Project for Keith Ballard

Proposed project

The proposed project is to develop a simulator time-dependent thermomechanical problems. In particular, the simulator should solve the following:

- The time dependent heat equation where temperature changes are either driven by a prescribed boundary temperature or a heat flux.
- The *instantaneous* displacement of the body due to the interior stresses caused by the temperature deviation from the equilibrium state. At least at first, that means solving the *static* elasticity equations at each time step. This rests on the assumption that the temperature-induced displacement is slow.
- The program should run in parallel.

Work on these topics in this order, i.e., start by developing a heat conduction solver, then add the elasticity, then make it parallel.

The final deliverable of your project is a report that contains an introduction and a results section in the style used in the later tutorial programs, as well as a well-documented program with which your numerical results have been obtained.

Prerequisites

- There is not currently a simulator for the heat equation. However, there is step-23 that solves the wave equation and that you can take as an inspiration. Use either the Crank-Nicolson or the BDF-2 time stepping (which is used in step-31, for example).
- For the elasticity equation, take a look at step-8. There is also an extensive discussion in the documentation module on vector-valued problems. Since the coupling is one-way, you can deal with one effect at a time but it will be useful to structure everything as part of one big block system.
- For parallelization, see step-40 for the general approach, step-32 and the currently unreleased step-42 (`http://www.dealii.org/developer/doxygen/deal.II/step_42.html`).

Project tasks

Milestone 1 (March 21, 2013). Write a program that:

- Solves the heat equation and takes the temperature distribution to then solve for the elasticity equation where the temperature introduces an internal stress state that forms the right hand side of the elasticity equation. You may want to talk to Daniel Castanon Quiroz in this class who also has this as one of his steps.
- Does so on uniformly refined meshes on a simple geometry of practical interest.
- Is well documented in the style of the step-X example programs. This includes an introduction that shows what problem we are solving and what mathematical methods underly the formulation, as well as a section that shows results.

Prepare a preliminary presentation on your algorithms, implementation, and results.

Milestone 2 (May 2, 2013) Complete the program by:

- Parallelizing the program in the style of how step-40 generalizes step-6.
- Finishing documentation within the program, as well as the introduction and results sections.
- Providing results for an interesting testcase, for example one for which you already have data from the BETA code.

Prepare a presentation on your algorithms, implementation, and results.

Grading: Determination of that part of your grade resulting from your project work will be based on the following criteria:

- Sophistication of the code beyond the program from which it was started
- Extent of documentation in the code
- Extent of the documentation surrounding the program, i.e. description of the equation and its properties, description of the principles used in the implementation, and documentation of worked-out examples computed with the program
- Sophistication and realism of the testcases to which you apply your numerical scheme.

As an example for projects, take a look at the deal.II tutorial programs at `http://www.dealii.org/developer/doxygen/tutorial/index.html`. If you are interested, good enough projects may be published as part of the library and distributed with future versions (see for example the step-21, step-24, and step-25 tutorial programs that were created by students of a prior class). Of course, you will then be credited for their work.