Echoes

Extended Calculator of HOmogEnization Schemes

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Welcome

The library `echoes` allows to implement various mean-field homogenization schemes of random media involving different types of heterogeneities in the framework of elasticity, conductivity, viscoelasticity as well as nonlinear homogenization.

This book gathers tutorials presenting the main features of the library:

- elements of tensor calculus,
- Hill and Eshelby tensors and their derivatives with respect to reference medium moduli,
- concentration problems,
- RVEs and schemes in linear homogenization,
- extension to nonlinear homogenization,
- extension to linear time-dependent behaviors.

Download

The core of `echoes` has been developed in C++ and wrapped by a Python interface. Hence its use requires first the installation of a Python environment including `pip` executable (for instance Anaconda).

Wheel packages can be downloaded for various versions of Python under Windows or Linux by choosing the appropriate file for your configuration under the link

https://doi.org/10.5281/zenodo.10559657

Once in possession of the relevant `.whl` file, the package can be installed in a console (Anaconda console or any console allowing to run `pip`) by

```
pip install -U echoes-XYZ.whl
# replacing echoes-XYZ.whl by the correct path to the whl file
```

Citation

If you use `echoes`, please cite it as (**?**) or in `bibtex` style

```
@software{echoes,
  title = {Echoes: {{Extended Calculator}} of {{HOmogEnization Schemes}}},
  shorttitle = {Echoes},
  author = {Barthélémy, Jean-François},
  date = {2022-11-22},
  doi = {10.5281/ZENODO.10559657},
  url = {https://zenodo.org/record/10559657},
  organization = {Zenodo},
  version = {v1.0.0},
}
```

About the author

Jean-François Barthélémy is a researcher at Cerema in the research team UMR MCD.

- GitHub
- ResearchGate
- Google scholar
- HAL
- Web Of Science
- ORCID
- Email

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Introduction

This book is aimed at researchers, engineers and students, knowing the fundamentals of mean-field theory to help them learn how to use the `echoes` library with some brief theoretical recalls when relevant. For a more exhaustive presentation of the theory of random medium homogenization, see (**?**), (**?**), (**?**) or (**?**) among others.

The objectives of the library can be summarized as follows:

- simple and quick implementation of Eshelby problems and homogenization schemes,

- multi-physics and multi-scale homogenization,

- effects of microstructure changes by chemical, physical or mechanical process.

> **Features**
>
> - Eshelby problem solved at 2nd (conductivity) et 4th orders (elasticity)
>
> - Isotropy and anisotropy
>
> - Several types of inclusions including generic (user-defined) inclusion
>
> - Large variety of schemes
>
> - Derivatives of the macroscopic elasticity with respect to lower scale moduli
>
> - Aging linear viscoelasticity
>
> - Complex moduli

In this manual, some snippets of Python codes are presented. The `echoes` library can be imported as

```
from echoes import *
```

or, to avoid any ambiguity between libraries, as

```
import echoes as ec
```

A usual start of any tutorial could be the following

```python
import numpy as np
from echoes import *
import matplotlib.pyplot as plt # if plots are needed

np.set_printoptions(precision=8, suppress=True)
# to display only 8 significant digits of array components
```

Whenever they are omitted, it is implicitly considered that these lines have previously been added.

Part I