Contribution to FEniCSx

Overview

I have made the following contributions to improve the demos of FEniCSx:

- Adding a demo for the Stokes equation with various stable pairs of finite elements in PR #2505 that aims to resolve issue #2312
- Adding a Python demo that solves the Poisson equation using matrix-free CG methods in PR #2517 to resolve issue #1776
- Reimplementing Python and C++ demos from legacy FEniCS for FEniCSx that solve the biharmonic equation using a discontinuous Galerkin method in PR #2508
- Adding a DOLFIN to DOLFINx cheat sheet in issue #2330

Apart from that I also made some minor contributions on the way:

- Fixing isort checks for some demos in PR #2506 that has been merged
- Updating the Slack invite link in the `README.md` in PR #2485 that has been merged and on the website in issue FEniCS/web#121
- Slightly improving the semi-official DOLFINx tutorial in PR jorgensd/dolfinx-tutorial#110 that has been merged

Contribution process

Motivation

I have noticed that many users have not yet switched from legacy FEniCS to the new FEniCSx. In my opinion, this is mainly because FEniCSx is not backward compatible and there are few demos available for reference. That makes it difficult for new users to get started with FEniCSx and to migrate code from legacy FEniCS to FEniCSx.

Issue selection

I discovered the following issues that seemed interesting for my contribution:

- Issue #2312: Add a demo using an Enriched Element
- Issue #1776: Add matrix-free solver demos

- Issue #2330: Create a DOLFIN to DOLFINx “cheat sheet”
- Issue #28: Reimplement PointSource

Then I decided as follows:

Issue #28 is one of the oldest issues of FEniCSx and deals with the reimplementation of an important feature. However, the FEniCSx maintainers are not sure yet how exactly the feature should be implemented. Hence, I did not consider this issue further.

Therefore I selected the three other issues for my contributions.

Implementation

I started with issue #2312, i.e. adding a demo using an Enriched Element. A popular Enriched Element is the MINI element which can be used to solve the Stokes equations. Hence, I created a Python demo for the Stokes equation where various stable pairs of finite elements are compared in PR #2505. The author of the issue and another maintainer appreciated the effort and also suggested extending the demo, which I did then.

After that, I looked through the demos of legacy FEniCS and found the following demos that seemed interesting also for FEniCSx, which I started to prepare:

- Biharmonic C++ demo
- Nonlinear Poisson C++ demo
- Geometric Multigrid Poisson C++ demo

Later I found out that there is already a demo similar to the nonlinear Poisson demo outside the repository. Thus, I did not add my reimplementation as a PR.

Unfortunately, it was not possible to get the multigrid demo to work for FEniCSx without “hacking” since the necessary interpolation operator has been removed.

Instead, I added my reimplementations of Python and C++ demos from legacy DOLFIN that solve the biharmonic equation using a discontinuous Galerkin method in PR #2508.

Then, I turned my focus to the matrix-free solver demo for Python that was requested in issue #1776. There was already a C++ demo from PR #1959, which should be reimplemented for Python. I found several ways to implement matrix-free solvers for FEniCSx in Python. I created PR #2517 to add the implemented demo to FEniCSx.

The first version of my PR did not support MPI parallelization like the C++ demo. Achieving this was not straightforward, as the C++ and Python APIs of DOLFINx are inconsistent about when and how exactly

to communicate between processes. After some time of debugging, I was able to solve the problems, making the Python demo behave the same as the C++ demo.

Finally, I have attached a DOLFIN to DOLFINx cheat sheet that I created along the way to issue #2330.

Review and further course

As far as I can tell, my demos are working as intended and the pipeline is running successfully. While some maintainers already reacted positively to my Stokes demo in PR #2505 and the matrix-free solver demo in PR #2517, there was unfortunately no detailed review yet. As soon as this is available, I will adjust the demos accordingly. There is also still no feedback on my biharmonic demos in PR #2508. If the maintainers decide not to merge the demos, I will try to add them to a FEniCSx tutorial outside the repository instead.

Learnings

- Maintainers of large open-source projects tend to be busy, resulting in delayed reviews. Still, they put in a lot of effort and are supportive.
- Even if some maintainers indicate approval, this does not mean that all maintainers are behind it.
- Don't forget to test your code on a FEniCSx build with `PETSC_ARCH=linux-gnu-complex-32`, since the DOLFINx pipeline runs the demos also on this architecture and with complex numbers things can be different!
- For `petsc4py` it is easier to look in the source code than in the incomplete documentation.
- `jupytext` is a great tool to create a `git diff`-able format for Jupyter notebooks.