

# Package: PhysioHeadModels (via r-universe)

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**Title** Realistic EEG Head Models and Forward Solvers for the Physio Ecosystem

**Version** 0.1.1

**Description** Provides EEG forward-model building blocks for the Physio ecosystem: an analytic multi-concentric-sphere leadfield, a boundary element method (BEM) solver with the double-layer operator for custom head meshes, cortical source-space helpers with surface normals, and on-demand fetchers for large published head models (the New York Head and FreeSurfer fsaverage) that are downloaded to a per-user cache rather than shipped.

**Depends** R (>= 4.2)

**Imports** utils

**Suggests** hdf5r, knitr, rmarkdown, testthat (>= 3.2.0)

**VignetteBuilder** knitr

**License** MIT + file LICENSE

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**URL** <https://github.com/x-biosignal/PhysioHeadModels>

**BugReports** <https://github.com/x-biosignal/PhysioHeadModels/issues>

**Repository** <https://x-biosignal.r-universe.dev>

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|              |                                                    |
|--------------|----------------------------------------------------|
| bemLeadfield | <i>Boundary element method (BEM) EEG leadfield</i> |
|--------------|----------------------------------------------------|

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### Description

Solves the piecewise-homogeneous EEG forward problem with the classic collocation double-layer boundary element method (Geselowitz boundary integral, van Oosterom-Strackee solid angles, average-reference deflation) on one or more nested triangulated surfaces. Validated against the analytic single-sphere solution: on a sphere mesh the leadfield topography matches to a small relative difference measure (RDM); absolute amplitude carries the usual coarse-collocation bias, so use RDM (topography) for validation and note that source localization is invariant to a global leadfield scale.

### Usage

```
bemLeadfield(surfaces, conductivities, electrodes, sources)
```

### Arguments

|                |                                                                                                                                                                                                                             |
|----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| surfaces       | A single mesh (list with vertices, faces) or a list of nested meshes from innermost to outermost.                                                                                                                           |
| conductivities | Conductivity of each region from innermost to the exterior; length <code>n_surfaces + 1</code> (the last is the exterior, usually 0 for air). For a single surface, a length-2 vector <code>c(sigma_in, sigma_out)</code> . |
| electrodes     | An <code>n_electrodes x 3</code> matrix of electrode positions.                                                                                                                                                             |
| sources        | An <code>n_sources x 3</code> matrix of dipole positions (in the innermost region).                                                                                                                                         |

### Value

An `n_electrodes x (n_sources * 3)` leadfield matrix.

## References

- Geselowitz, D. B. (1967). On bioelectric potentials in an inhomogeneous volume conductor. *Biophysical Journal*, 7(1), 1-11.
- Oostendorp, T. F., & van Oosterom, A. (1989). Source parameter estimation in inhomogeneous volume conductors of arbitrary shape. *IEEE Transactions on Biomedical Engineering*, 36(3), 382-391.

## See Also

[sphereLeadfield\(\)](#), [solidAngle\(\)](#)

## Examples

```
m <- icosphere(2)
e <- m$vertices[1:19, ]
s <- rbind(c(0, 0, 0.5), c(0.3, 0, 0.2))
dim(bemLeadfield(m, c(0.33, 0), e, s))
```

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constrainOrientation    *Constrain a free-orientation leadfield to surface normals*

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## Description

Collapses the three orientation columns of each source to a single surface-normal-oriented column, giving an `n_electrodes` x `n_sources` leadfield.

## Usage

```
constrainOrientation(leadfield, normals)
```

## Arguments

|                        |                                                                                          |
|------------------------|------------------------------------------------------------------------------------------|
| <code>leadfield</code> | An <code>n_electrodes</code> x ( <code>n_sources</code> * 3) free-orientation leadfield. |
| <code>normals</code>   | An <code>n_sources</code> x 3 matrix of unit source normals.                             |

## Value

An `n_electrodes` x `n_sources` orientation-constrained leadfield.

## Examples

```
ss <- sphericalSourceSpace(40, radius = 0.6)
e <- icosphere(2)$vertices[1:19, ]
lf <- sphereLeadfield(e, ss$positions)
lc <- constrainOrientation(lf, ss$normals)
dim(lc)
```

---

|                |                                                          |
|----------------|----------------------------------------------------------|
| fetchFsaverage | <i>Fetch the FreeSurfer fsaverage surfaces on demand</i> |
|----------------|----------------------------------------------------------|

---

### Description

A thin placeholder fetcher for the FreeSurfer / MNE fsaverage template surfaces. Because fsaverage is distributed through FreeSurfer / MNE (with its own licence and download mechanism), this returns the cache directory into which the user should place (or a future version will fetch) the surfaces, and errors informatively if they are absent.

