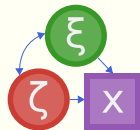
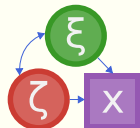


Extensible Software for Research



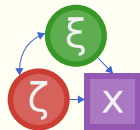
Contents

- Principles of Extensible Research Software
- Application: StructuralEquationModels.jl



A day in the life of ...

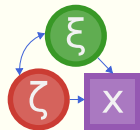
a statistical methods researcher



A day in the life of ...

a statistical methods researcher

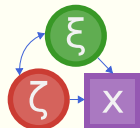
- work with a specific type of model
 - regression, structural equation models, deep learning, ...



A day in the life of ...

a statistical methods researcher

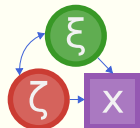
- work with a specific type of model
 - regression, structural equation models, deep learning, ...
- have an idea



A day in the life of ...

a statistical methods researcher

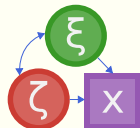
- work with a specific type of model
 - regression, structural equation models, deep learning, ...
- have an idea
- test it



A day in the life of ...

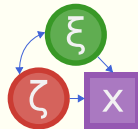
a statistical methods researcher

- work with a specific type of model
 - regression, structural equation models, deep learning, ...
- have an idea
- test it
- make it available to applied researchers



We need to write Software

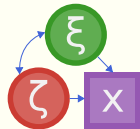
- to test \rightarrow prototype
- to make it available \rightarrow distribute



We need to write Software

- to test \rightarrow prototype
- to make it available \rightarrow distribute

What's the fastest way to get there?



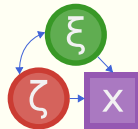
We need to write Software

❏ to test → prototype

❏ to make it available → distribute

What's the fastest way to get there?

We are already working with existing software.



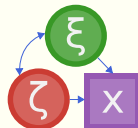
We need to write Software

- to test \rightarrow prototype
- to make it available \rightarrow distribute

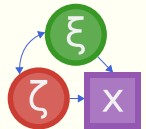
What's the fastest way to get there?

We are already working with existing software.

It would be nice if we could extend existing software!

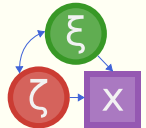


But ...



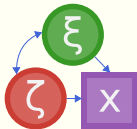
But ...

- **understand** 1000s of lines of code



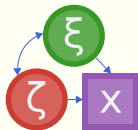
But ...

- **understand** 1000s of lines of code
- make **changes**, possibly breaking stuff



But ...

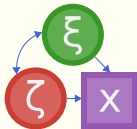
- **understand** 1000s of lines of code
- make **changes**, possibly breaking stuff
- get maintainers to **adopt** our changes



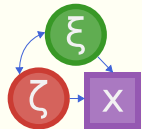
But ...

- **understand** 1000s of lines of code
- make **changes**, possibly breaking stuff
- get maintainers to **adopt** our changes

These hurdles are often too high!

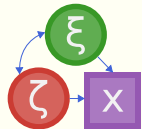


A day in the life of ...



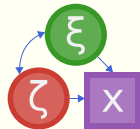
A year in the life of ...

- ✚ to test: minimal reimplementation
 - ✚ waste of time
 - ✚ not well tested
 - ✚ hard to reproduce
 - ✚ slow




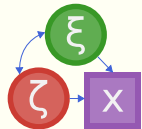
A year in the life of ...

- ❏ to test: minimal reimplementation
 - ❖ waste of time
 - ❖ not well tested
 - ❖ hard to reproduce
 - ❖ slow
- ❏ to deploy: put code on github
 - ❖ bad user interface, no documentation
 - ❖ missing features
 - ❖ incompatible to existing software



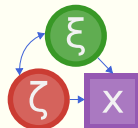
My Experience

from R → 



Culture

- care about extensibility
- developer documentation
- assume their code is read



An Example

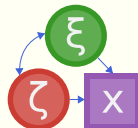
Let's make a thought experiment...

❏ encyclopedia

- ❖ add an entry
- ❖ some syntactical requirements
300-400 words, alphabetical, ...

❏ book

- ❖ a draft already exists
- ❖ add something everywhere it is applicable



An Example

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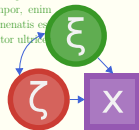
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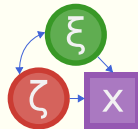
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Software Design

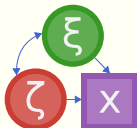
Not all research articles can be encyclopedias, but maybe all research software can be...



Software Design

You need to be able to add new features...

