Communicating Relational Thinking

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FMCS 2024, Kananaskis
July 11

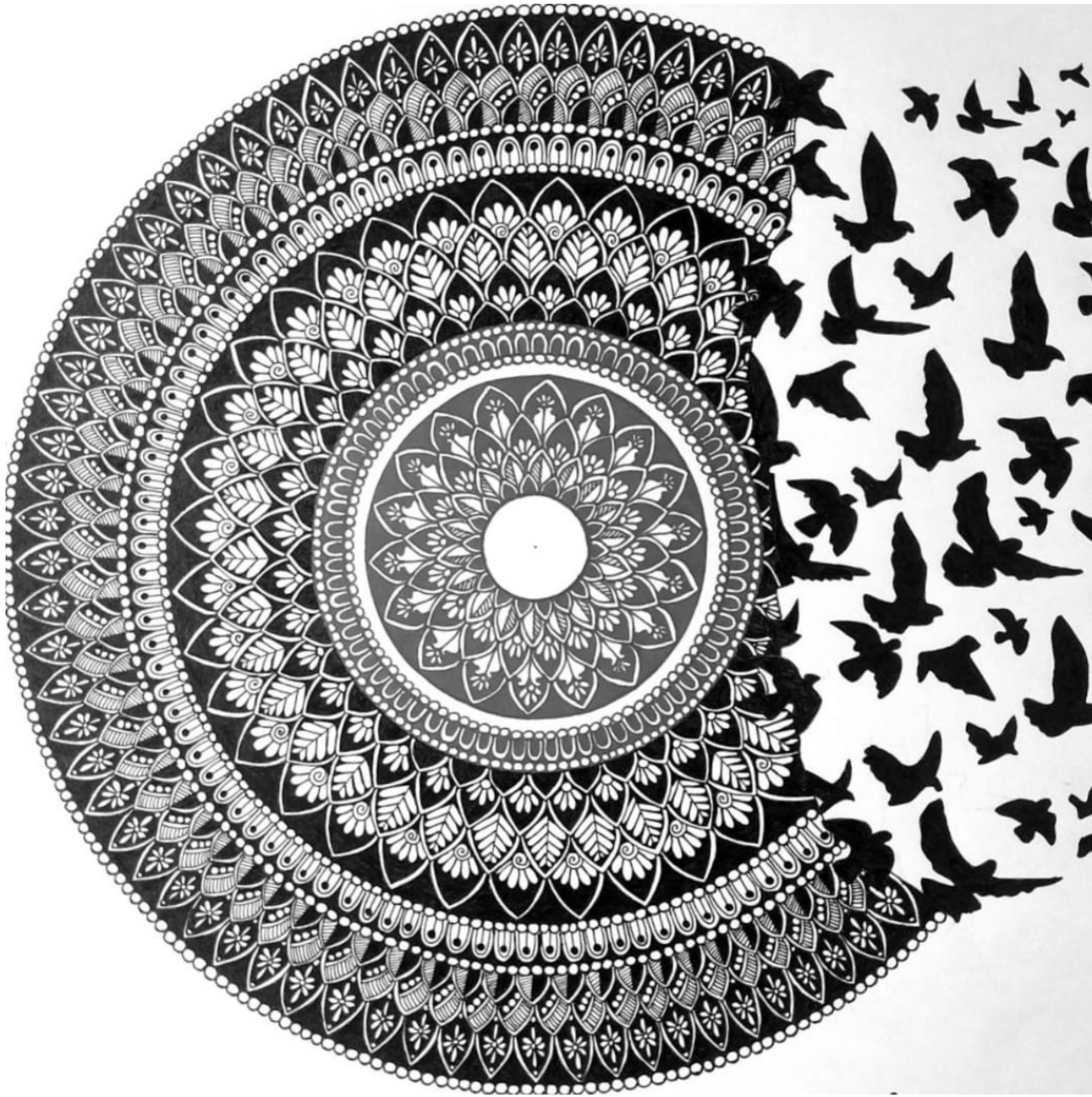
🥳 Announcement 🥳

The senate of Tallinn University of Technology has decided to bestow Robin the title of Doctor Honoris Causa (Honorary Ph.D.) on Jan 23, 2024 for his (awesome) research in Category Theory and his services to the community.

The conferral ceremony will take place on Sep 17, 2024.

Compassionate mathematics

Compassionate Math acknowledges that different learners take different roads to understanding the same mathematical idea and encourages one to consider this inherent plurality of thought patterns when communicating mathematics.



