treeIDW

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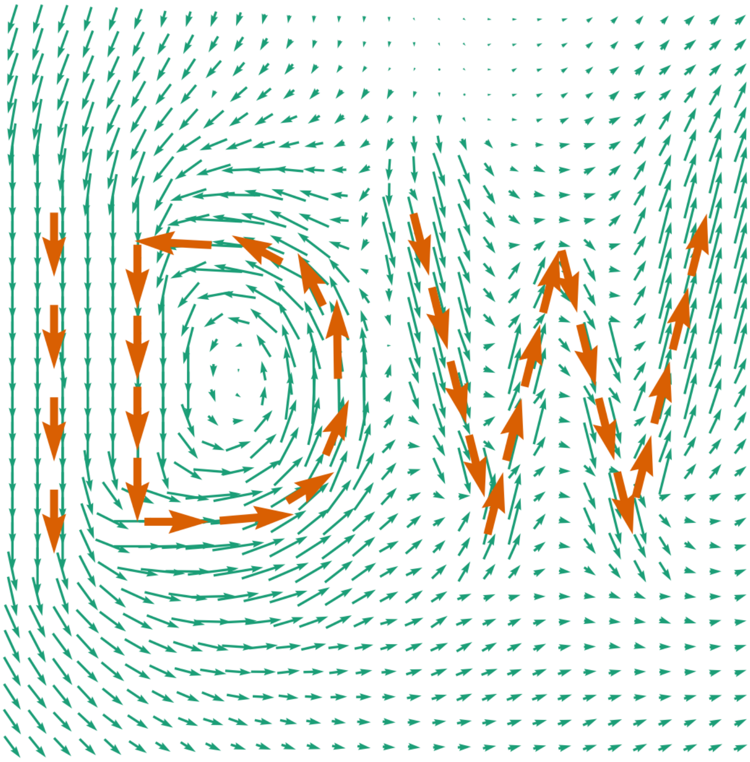

treeIDW is a Python library for performing **Inverse Distance Weighting (IDW)** interpolation using an efficient **KD-tree-based selection strategy**.
It is designed to be easy to use for newcomers while offering fine-grained control and performance-oriented options for advanced users in numerical methods and spatial data analysis.

Key Features

- Efficient IDW interpolation using KD-tree nearest-neighbor selection
- Automatic exclusion of boundary nodes with negligible contribution
- Optimized numerical kernels powered by `numba`
- Scalable to large datasets (millions of interpolation points)
- Simple API with expert-level tunable parameters

Installation

treeIDW is available on PyPI.

```
pip install treeIDW
```

Development installation (from source)

```
git clone https://github.com/Dorian210/treeIDW
cd treeIDW
pip install -e .
```

Dependencies

The core dependencies are:

- `numpy`

- `scipy`
- `numba`

These are automatically installed when using `pip` .

Package Structure

- **treeIDW.treeIDW**
  Core IDW interpolation engine.
  Uses a KD-tree to select only boundary nodes with significant influence, improving both accuracy and performance.

- **treeIDW.helper_functions**
  Low-level, performance-critical routines for IDW weight computation.
  Implemented with `numba` , including vectorized and parallelized variants.

- **treeIDW.weight_function**
  Definition of the IDW weight function.
  The default implementation uses inverse squared distance, but custom weight laws can be implemented if needed.

Examples

Example scripts are provided in the `examples/` directory:

- **Graphical demonstration**
  Interpolation of a rotating vector field inside a square domain.

- **Large-scale computation**
  Propagation of a scalar field from 1,000 boundary nodes to 1,000,000 internal points, highlighting scalability.

- **Logo generation**
  The generation process of the *treeIDW* logo itself, where the letters “IDW” are encoded as a vector field and interpolated on a 2D grid.

Documentation

- Online documentation: https://dorian210.github.io/treeIDW/
- API reference is also available in the `docs/` directory of the repository.

Contributions

This project is currently not open to active development contributions.
However, bug reports and suggestions are welcome via the issue tracker.

