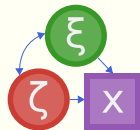
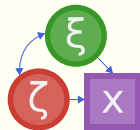


# Extensible Software for Research



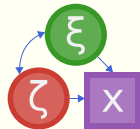
# Contents

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



# A day in the live of ...

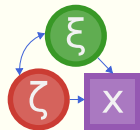
a statistical methods researcher



# A day in the live of ...

a statistical methods researcher

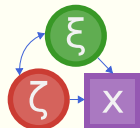
- work with a specific type of model
  - regression, structural equation models, deep learning, ...



# A day in the live of ...

a statistical methods researcher

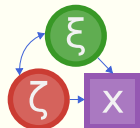
- work with a specific type of model
  - regression, structural equation models, deep learning, ...
- have an idea



# A day in the live of ...

a statistical methods researcher

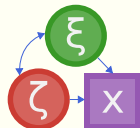
- work with a specific type of model
  - regression, structural equation models, deep learning, ...
- have an idea
- test it



# A day in the live of ...

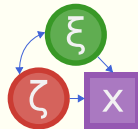
a statistical methods researcher

- 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

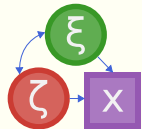




# We need to write Software

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

What's the fastest way to get there?

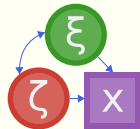


# We need to write Software

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

What's the fastest way to get there?

We are already working with existing software.



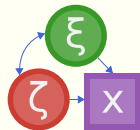
# We need to write Software

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

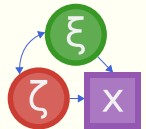
What's the fastest way to get there?

We are already working with existing software.

**It would be nice if we could extend existing software!**

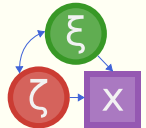


# But ...



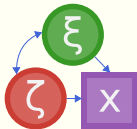
# But ...

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



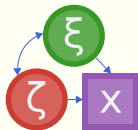
# But ...

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



# But ...

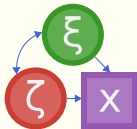
- **understand** 1000s of lines of code
- make **changes**, possibly breaking stuff
- get maintainers to **adopt** our changes



# But ...

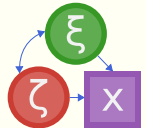
- **understand** 1000s of lines of code
- make **changes**, possibly breaking stuff
- get maintainers to **adopt** our changes

**these hurdles are often too high!**



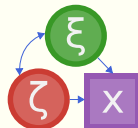


# A day in the live of ...



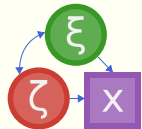
# A year in the live of ...

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



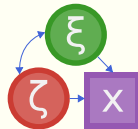
# A year in the live of ...

- ❏ 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



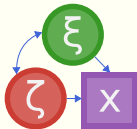
# My Experience

from R → **julia**



# Culture

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



# An Example

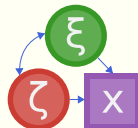
Let's make a thought experiment...

## ❏ 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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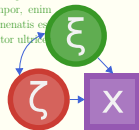
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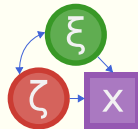
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# Software Design

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

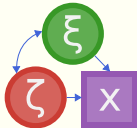




# Software Design

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

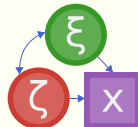
- ✦ user interface
- ✦ better documentation
- ✦ faster availability of new features
- ✦ less bugs
- ✦ higher performance

## Statistical Researchers

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

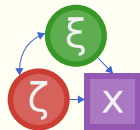
## Maintainers

- ✦ changes are easier to integrate



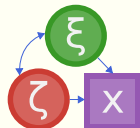
# A few days in a methods researchers life

- ❏ 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.



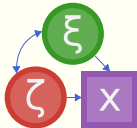
# An hour in our life

- 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.



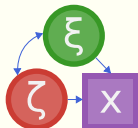
# Two hours in our life

- ❏ 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.



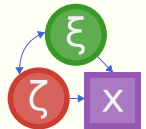
# Why?

- ❖ 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

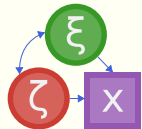
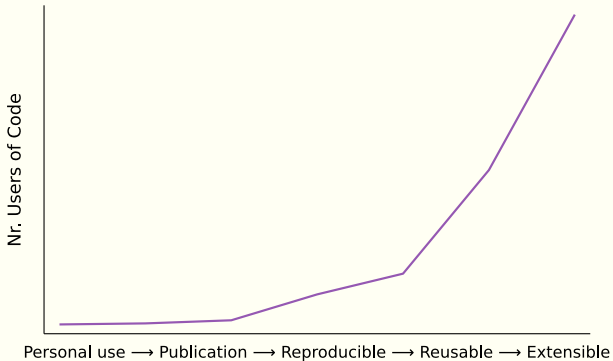


# But why?

convenience



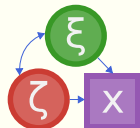
# The leverage of extensible software



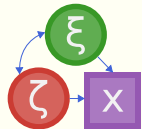
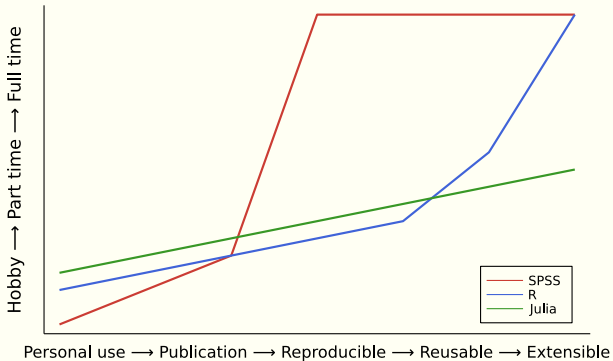


# How to improve convenience?

1. Extensible Software
2. Dokumentation
3. User Interface

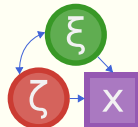


# Time is limited



# Dokumentation

- Dokumentation for users
- Dokumentation for contributors/developers



# User Interface

- Frictionless
- Connected to prior knowledge

