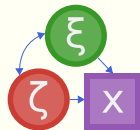
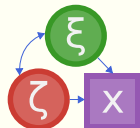


Extensible Software for Research



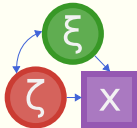
Contents

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



A day in the live of ...

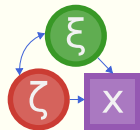
a statistical methods researcher



A day in the live of ...

a statistical methods researcher

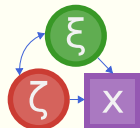
- work with a specific type of model
 - regression, structural equation models, deep learning, ...



A day in the live of ...

a statistical methods researcher

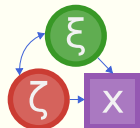
- work with a specific type of model
 - regression, structural equation models, deep learning, ...
- have an idea



A day in the live of ...

a statistical methods researcher

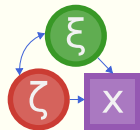
- work with a specific type of model
 - regression, structural equation models, deep learning, ...
- have an idea
- test it



A day in the live of ...

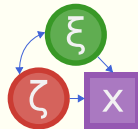
a statistical methods researcher

- 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

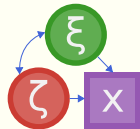
- to test \rightarrow prototype
- to make it available \rightarrow distribute



We need to write Software

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

What's the fastest way to get there?



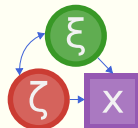
We need to write Software

❏ to test → prototype

❏ to make it available → distribute

What's the fastest way to get there?

We are already working with existing software.



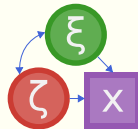
We need to write Software

- to test → prototype
- to make it available → distribute

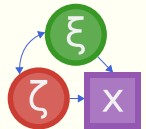
What's the fastest way to get there?

We are already working with existing software.

It would be nice if we could extend existing software!

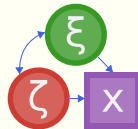


But ...



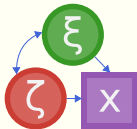
But ...

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



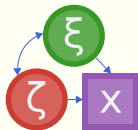
But ...

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



But ...

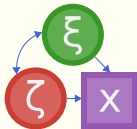
- **understand** 1000s of lines of code
- make **changes**, possibly breaking stuff
- get maintainers to **adopt** our changes



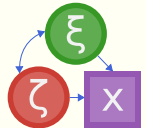
But ...

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

these hurdles are often too high!

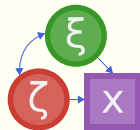


A day in the live of ...



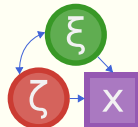
A year in the live of ...

- ✚ to test: barebone, minimal reimplementatation
 - ✚ waste of time
 - ✚ not well tested
 - ✚ hard to reproduce
 - ✚ slow




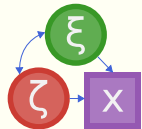
A year in the live of ...

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



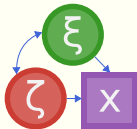
My Experience

from R → 



Culture

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



An Example

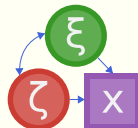
Let's make a thought experiment...

❏ The 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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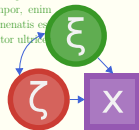
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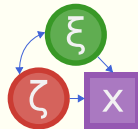
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Software Design

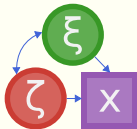
Not all research articles can be encyclopedias, but maybe all research software can be...



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 communicatable!**



The Benefits

Applied Researchers

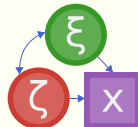
- ✧ user interface
- ✧ better documentation
- ✧ faster availability of new features
- ✧ less bugs
- ✧ higher performance

Statistical Researchers

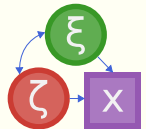
- ✧ no re-implementation → less time-consuming
- ✧ more users
- ✧ no software engineering skills needed

Maintainers

- ✧ changes are easier to integrate

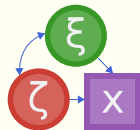


Less Abstract



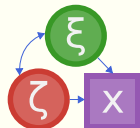
A few days in a methods researchers life

- ❖ 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.



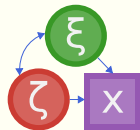
An hour in our life

- 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.



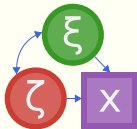
Two hours in our life

- Simulation in Juila works (converges as it should)



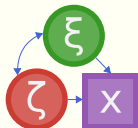
Two hours in our life

- ❏ 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.



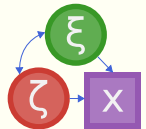
Why?

- 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



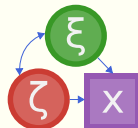
But why?

convenience

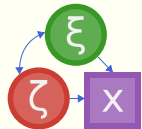
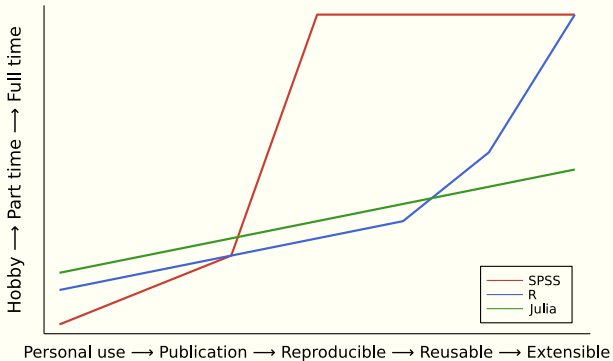


How to improve convenience?

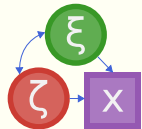
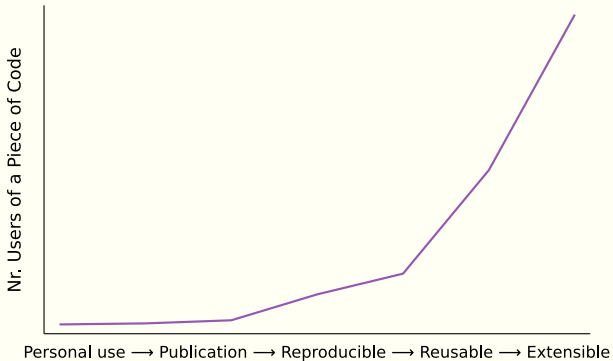
1. Extensible Software
2. Dokumentation
3. User Interface



Time is limited

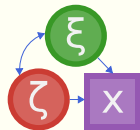


The leverage of extensible software



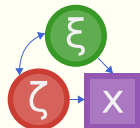
Documentation

- Documentation for users
- Documentation for contributors/developers



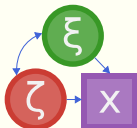
Documentation

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



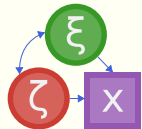
Documentation

- 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

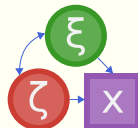


User Interface

- Frictionless
- Connected to prior knowledge



Less Abstract



StructuralEquationModels.jl