### Usage

```
fetchFsaverage(dest = NULL)
```

### Arguments

dest                      Optional destination directory (defaults to the cache).

### Value

The path to the fsaverage directory in the cache.

### See Also

[fetchNYHead\(\)](#)

### Examples

```
# With the surfaces already in place the fetcher just resolves their path.
# Here a temporary stand-in directory shows that resolution offline (a real
# run needs the FreeSurfer/MNE fsaverage surfaces placed in the directory).
dir <- file.path(tempdir(), "fsaverage")
dir.create(dir, showWarnings = FALSE)
fetchFsaverage(dest = dir)
```

---

|             |                                                |
|-------------|------------------------------------------------|
| fetchNYHead | <i>Fetch the New York Head model on demand</i> |
|-------------|------------------------------------------------|

---

### Description

Downloads the New York Head leadfield (sa\_nyhead.mat, about 678 MB, Huang, Parra & Haufe 2016) to the per-user cache the first time it is needed. The file is a MATLAB v7.3 (HDF5) file and requires the **hdf5r** package to read; it is deliberately not shipped with this package.

### Usage

```
fetchNYHead(dest = NULL, quiet = FALSE, timeout = 3600)
```

**Arguments**

|         |                                                      |
|---------|------------------------------------------------------|
| dest    | Optional destination path (defaults to the cache).   |
| quiet   | Suppress the download progress bar (default: FALSE). |
| timeout | Download timeout in seconds (default: 3600).         |

**Value**

The path to the downloaded .mat file.

**References**

Huang, Y., Parra, L. C., & Haufe, S. (2016). The New York Head - a precise standardized volume conductor model for EEG source localization and tES targeting. *NeuroImage*, 140, 150-162.

**See Also**

[nyHeadLeadfield\(\)](#), [fetchFsaverage\(\)](#)

**Examples**

```
## Not run:
path <- fetchNYHead()

## End(Not run)
```

---

|                |                                                 |
|----------------|-------------------------------------------------|
| headModelCache | <i>Cache directory for head-model downloads</i> |
|----------------|-------------------------------------------------|

---

**Description**

Cache directory for head-model downloads

**Usage**

```
headModelCache()
```

**Value**

The per-user cache path (created if needed), from [tools::R\\_user\\_dir\(\)](#).

**Examples**

```
# The cache normally lives under tools::R_user_dir(); redirect it to a
# temporary directory here so the example leaves nothing behind.
old <- Sys.getenv("R_USER_CACHE_DIR", unset = NA)
Sys.setenv(R_USER_CACHE_DIR = tempdir())
headModelCache()
if (is.na(old)) Sys.unsetenv("R_USER_CACHE_DIR") else
  Sys.setenv(R_USER_CACHE_DIR = old)
```

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|           |                                                     |
|-----------|-----------------------------------------------------|
| icosphere | <i>Triangulated sphere (subdivided icosahedron)</i> |
|-----------|-----------------------------------------------------|

---

**Description**

Builds a geodesic sphere mesh by recursively subdividing an icosahedron, giving nearly uniform triangles - a convenient scalp/skull/brain surface for the BEM solver or for placing electrodes.

**Usage**

```
icosphere(subdivisions = 2L, radius = 1)
```

**Arguments**

|              |                                                                                                              |
|--------------|--------------------------------------------------------------------------------------------------------------|
| subdivisions | Number of subdivision passes (default: 2; 0 gives the 20-face icosahedron, each pass multiplies faces by 4). |
| radius       | Sphere radius (default: 1).                                                                                  |

**Value**

A list with vertices (n x 3) and faces (m x 3 integer vertex indices, outward winding).

**Examples**

```
m <- icosphere(2)
nrow(m$faces)
```

---

|              |                                                                                |
|--------------|--------------------------------------------------------------------------------|
| leadfieldRDM | <i>Relative difference measure and magnitude ratio between two lead-fields</i> |
|--------------|--------------------------------------------------------------------------------|

---

**Description**

Standard BEM validation metrics on average-referenced potentials: RDM (topography error, 0 = identical) and MAG (amplitude ratio, 1 = identical).

**Usage**

```
leadfieldRDM(test, reference)
```

**Arguments**

|                 |                                       |
|-----------------|---------------------------------------|
| test, reference | Leadfield matrices of the same shape. |
|-----------------|---------------------------------------|

**Value**

A named numeric vector c(RDM, MAG) (means over columns).