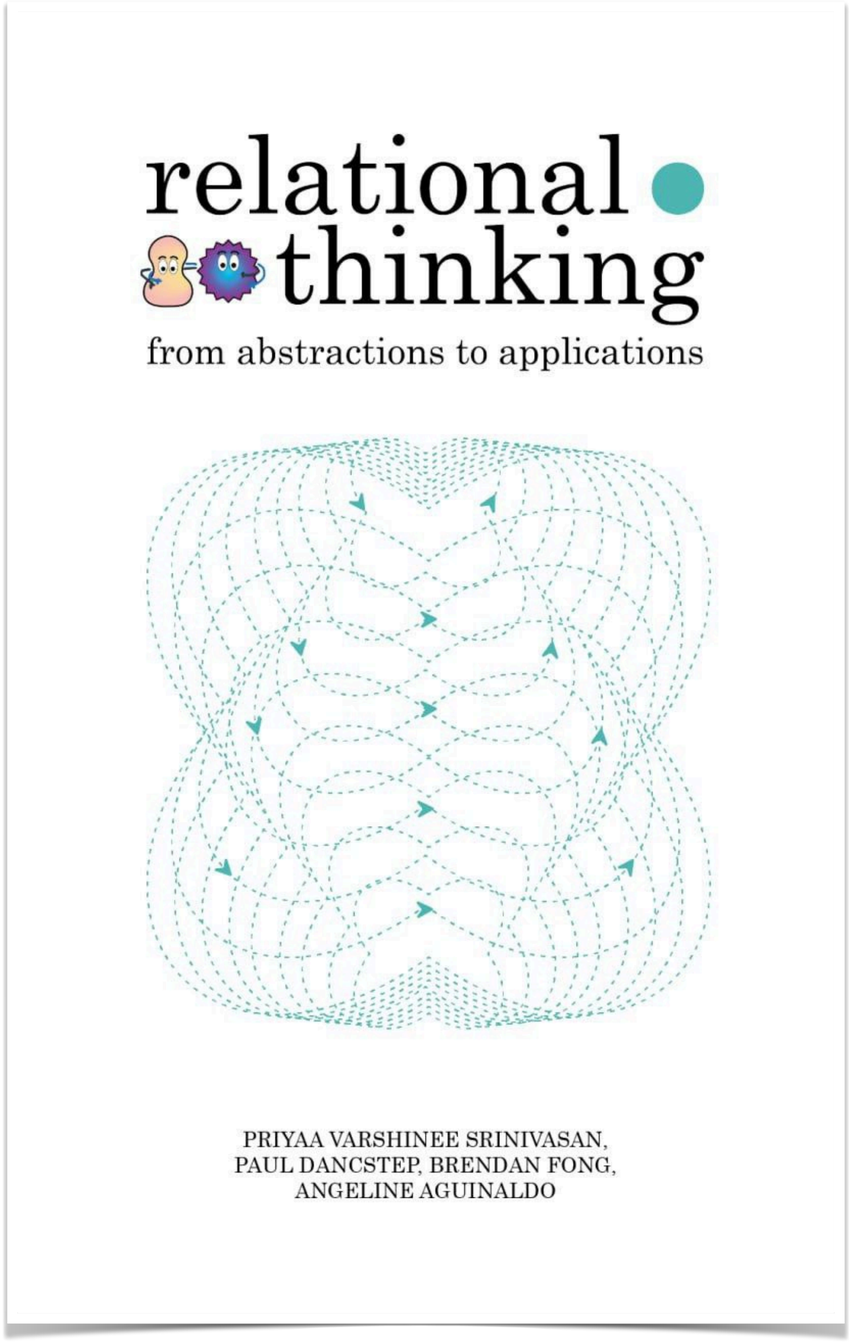
Compassionate Math club

- Compassionate Math seminar series - In this monthly seminar series, we talk about math we do not get to hear in the usual talks. The talks in this series will be somewhere in between a technical talk and a podcast, moderately formal. https://researchseminars.org/seminar/CompMath

- Talks are recorded and available at the @Relatorium YouTube channel

- AMS Special Session on Tools and methods of compassionate math at the Joint Mathematics Meeting (JMM) 2025, Seattle - https://jointmathematicsmeetings.org/meetings/national/jmm2025/2314_progfull.html. If you are interested in submitting an abstract for a talk, please contact me priyaavarshinee@gmail.com.

My personal website: www.priyaa.org



https://tinyurl.com/RThinking

Free online interactive book on categorical thinking and implementation

1. Content

2. Technology

Joint work with

Angeline
Ph.D. candidate
Univ. Maryland

Paul
Illustrator
Category theory enthusiast

Brendan
CEO
Topos Institute

Priyaa
Postdoc
Topos Institute

1. Content

Algebraic Julia

- Julia is a fast, high-level, programming language ideal for machine learning, data mining, and other computational sciences.

- Algebraic Julia is a programming library for Julia language

- (Naively) It provides categorical data structures for modeling systems in the Julia language

Mission: *to create novel approaches to scientific computing based on applied category theory*

Website*:* https://www.algebraicjulia.org/

The landscape of AlgebraicJulia

Package	Description
Catlab.jl	Data structures, algorithms, visualization, computer algebra
AlgebraicDynamics.jl	Open dynamical systems
AlgebraicPetri.jl	Petri nets operations, including rate equation simulation
AlgebraicRewriting.jl	Rewriting systems for combinatorial data structures
AlgebraicRelations.jl	Database integration
CombinatorialSpaces.jl	Meshes for PDEs
Decapodes.jl	Discrete Exterior Calculus
StockFlow.jl	Stockflow diagrams and simulations
Semagrams.jl	User interfaces built around graphical syntax (Scala.js+Julia)

I want support to develop learning material on Algebraic Julia

Sometime in 2022 ...

Sure, here is some money! But, make the material inclusive!

This project was by a grant from Mozilla Internet Ecosystem Program
To advance the internet and
To ensure it remains a force of good

In Nov 2023 …

An inclusive online material on Algebraic Julia

In Nov 2023 …

Categorical thinking

Programming

An inclusive online material on Algebraic Julia

We do not have to worry about not having enough to say! Lets simplify as much as possible!

Whew, OK!!

“Simplicity is the key”

We do not have to worry about not having enough to say! Lets simplify as much as possible!

Whew, OK!!

“Simplicity is the key”

Use approachable layman language

We do not have to worry about not having enough to say! Lets simplify as much as possible!

Whew, OK!!

