Nidhoggr User Manual

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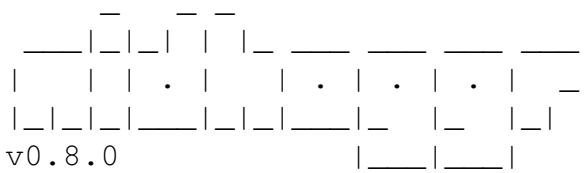
v0.8.0

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1 Introduction

The Nidhoggr (pronounced Nith-hewer) is the mythical beast that gnaws at the roots of the world-tree, Yggdrasil. This may or may not have been inspired by my simultaneous loathing and admiration for tree codes.

1.1 Purpose of Nidhoggr

Nidhoggr is a generic physics simulation framework. It is designed to be used as a base for varied physics simulation methods (FVM,FEM,etc) while keeping helper methods like equations of state and integrators generic enough to be portable to a wide variety of methods choices. Nidhoggr's major classes and methods are written in C++ and wrapped in Python using pybind11 to enable them to be imported as Python3+ modules inside a runscript. Python holds and passes the pointers to most objects inside the code, while the integration step is always handled by compiled C++ code. Any Python class that returns the expected data types of the compiled C++ classes can substitute for a precompiled package (e.g. a custom equation of state), though speed will suffer.

1.2 Overview of capabilities

Nidhoggr's capabilities as of April 25, 2025 are given in Table 1.

1.3 Intended audience

Nidhoggr's intended audience is computational scientists who want a toy simulation code to scope simple problems with that's easily driveable and scriptable with a Python interface, and anyone who doesn't mind getting their hands dirty writing their own physics packages in a fully abstracted simulation framework.

Table 1: Status of major components in Nidhoggr

Component	**Working**	**Development**	**Planned**
Physics	N-body gravity Gravity point sources Constant direction gravity sources Particle kinetics Acoustic wave solvers Shallow wave equation solvers Chemical reaction solvers	HLL hydro FEM	SPH
Equations of State	Ideal gas Polytrope		Helmholtz
Time Integrators	Forward Euler 2nd Order Runge-Kutta 4th Order Runge-Kutta		Symplectic
Meshing	Eulerian grid	FEM	AMR
Data IO	Silo vtk obj wav		
Custom Data Types	Vectors Tensors Cosmologies Units	Elements	
Parallel	OpenMP		MPI

2 Installation

- System requirements
- Dependencies
- Downloading the source code
- Building and installing

3 Getting Started

- Basic concepts
- First run: a simple example

4 Usage

- Running Nidhoggr
- Command-line options

5 Core Concepts

As previously described, Nidhoggr is a compiled C++ codebase that is driven primarily by Python via compiled Python modules. If you're familiar with how NumPy works, you have most of the knowledge you'll need to understand how Nidhoggr works. In fact, while Nidhoggr does have many linear algebra classes and methods builtin, it often works best when paired with other popular Python modules, like NumPy and Matplotlib.

5.1 Importing Nidhoggr Modules

The `nidhoggr.py` file in the tests and examples directories imports all of the compiled Nidhoggr modules for you, and so if you wish to import the entire codebase, you can simply `from nidhoggr import *`. However, you may choose to import only a subset of the available modules for your specific problem. Consult `nidhoggr.py` for the full list of modules.

5.2 Units and Constants

Nidhoggr is unit agnostic. That is to say, the code does not *prescribe* any particular units for you. However, for most problems, you will want to define your units in order for certain universal constants like G to have their correct values. This is done via the PhysicalConstants object which has two constructor methods. You can either supply the full scope of your desired units with unit length (in meters), unit mass (in kg), unit time (in seconds), unit temperature (in Kelvin), and unit charge (in Coulomb), or just a subset of the first three, wherein temperature will be assumed to be Kelvins and charge will be assumed to be Coulombs.

For example, in order to simulate something like the Earth with state quantities near 1, you may choose to instantiate your units like so:

```
PhysicalConstants(6.387e6, 5.97e24, 1.0)
```

From these units, Nidhoggr will calculate at the time of the constructor new values for all of the universal constants to use in your chosen physics packages.

Nidhoggr also comes with some helper methods for a handful of frequently used unit systems in `Units.py`, like `MKS()`, `CGS()`, and `SOL()`. Simply invoke them with `myUnits = MKS()` if you've imported the `Units` module.

5.3 Nodelists and Fields

- Physics methods
- Equations of State
- Mesh/grid handling
- Boundary conditions
- Integrators

- The Controller
- Periodic work

6 Examples

The `examples` folder holds Python runscripts that each solve a particular notional physics (or purely calculational) problem.

Table 2: Examples included in the main branch.

File	**Purpose**
`cherenkov.py`	Simulates a supersonic (or superluminal) point source moving through a medium at a speed greater than c.
`cosmo.py`	Creates an example cosmology (Ω_m,Λ,H_0) and reports the properties of that cosmology at the chosen redshift.
`diffractionGrating.py`	Simulates the transmission of an acoustic wave through a diffraction grating.
`imageToStringArt.py`	Creates the instructions for (and previews) an image made from strings stretched across a wheel with a chosen number of pins.
`oort.py`	Simulates a star passing through the Oort cloud and dislodging a comet from its orbit.
`plinko.py`	Simulates the Plinko game.
`relativity.py`	Calculates the time dilation for a relativistic traveler.
`rps.py`	Simulates the destruction of chemical mixtures in a rock-paper-scissors-like reaction setup, where $A \to B \to C \to A$.
`tensors.py`	Creates some tensors and does some linear algebra with them.
`vectors.py`	Creates some vectors and does some linear algebra with them.
`waveLogo.py`	Simulates acoustic waves inside a region with Dirichlet boundary conditions arranged in a unique fashion.

6.1 Simple test cases

Many of the Python scripts inside the `tests` folder stress single components of Nidhoggr, or a small subset of them. For instance, `waveBox.py` tests the acoustic wave solver with a single oscillatory source in the center of a box with two openings on either end (using Dirichlet boundaries to create the box).

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11 Acknowledgments

- Contributors
- Funding and support

12 License

- License terms
- How to cite Nidhoggr

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