License

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treeIDW.weight_function

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```python
@nb.njit(cache=True)
def compute_weight(dist_squared: float) -> float:
```

- View Source

Compute the IDW weight. Can be changed but is usually `1/dist_squared` .

Parameters

- **dist_squared** (float): Squared distance between the interior node and the boundary node.

Returns

- **weight** (float): IDW weight.

treeIDW.treeIDW

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```
def treeIDW(
    boundary_nodes: numpy.ndarray[typing.Any, numpy.dtype[numpy.floating]],
    boundary_field: numpy.ndarray[typing.Any, numpy.dtype[numpy.floating]],
    internal_nodes: numpy.ndarray[typing.Any, numpy.dtype[numpy.floating]],
    neglectible_treshold: float = 0.2,
    bisect_rtol: float = 0.001,
    parallel: bool = False
) -> numpy.ndarray[typing.Any, numpy.dtype[numpy.floating]]:
```

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Performs IDW interpolation using a KD-tree to select relevant boundary nodes for each internal node. Only boundary nodes with significant weights are included in the interpolation.

Parameters

- **boundary_nodes** (NDArray[np.floating]): Boundary nodes where the data is known. Must be of shape (`n_interp`, `space_dim`).
- **boundary_field** (NDArray[np.floating]): Known data. Must be of shape (`n_interp`, `field_dim`).
- **internal_nodes** (NDArray[np.floating]): Internal nodes where the interpolator is evaluated. Must be of shape (`n_eval`, `space_dim`).
- **neglectible_treshold** (float, optional): Relative weight threshold below which boundary nodes are ignored, by default 0.2
- **bisect_rtol** (float, optional): Relative tolerance for bisection convergence, by default 1e-3
- **parallel** (bool, optional): Whether to use parallel implementation, by default False

Returns

- **internal_field** (NDArray[np.floating]): Interpolated data. Should be of shape (`n_eval`, `field_dim`).

treeIDW.helper_functions

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```
@nb.njit(cache=True)
def inv_dist_weight(
    boundary_nodes: numpy.ndarray[typing.Any, numpy.dtype[numpy.floating]],
    boundary_field: numpy.ndarray[typing.Any, numpy.dtype[numpy.floating]],
    internal_nodes: numpy.ndarray[typing.Any, numpy.dtype[numpy.floating]],
    relevant_nodes_inds_flat: numpy.ndarray[typing.Any, numpy.dtype[numpy.integer]],
    relevant_nodes_inds_sizes: numpy.ndarray[typing.Any, numpy.dtype[numpy.integer]]
) -> numpy.ndarray[typing.Any, numpy.dtype[numpy.floating]]:
```

- View Source

Performs the Inverse Distance Weighting interpolation method using only provided boundary nodes indices in the weighted sum. This function is designed to be used after selecting the relevant nodes through a KD-tree method.

Parameters

- **boundary_nodes** (NDArray[np.floating]): Boundary nodes where the data is known. Must be of shape (`n_interp`, `space_dim`).
- **boundary_field** (NDArray[np.floating]): Known data. Must be of shape (`n_interp`, `field_dim`).
- **internal_nodes** (NDArray[np.floating]): Internal nodes where the interpolator is evaluated. Must be of shape (`n_eval`, `space_dim`).
- **relevant_nodes_inds_flat** (NDArray[np.integer]): Boundary nodes indices that weight in the IDW interpolator for each internal node. Must contain `n_eval` concatenated lists of indices between 0 and `n_interp` excluded.
- **relevant_nodes_inds_sizes** (NDArray[np.integer]): Sizes of each of the `n_eval` lists concatenated in `relevant_nodes_inds_flat`.

Returns

- **internal_field** (NDArray[np.floating]): Interpolated data. Should be of shape (`n_eval`, `field_dim`).

