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Pywaterflood: Well connectivity analysis through capacitance-resistance modeling

Frank Male [1¶]

1 Pennsylvania State University, University Park, PA, USA ¶ Corresponding author

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Software

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Editor: Jayaram Hariharan

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- @mgcooper
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Summary

Well connectivity analysis has many applications for subsurface energy, from waterfloods to CO_2 floods to geothermal. Capacitance Resistance Models are useful for performing well connectivity analysis with limited information about the geology of the reservoirs involved. They are so-called because the equations describing well influence mimic a network of capacitors and resistors.

Pywaterflood is a Python package that uses Capacitance Resistance Modeling to estimate well connectivity. The CRM submodule forms the bulk of this package. It can perform capacitance resistance modeling with differing levels of complexity, from assuming that producing and injecting wells share one universal time constant, to each producer has the same time constant with all injectors, to each producer-injector pair has an its own time constant. CRM was developed by Yousef et al. (2006). The MPI submodule uses a geometrical model of well influence (Valko et al., 2000), extended and applied to reservoirs with both injecting and producing wells (Kaviani & Valkó, 2010).

Statement of need

Interwell connectivity analysis is important for understanding the geology of subsurface systems. This can be used to improve oil recovery efficiency (Albertoni & Lake, 2003), better sequester CO_2 (Tao & Bryant, 2015), and optimize geothermal fields (Akin, 2014).

Pywaterflood uses a reduced-physics model to match connections between injecting and producing wells. As explained in Holanda et al. (2018), capacitance-resistance modeling provides a method for connectivity analysis more sophisticated than empirical decline analysis, but more approachable than full reservoir simulation.

There is another publicly available tool for capacitance resistance modeling reservoirs like pywaterflood (Sayarpour, 2008). However, that tool comes in the form of an Excel workbook and no associated license. This python package provides more extensibility and better performance than an Excel file. There are other programs for performing waterflood analysis with [illegible] in the industry, but they are not open sourced or available for researchers to use.

The pywaterflood library can perform the following tasks:

1. Estimate connectivity between wells in fluid or pressure communication
2. History-match and forecast the production of wells in waterfloods, CO_2 floods, or geothermal fields
3. Provide purely geometric estimates of well connectivity before production data is available

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This project relies on the following open-source Python packages: NumPy (Harris et al., 2020; Walt et al., 2011), SciPy (Virtanen et al., 2020), and pandas (McKinney, 2010). It also uses the Rust crates ndarray, numpy, and pyo3.

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