“Simplicity is the key”

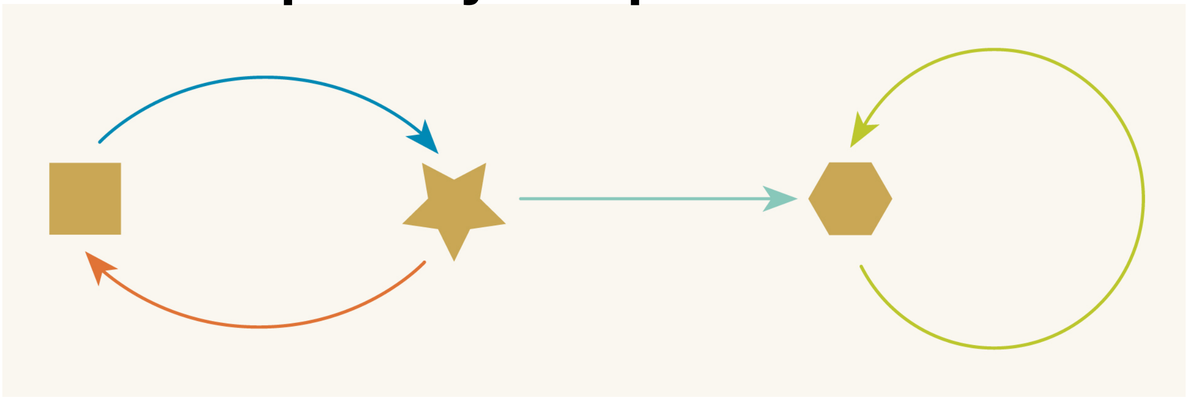
Use approachable layman language

We rephrased category theory to

relational thinking

from abstractions to applications

Our primary computational tool



“Simplicity is the key”

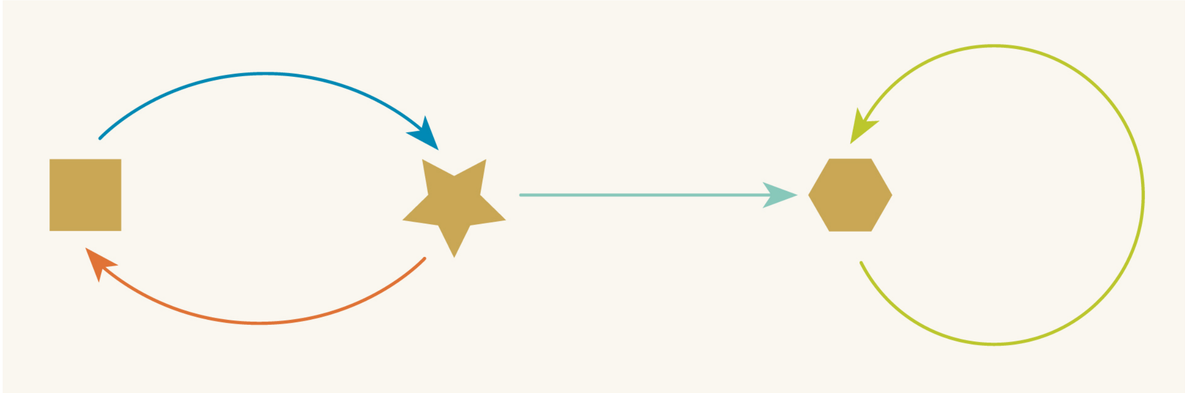
Use approachable layman language

We rephrased category theory to

relational thinking

from abstractions to applications

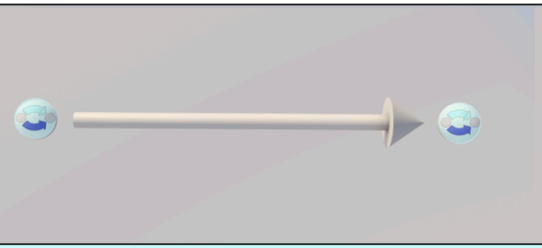
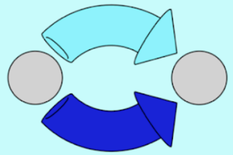
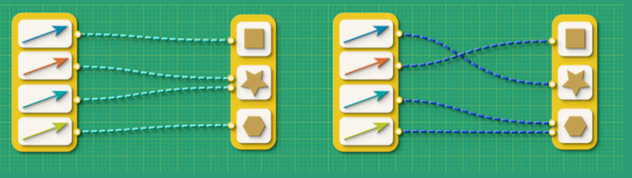
Central concept used to demonstrate the goodness of relational thinking



Double pushout rewriting on directed graphs

One cannot teach relational thinking but
can inspire relational thinking by showing its value

