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Flexible Automatic Discretization for Finite Differences: Eliminating the Human Factor

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In the geophysical numerical modelling community, finite differences are (in part due to their small footprint) a popular spatial discretization method for PDEs in the regular-shaped continuum that is the earth. However, they rapidly become prone to programming mistakes when physics increase in complexity. To eliminate opportunities for human error, we have designed an automatic discretization algorithm using Wolfram Mathematica, in which the user supplies symbolic PDEs, the number of spatial dimensions, and a choice of symbolic boundary conditions, and the script transforms this information into matrix- and right-hand-side rules ready for use in a C++ code that will accept them. The symbolic PDEs are further used to automatically develop and perform manufactured solution benchmarks, ensuring at all stages physical fidelity while providing pragmatic targets for numerical accuracy. We find that this procedure greatly accelerates code development and provides a great deal of flexibility in ones choice of physics.