### Examples

```
e <- icosphere(2)$vertices[1:19, ]
s <- rbind(c(0, 0, 0.5), c(0.3, 0, 0.2))
lf <- sphereLeadfield(e, s)
# A leadfield compared with itself is identical: RDM 0, MAG 1.
leadfieldRDM(lf, lf)
```

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nyHeadLeadfield

Load a New York Head leadfield for a montage

---

### Description

Reads the New York Head leadfield (fetched by [fetchNYHead\(\)](#)) and extracts the sub-leadfield for a set of electrode labels, in the  $n\_electrodes \times (n\_sources * 3)$  convention used across the ecosystem. Requires the **hdf5r** package and the downloaded .mat; both are optional, so this errors informatively when either is missing.

### Usage

```
nyHeadLeadfield(montage_labels, path = NULL, normal_only = FALSE)
```

### Arguments

**montage\_labels** Character vector of electrode labels to extract.

**path** Path to sa\_nyhead.mat (defaults to the cached download).

**normal\_only** Return the surface-normal-constrained leadfield ( $n\_electrodes \times n\_sources$ ) instead of the free-orientation one (default: FALSE).

### Value

A list with leadfield, source\_positions, source\_normals, electrode\_labels, and electrode\_index.

### See Also

[fetchNYHead\(\)](#)

### Examples

```
## Not run:
lf <- nyHeadLeadfield(c("C3", "C4", "Cz"))
dim(lf$leadfield)

## End(Not run)
```

---

|            |                                                                               |
|------------|-------------------------------------------------------------------------------|
| solidAngle | <i>Solid angle subtended by a triangle at a point (van Oosterom-Strackee)</i> |
|------------|-------------------------------------------------------------------------------|

---

**Description**

Solid angle subtended by a triangle at a point (van Oosterom-Strackee)

**Usage**

```
solidAngle(v1, v2, v3, r)
```

**Arguments**

|            |                                     |
|------------|-------------------------------------|
| v1, v2, v3 | Numeric length-3 triangle vertices. |
| r          | Numeric length-3 observation point. |

**Value**

The signed solid angle in steradians.

**Examples**

```
# One face of the unit octahedron, seen from the centre, spans an eighth
# of the full sphere: pi / 2 steradians.
solidAngle(c(1, 0, 0), c(0, 1, 0), c(0, 0, 1), c(0, 0, 0))
```

---

|                 |                                             |
|-----------------|---------------------------------------------|
| sphereLeadfield | <i>Analytic single-sphere EEG leadfield</i> |
|-----------------|---------------------------------------------|

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**Description**

Computes the leadfield for a homogeneous conducting sphere with an insulating outer boundary, using the Legendre-series solution (the classic analytic forward model, e.g. FieldTrip's single sphere). Each source contributes three contiguous columns (x, y, z unit dipoles).

**Usage**

```
sphereLeadfield(electrodes, sources, radius = 1, sigma = 0.33, n_terms = 60L)
```

**Arguments**

|            |                                                                                     |
|------------|-------------------------------------------------------------------------------------|
| electrodes | An n_electrodes x 3 matrix of electrode positions (on the sphere of radius radius). |
| sources    | An n_sources x 3 matrix of dipole positions (inside the sphere).                    |
| radius     | Sphere radius (default: 1).                                                         |
| sigma      | Conductivity in S/m (default: 0.33).                                                |
| n_terms    | Legendre series truncation (default: 60).                                           |

**Value**

An  $n_{\text{electrodes}} \times (n_{\text{sources}} * 3)$  leadfield matrix.

**Examples**

```
e <- icosphere(2)$vertices[1:19, ]
s <- rbind(c(0, 0, 0.5), c(0.4, 0, 0.2))
dim(sphereLeadfield(e, s))
```

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sphericalSourceSpace    *Spherical cortical source space*

---

**Description**

Places dipole sources on a sphere (a spherical-cortex approximation), returning vertex positions and outward surface normals - the structured source space a realistic forward model uses in place of a random source cloud.

**Usage**

```
sphericalSourceSpace(n_sources = 400L, radius = 0.7)
```

**Arguments**

|                        |                                               |
|------------------------|-----------------------------------------------|
| <code>n_sources</code> | Approximate number of sources (default: 400). |
| <code>radius</code>    | Source-shell radius (default: 0.7).           |

**Value**

A list with positions ( $n \times 3$ ) and normals ( $n \times 3$ , unit radial).

**Examples**

```
ss <- sphericalSourceSpace(200)
nrow(ss$positions)
```

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