Plot of the book

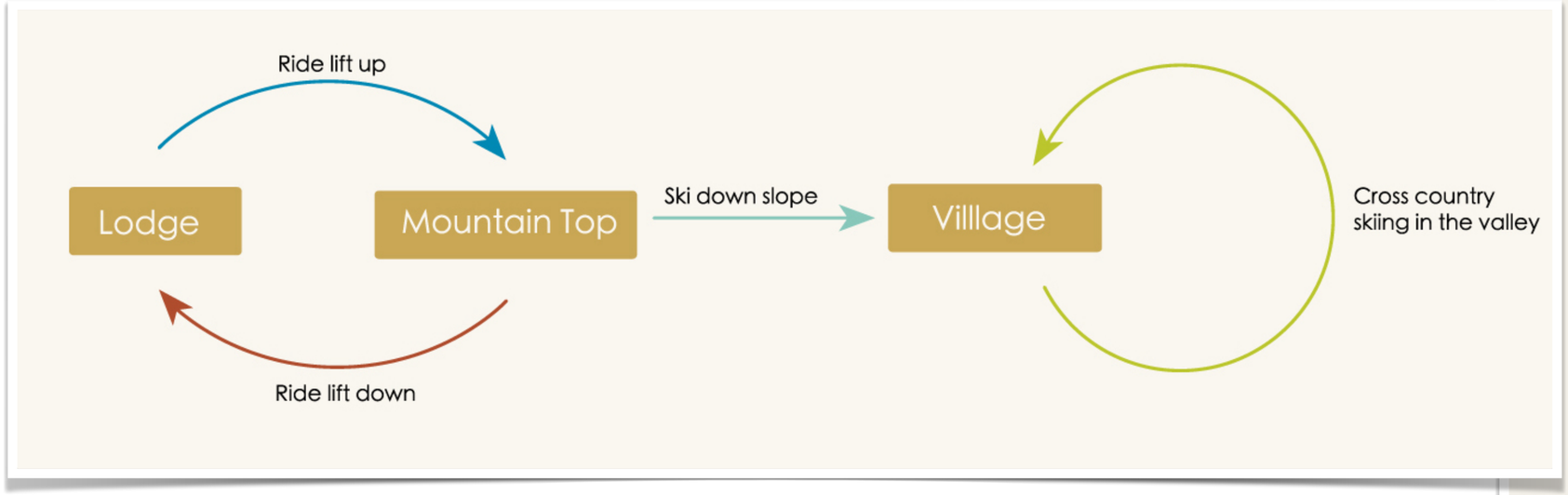
Our ladder of abstractions	
	**rung 4:** categories
	**rung 3:** blueprints
	**rung 2:** data
	**rung 1:** directed graphs