```
@nb.njit(parallel=True, cache=True)
def inv_dist_weight_parallel(
    boundary_nodes: numpy.ndarray[typing.Any, numpy.dtype[numpy.floating]],
    boundary_field: numpy.ndarray[typing.Any, numpy.dtype[numpy.floating]],
    internal_nodes: numpy.ndarray[typing.Any, numpy.dtype[numpy.floating]],
    relevant_nodes_inds_flat: numpy.ndarray[typing.Any, numpy.dtype[numpy.integer]],
    relevant_nodes_inds_sizes: numpy.ndarray[typing.Any, numpy.dtype[numpy.integer]]
) -> numpy.ndarray[typing.Any, numpy.dtype[numpy.floating]]:
```

- View Source

Performs the Inverse Distance Weighting interpolation method using only provided boundary nodes indices in the weighted sum. This function is designed to be used after selecting the relevant nodes through a KD-tree method.

Parameters

- **boundary_nodes** (NDArray[np.floating]): Boundary nodes where the data is known. Must be of shape (`n_interp`, `space_dim`).
- **boundary_field** (NDArray[np.floating]): Known data. Must be of shape (`n_interp`, `field_dim`).
- **internal_nodes** (NDArray[np.floating]): Internal nodes where the interpolator is evaluated. Must be of shape (`n_eval`, `space_dim`).
- **relevant_nodes_inds_flat** (NDArray[np.integer]): Boundary nodes indices that weight in the IDW interpolator for each internal node. Must contain `n_eval` concatenated lists of indices between 0 and `n_interp` excluded.
- **relevant_nodes_inds_sizes** (NDArray[np.integer]): Sizes of each of the `n_eval` lists concatenated in `relevant_nodes_inds_flat`.

Returns

- **internal_field** (NDArray[np.floating]): Interpolated data. Should be of shape (`n_eval`, `field_dim`).

```
@nb.njit(cache=True)
def bisect_weight_elem(
 dist_squared_a: float,
 dist_squared_b: float,
 weight_treshold: float,
 rtol: float
) -> float:
```

- View Source

Compute the squared distance that correspond to a specific weight threshold using a bisection approach.

Parameters

- **dist_squared_a** (float): Left boundary of the interval containning the looked for weight treshold preimage.
- **dist_squared_b** (float): Right boundary of the interval containning the looked for weight treshold preimage.
- **weight_treshold** (float): Image of the looked for squared distance by the weight function of the IDW algorithm.
- **rtol** (float, optional): The relative tolerance is used to compute the necessary number of bisection iterations, by default 1e-3

Returns

- **dist_squared_c** (float): Weight treshold preimage found through bisection.

bisect_weight = <numba._GUFunc 'bisect_weight'>

Vectorized version of bisect_weight_elem that finds squared distances corresponding to weight thresholds.

Parameters

- **dist_squared_a** (float): Left boundary of interval containing weight threshold preimage
- **dist_squared_b** (float): Right boundary of interval containing weight threshold preimage
- **weight_treshold** (float): Target weight threshold value
- **rtol** (float): Relative tolerance for bisection convergence
- **out** (ndarray): Output array for storing computed squared distance

bisect_weight_parallel = <ufunc 'bisect_weight_parallel'>

Vectorized version of bisect_weight_elem that finds squared distances corresponding to weight thresholds. Parallelized version of the function.

Parameters

- **dist_squared_a** (float): Left boundary of interval containing weight threshold preimage
- **dist_squared_b** (float): Right boundary of interval containing weight threshold preimage
- **weight_treshold** (float): Target weight threshold value
- **rtol** (float): Relative tolerance for bisection convergence
- **out** (ndarray): Output array for storing computed squared distance

compute_weight_vectorized = <numba._GUFunc 'compute_weight_vectorized'>

Vectorized version of compute_weight function for IDW calculations.

Parameters

- **dist_squared** (float): Squared distance between interior and boundary nodes.
- **out** (ndarray): Output array containing the computed IDW weights.

compute_weight_vectorized_parallel = <ufunc 'compute_weight_vectorized_parallel'>

Vectorized version of compute_weight function for IDW calculations. Parallelized version of the function.

Parameters

- **dist_squared** (float): Squared distance between interior and boundary nodes.
- **out** (ndarray): Output array containing the computed IDW weights.