- without **understanding** existing code
- without **changing** existing code
- syntactical requirements need to be **clear** and **easy communicable!**



The Benefits

Applied Researchers

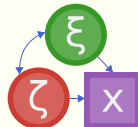
- ✧ user interface
- ✧ better documentation
- ✧ faster availability of new features
- ✧ less bugs
- ✧ higher performance

Statistical Researchers

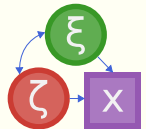
- ✧ no re-implementation → less time-consuming
- ✧ more users
- ✧ no software engineering skills needed

Maintainers

- ✧ changes are easier to integrate

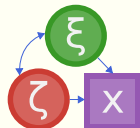


Less Abstract



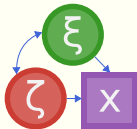
A few days in a methods researchers life

- ❏ Do you have any ideas why this does not converge?
- ❏ Staring puzzled at the theory (should work?!).
- ❏ Staring very puzzled at the implementation in C++.
- ❏ Rinse and repeat for a couple of days and researchers.



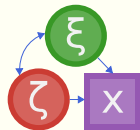
An hour in our life

- Look at the formula: $\text{ridge}(x, \lambda) = \lambda \sum_{j=1}^p x^2$
- Implement in Julia: `ridge(x, λ) = λ * sum(x.^2)`
- add 30 lines of API (formal requirements)
- Enjoy.



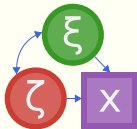
Two hours in our life

- Simulation in Juila works (converges as it should)



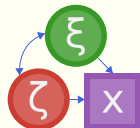
Two hours in our life

- ❏ Simulation in Juila works (converges as it should)
- ❏ Original simulation takes weeks on a dedicated workstation.
- ❏ Original simulation freezes our cluster due to poor parallelization.
- ❏ Simulation in Julia takes 2 hours on my laptop.



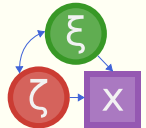
Why?

- Some investments in extensibility
- division of labor:
 - optimizing linear algebra is done by Intel
 - numerical optimization is done by dedicated experts
 - differentiation is automated
- modern infrastructure



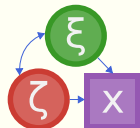
But why?

convenience

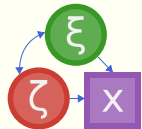
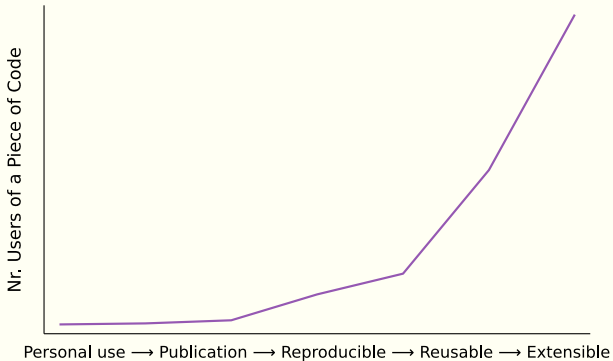


How to improve convenience?

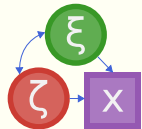
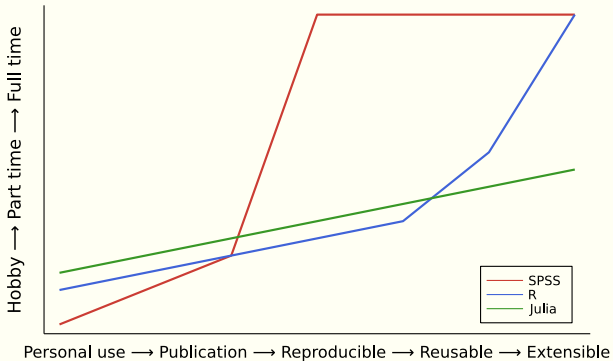
1. Extensible Software
2. Documentation
3. User Interface



The leverage of extensible software

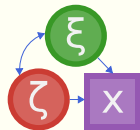


Time is limited



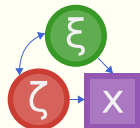
Documentation

- Documentation for users
- Documentation for contributors/developers



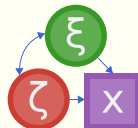
Documentation

- Documentation for users
- Documentation for contributors/developers
- Documentation is not always called documentation (e.g. papers/talks/blog posts)



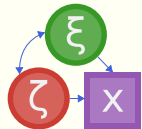
Documentation

- ❏ Documentation for users
- ❏ Documentation for contributors/developers
- ❏ Documentation is not always called documentation (e.g. papers/talks/blog posts)
- ❏ Code itself is the best developer documentation

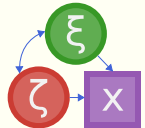


User Interface

- Frictionless
- Connected to prior knowledge



More Concrete



StructuralEquationModels.jl