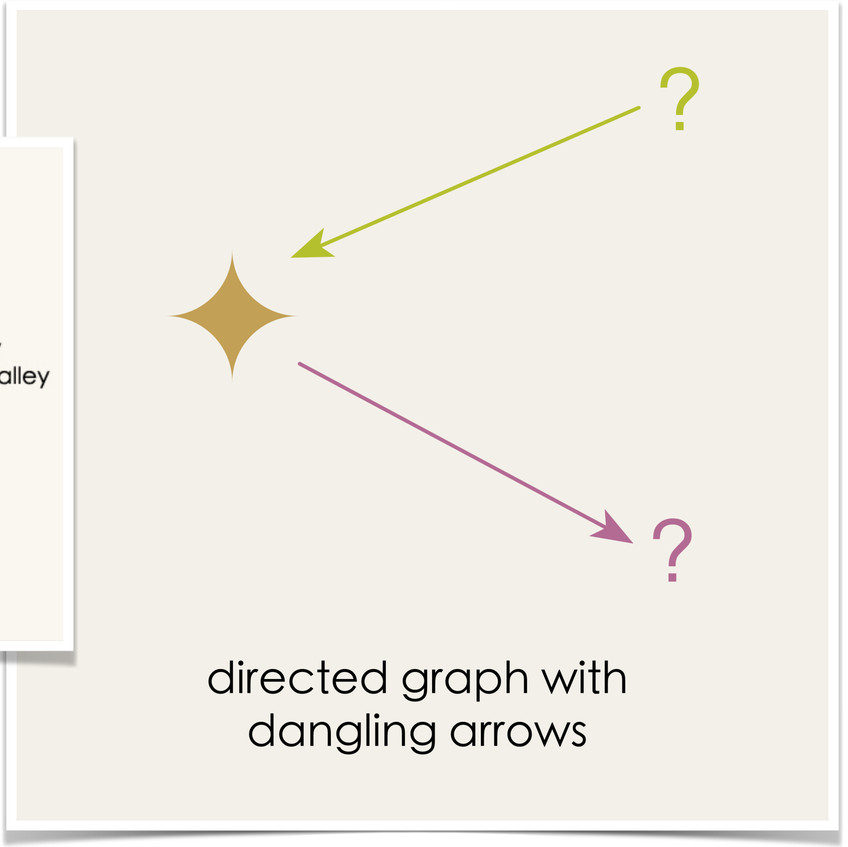
Computational

Visual

Rung 1: Directed graphs

Setting up the problem: Updating graphs as underlying situation changes



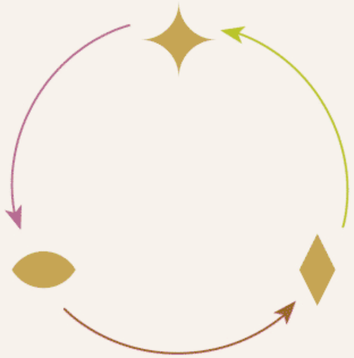


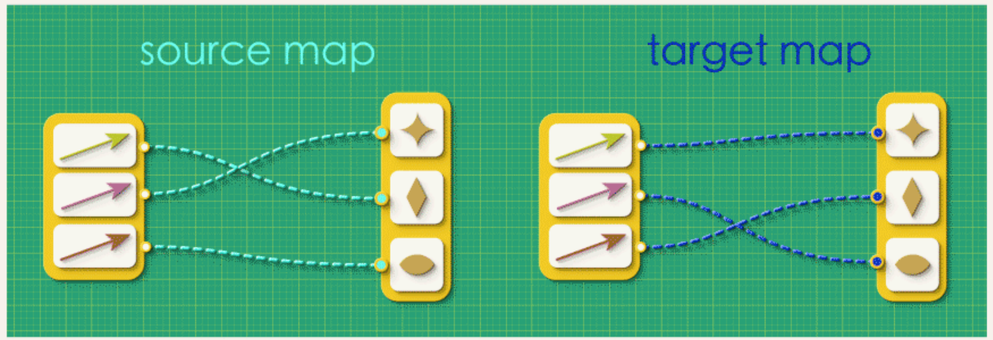
Chapter 0 : Directed Graphs

Rung 2: Data

