

1 Installation

Clone with submodules:

```
git clone http://www.sternwarte.uni-erlangen.de/gitlab/collischon/litchi.git
cd litchi; git submodule update --init --recursive
cd ..
```

Create a build directory and create the Makefile if your standard compiler can handle C++20 (e.g. g++-10, can be checked with `g++ -v`):

```
mkdir litchi-build; cd litchi-build;
cmake ../litchi ./
```

Some setups may enable you to load a module that changes your compiler version beforehand, (e.g. module load gcc/10 on Remeis). Ask your administrator about this.

If you need to specify a different compiler (such as g++-10), name it before calling cmake:

```
CC=gcc-10 CXX=g++-10 cmake ../litchi ./
```

Compile:

```
make
```

Litchi requires Healpix to be installed. Its folder should either be specified in an environment variable called HEALPIX (Healpix does this if you compile it yourself, check with `echo $HEALPIX`). Alternatively, it should be in the system's include/library paths (e.g. after installing with the package manager or adding it manually).

Optional: create code documentation with doxygen by going to litchi/doc and then calling `doxygen doxygen.config`

2 How to use litchi

2.1 Command line arguments

`--infile, -i` Filename of input file

`--outfile, -o` Filename of output file, parameters are by default appended to name and to Fits-header (see also `-forceOutname`)

`--mask, -m` Filename of maskfile, everything touching the masked area will be set to NAN. Must have same Nside and scheme as input file. Default: Empty (no masking)

`--maskThresh` Threshold to be applied to mask, every pixel below this in the mask will be set to NAN in the input image (higher threshold leads to stricter mask). Default: 0.9

`--rankA, -A` First rank of Tensor, exponent of r . Default: 0

`--rankB, -B` Second rank of Tensor, exponent of n . Default: 0

`-curvI, -C, -c` Third index of tensor/functional. Default: 0

`--mint` minimal Threshold. Default: 0

`--maxt` maximal threshold. Default: 1

`--numt` Number of thresholds. Default: 1 (mint)

--nside Set Nside for input image if it should be degraded (simple downscaling without Fourier transform etc.). Must be power of 2 and smaller than Nside of the original image. Default: 0 (no downscaling)

--smooth Downscale output by given factor before calculating scalar from Minkowskis to get information at larger scales. One output image pixel will contain information from input image pixels in a circle with radius $\sim 1.5 \times$ distance pixel center-corner. Overwrites smoothRad and NsideOut. Default: 0 (no downscaling)

--NsideOut Set Nside for output image if smooth is not set. Combine with use in combination with smoothRad. Must be power of 2 or zero. Default: 0 (will be set equal to Nside)

--smoothRad One output image pixel will contain information from input image pixels in a circle with radius smoothRad (in rad). Overwritten by smooth. Default: 0

--linThresh Set linear spacing of thresholds. Default: active.

--logThresh Set logarithmic spacing of thresholds. Default: inactive.

--forceOutname Writes file with exactly given file name without appending the parameters to name (parameters are always in Fits-header). Default: inactive (append parameters)

--trace Calculate trace of tensors for outputmap. Default: active

--quotient, --evq Calculate quotient of eigenvalues of tensors for outputmap instead of trace. Default: inactive

--direction, --evd Calculate direction of vector functional/Eigenvector with largest eigenvalue for outputmap instead of trace. Default: inactive

--sequence Generate a sequence of single-threshold Minkowski maps instead of one map averaged over several thresholds

2.2 Quick guide

- Enter input filename with **-i / --infile**
- For masking the input file, give a mask file with **-m / --maskThresh**. By default, mask pixels > 0.90 are treated as unmasked. For different thresholds, set **--maskThresh**
- Enter ranks of the desired Minkowski tensor/functional with **-A, -B, -C**. A and B are tensor indices (set to zero for functionals), C is the type of Minkowski functional/tensor (often denoted as ν ; 0 for area-like, 1 for boundary without curvature, 2 for curvature)
- Give the desired thresholds with **--mint, --maxt, --numt**. By setting **--linThresh** (default), they will be spaced linearly, and logarithmically with **--logThresh**. The boundaries (mint and maxt) are included.
- Do you want only one output map where maps for all thresholds have been averaged (default) or a sequence of Minkowski maps for a single threshold each? For the latter, set **--sequence**
- By default, the maximum resolution of the input file is used, which might be resource intensive. For lowering the resolution set **-Nside** to simply downscale the resolution. Warning: this is a simple downscaling function for quick tests that does not use spherical harmonics, pixel window functions, or the required smoothing needed for a serious analysis.
- The default output gives information on the scale of the 2x2px marching square window. For larger scales, there are two options:

- Enter a downscaling factor with `--smooth` that will be applied before calculating eigenvalues/trace. One output image pixel will contain information from input image pixels in a circle with radius $1.5 \times d_{max}$ where d_{max} is the maximum distance between a pixel center and its corners at output resolution.
- Enter a smoothing radius with `--smoothRad` and an output Nside with `--NsideOut`. One output image pixel will contain information from input pixels within a circle around its center with radius `smoothRad`
- `--trace` (default), `--EVquotient`, or `--EVDirection` determine whether the trace, the quotient of eigenvalues, or the direction of the vector pointing along the largest eigenvalue of the tensors is calculated for the output map

The output path and file prefix is entered with `-o / --outfile`. Several modifications are applied as necessary:

- By default, all relevant parameters are appended to the output name (before `.fits` ending if given. If not, `.fits` is appended)
- By using `--forceOutname`, the given name is used as is
- When using `--forceOutname` and `--sequence`, a three digit counter is added to the output name (before `.fits` ending if given)
- Independent from these settings, all parameters are written into the primary file header
- If the output directory does not exist yet, it is created

2.3 Examples

Generate Minkmap of trace of $W_1^{0,2}$ with one threshold at $1e-5$, and then smooth output to `Nside/4`, appending all relevant parameters to output filename and using a mask where only pixels with values > 0.95 are unmasked:

```
./litchi -i myfile.fits -A 0 -B 2 -C 1 --smooth 4 --mint 1e-5 --numt 1 \
-o ../litchi_output/myoutput.fits -m mymask.fits --maskThresh 0.95
```

Generate sequence of perimeter length at 19 linearly spaced thresholds between $-9e-5$ and $9e-5$, using the filename as given, appending only a counter:

```
./litchi -i myfile.fits -A 0 -B 0 -C 1 --EVquotient --mint -9e-5 \
--maxt 9e-5 --numt 19 -o ../litchi_output/mysequence --forceOutname --sequence
```

Generate Minkmap of eigenvalue quotient of $W_1^{0,2}$ with one threshold at 0, calculate the output map with Nside 256, using a window with radius 0.02rad, applying a mask where only pixels with values larger than 0.9 are unmasked:

```
./litchi -i myfile.fits --evq -A 0 -B 2 -C 1 --NsideOut 256 --smoothRad 2e-2 \
--mint 0 --numt 1 -o ../litchi_output/myoutput.fits -m mymask.fits
```

3 Using litchi's python bindings: litchieat

Compiling according to the above instructions will provide a python package in a file called `litchieat.cpython<version>.so`. It can be imported by adding its path using `sys` and then importing as usual:

```
import sys
sys.path.insert(0, '../path/to/litchi-build')
import litchieat as li
```

It provides the `paramStruct` class (create with `li.paramStruct()`) to contain the parameters for calling `litchi`. Its members stand for the same parameters as the command line arguments described above. After construction, the default values are the same as above.

The member names are: `Nside`, `NsideOut`, `rankA`, `rankB`, `curvIndex`, `mint`, `maxt`, `numt`, `smooth`, `smoothRad`, `linThresh`, `function`, `forceOutname`, `sequence`, `maskname`, `maskThresh`
`function` is a string and can be any of `trace`, `EVQuo`, `EVDir`
`linThresh`, `forceOutname` and `sequence` are boolean

For creating maps, the functions

`makeSingleMinkmap(string inname, paramStruct params, string outname)`
and

`makeSequence(string inname, paramStruct params, string outname)`

are provided. They create either a single Minkmap or a sequence of the file given by `inname` according to the parameters given in `params` and write the single map/the sequence to `outname`.