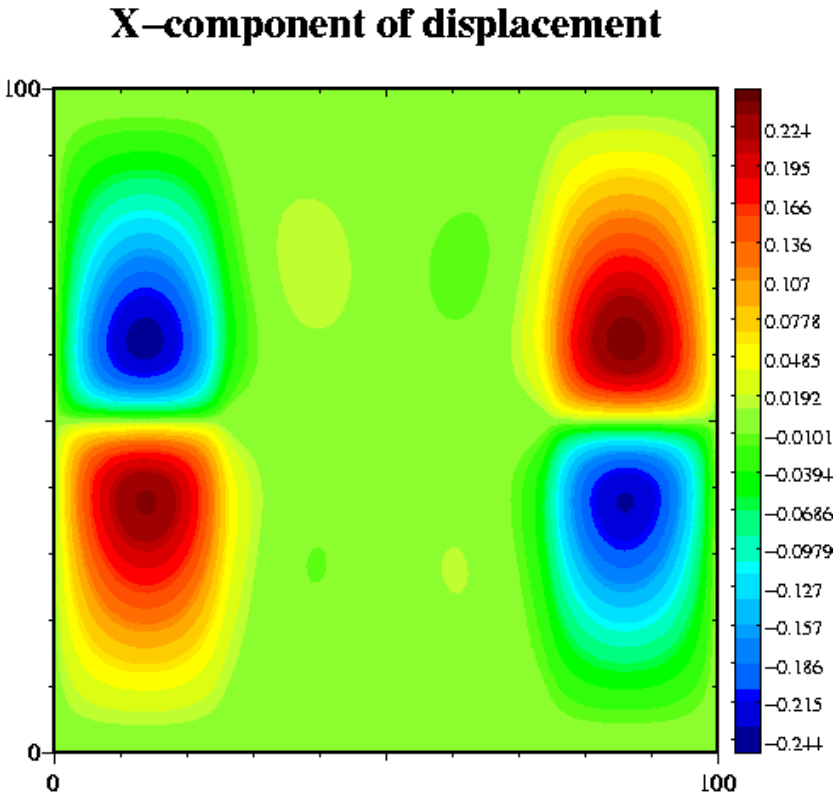
- A point in the rock is broken by applying Dirichlet b.c. at that point.
- I modified the code to

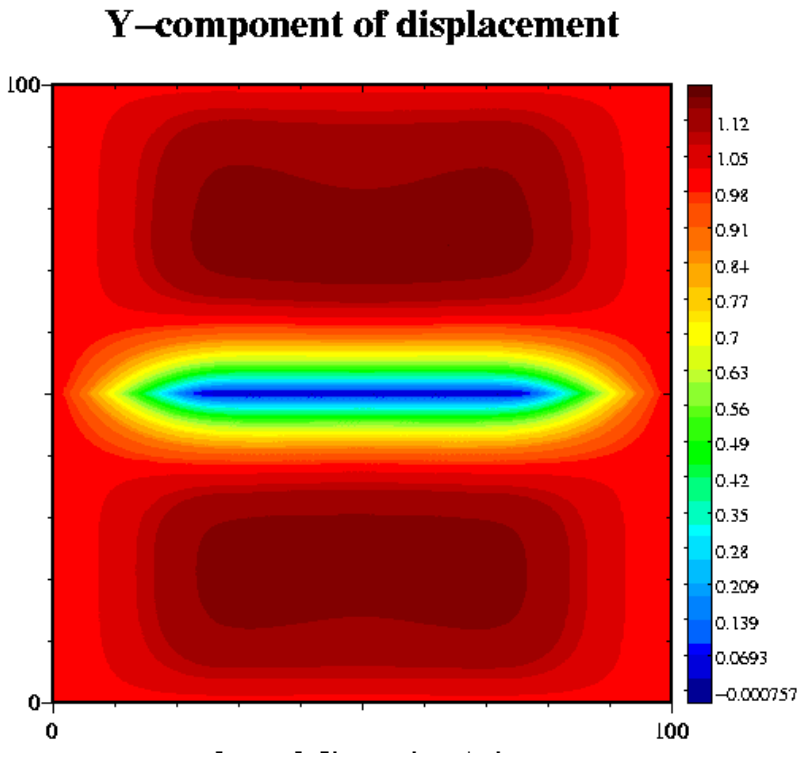
  Identify nodes between start and end point of a crack.

  Modify stiffness matrix (contains directional information of the Young's Modulus at each point) to apply Dirichlet b.c. to the nodes identified.

  I will also write a subroutine to generate random cracks.

Displacements





Calculating Stresses

- The stress matrix can be calculated from
  - the derivatives of the displacements in the x and y direction
  - and the Poisson's ratio and Young's Modulus of the material
- Invariants of stress matrix calculated

- Display stresses
- Crack propogation developments
  - Introduce heterogeneous strength field to the rock
  - Determine direction and length of breakage using stress at tips and grow crack accordingly
- Develop code involving forces
  - Direction
  - Size

Questions?