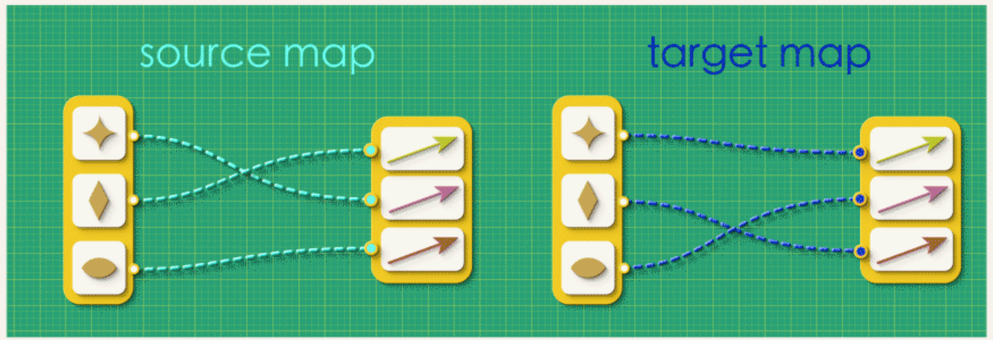
Chapter 1: Data

Finding a good abstraction early on is necessary



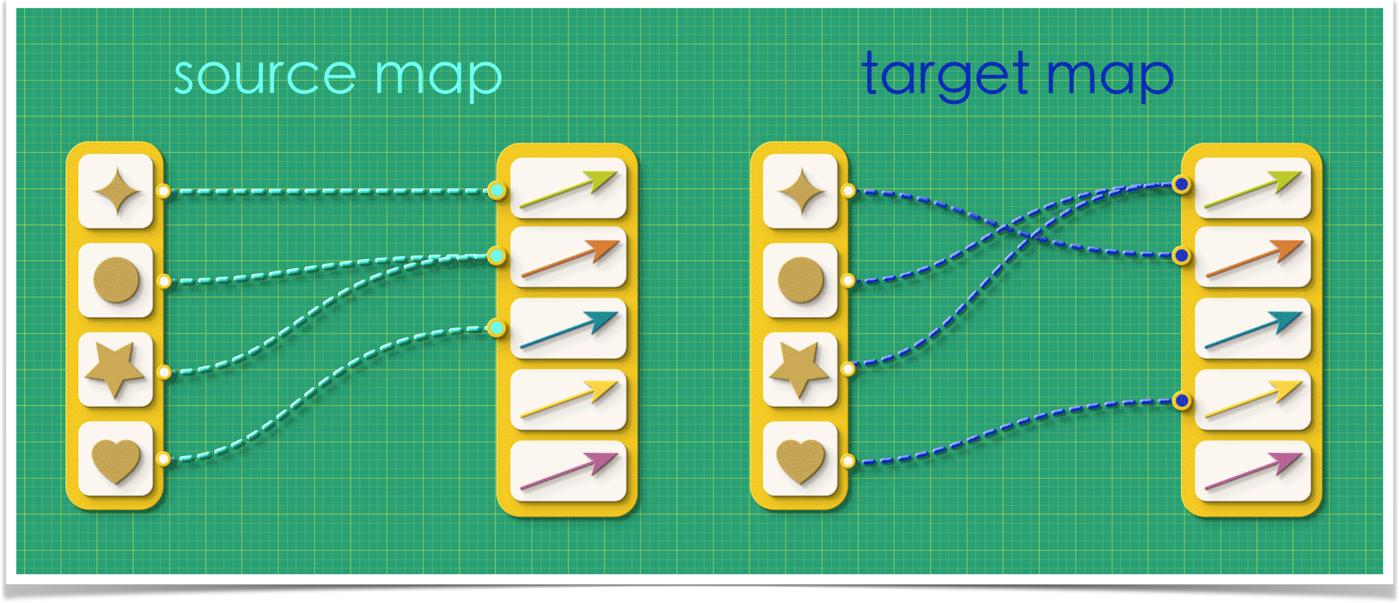


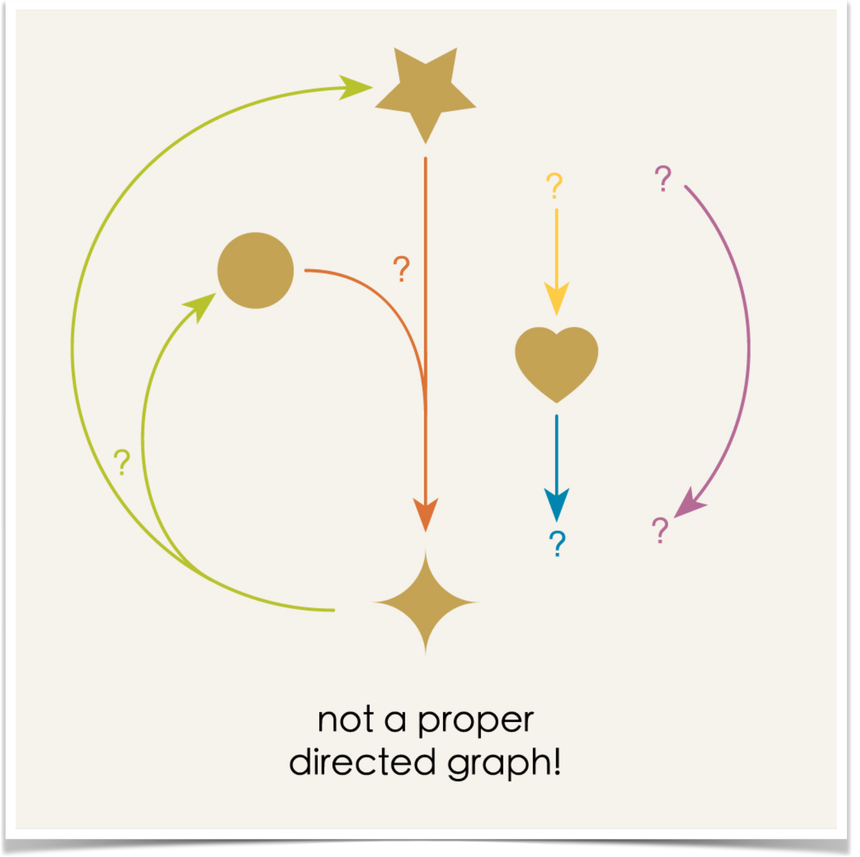
arrows first



vertices first

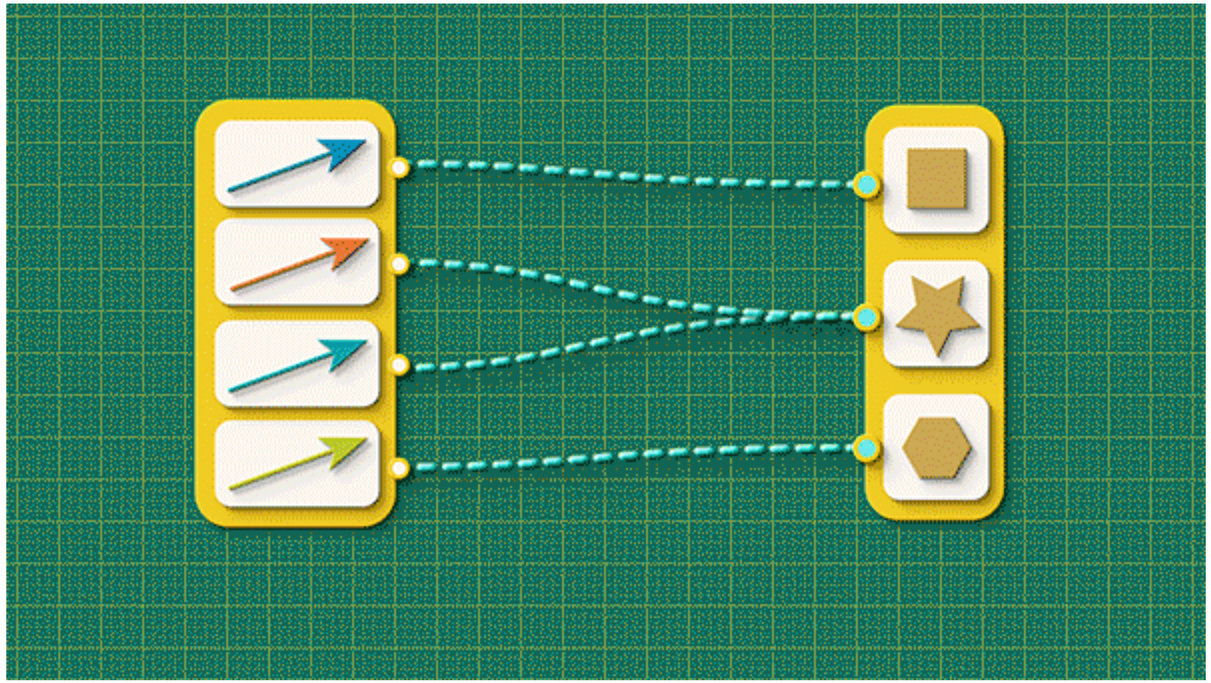
Finding the right abstraction





