The bifactor package

Marcos Jiménez [1] Francisco J. Abad [1] Eduardo Garcia-Garzon [2]
Luis E. Garrido [3] [4] Vithor R. Franco

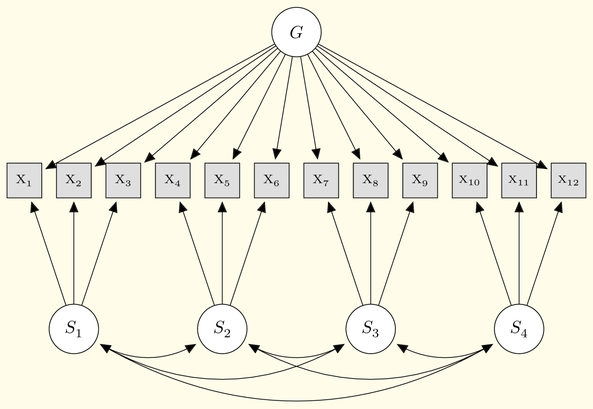
[1] Universidad Autónoma de Madrid, Spain [2] Shakers, Spain
[3] Pontificia Universidad Católica Madre y Maestra, Dominican Republic
[4] Universidade São Francisco, Brazil

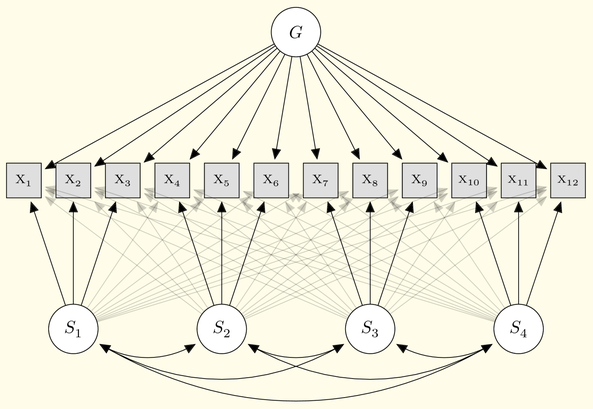
Universidad Autónoma de Madrid
Psychometric Models & Applications Lab.

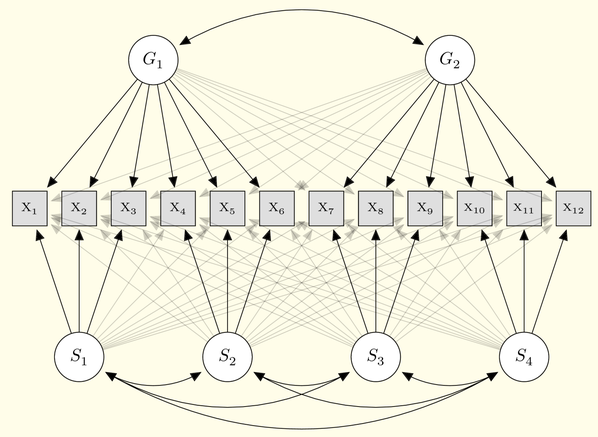
Available methods: Bifactor Analyses and beyond

Simple Models ..... **Complex Models**

Confirmatory Bi-factor | **Exploratory Bi-factor** | **Multiple General Factors (Exploratory)**







CFA functions

```
cfast(data, model, estimator, ...)
```

model: Specify any kind of model and constraint
estimator: ML, ULS, GLS, DWLS

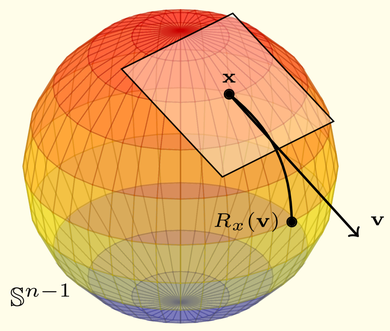
EFA functions

```
efast(data, nfactors, estimator, rotation, projection, ...)
bifactor(data, nfactors, estimator, projection, ...)
rotate(lambda, rotation, projection, ...)
```

estimator: ML, ULS, GLS, DWLS
rotation: Oblimin, Geomin, Target, Crawford-Ferguson, Bi-quartimin, Bi-geomin, etc.
projection: Orthogonal, Oblique, **Partially Oblique (New rotation only in `bifactor`!)**

Proper model identification

Constrained Optimization on Manifolds



The Partially Oblique Manifold

A square matrix $\mathbf{\Phi}$ is parametrized as $\mathbf{X}^\top\mathbf{X}$ to **ensure positive semi-definiteness** but specific cells in $\mathbf{\Phi}$ are **constrained to be zero**.

The Role of the Partially Oblique Rotation in EFA

- In **Bifactor models**, the general factors must be **uncorrelated** with the specific factors to obtain an interpretable solution.
- In **Multitrait-Multimethod designs**, the trait factors must be **uncorrelated** with the method factors.
- The `rotate` function achieves these goals thanks to the **partially oblique rotation**.

`warning: covariance matrix of latent variables is not positive definite`

- Using the `cfast` function, no warning messages will pop up for confirmatory factor analyses!
- With the **partially oblique manifold**, the matrices will always be, at least, positive semidefinite.

Extremely Fast and Accurate Convergence

Polychorics estimation

```
polyfast(X, cores, ...)
```

- **Thousands of times faster** than popular alternatives thanks to its **C++ implementation**.
- Estimation of the **correlations between hundreds of variables in very few seconds**.
- Even faster if **parallelizing** with the `cores` argument.
- **No need for smoothing**. The solution is always, at least, positive semidefinite.
- Use the function `parallel` for **fast parallel analysis** with polychorics.

EFA estimation

```
efast(data, nfactors, estimator, rotation, projection, cores, ...)
```

- **Very fast rotation** thanks to Newton-based optimization routines and their **C++ implementation**.
- Arbitrary number of random starts to **avoid local minima** in the rotation.
- **Parallelization** of the random starts with the `cores` argument.
- **No Heywood cases**.
- Great documentation and examples.

Additional Features and Next Developments

Additional Features

- SEM features: **Multigroup estimation (invariance) and correlated errors** for both confirmatory and exploratory models.
- **Robust standard errors** to non-normality and population error.
- **Mixed rotations**: In EFA, different rotation criteria can be combined or applied to different items and factors.
- **Fit indices, reliability, and indeterminacy** values available for all fitting functions.
- **Simulation** of realistic and complex structures **with population error** with the `sim_factor` function.

RoadMap

- Expanding the `cfast` and `efast` functions to the SEM and ESEM frameworks: latent regressions, outcomes, predictors, etc.
- Creating utilities and apps to visualize the model and its parameter estimates, fit, predictions, etc.
- Developing new rotation criteria for bifactor modeling.
- **Developing a new projection method to conduct Partial Invariance in EFA** (i.e., for specific loadings).
- Submitting to CRAN.