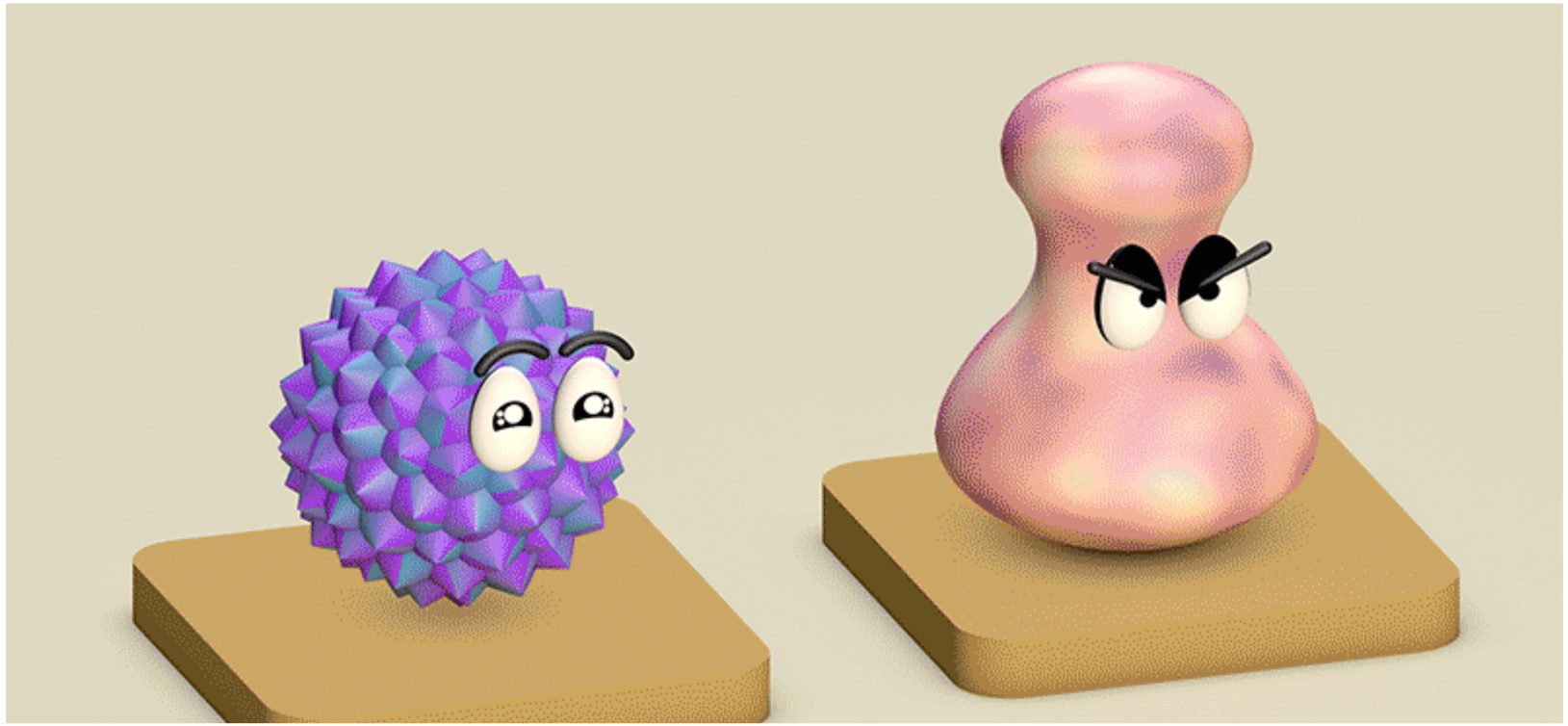
Rung 3: Blueprints

Chapters 3 and 4: Blueprints



Interlude: Dynamical systems

Chapter 2 : Dynamical systems with Kiki and Bouba

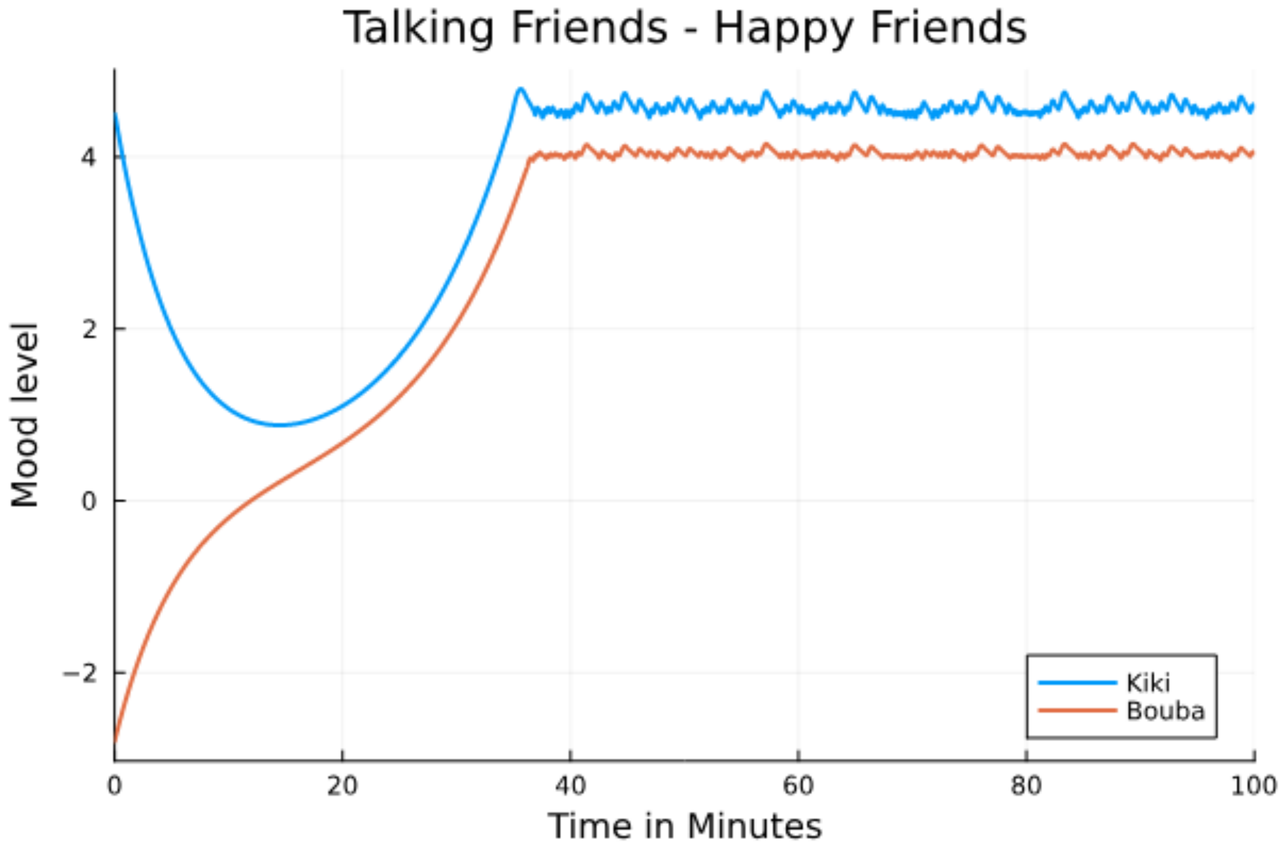


Two friends talking to each other

How does their mood levels change over time?

Interlude: Modeling Dynamical systems

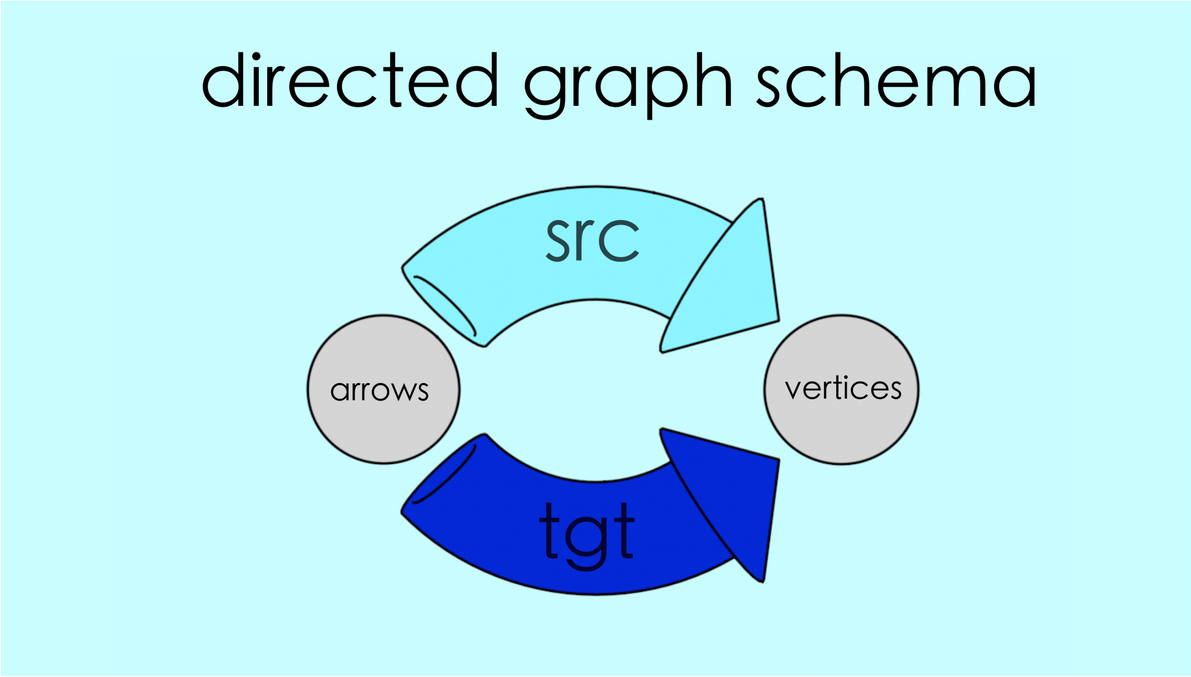
Chapter 2 : Dynamical systems with Kiki and Bouba

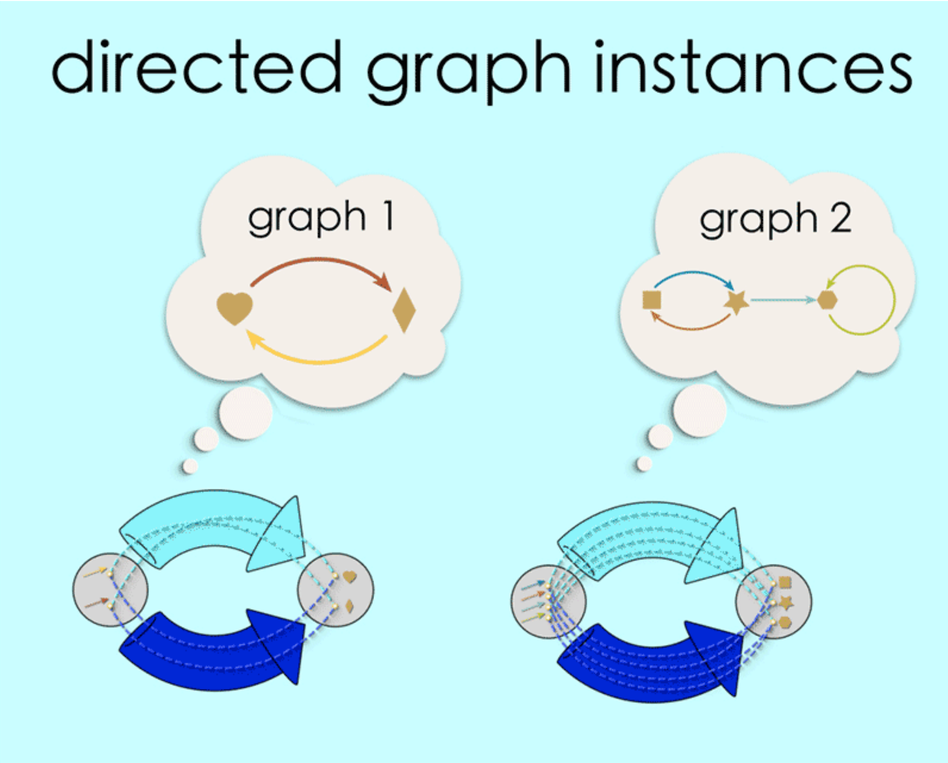


Generated using Algebraic dynamics package

Rung 3: Blueprints

Chapter 3 and Chapter 4

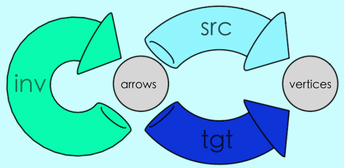




Rung 4: Categories

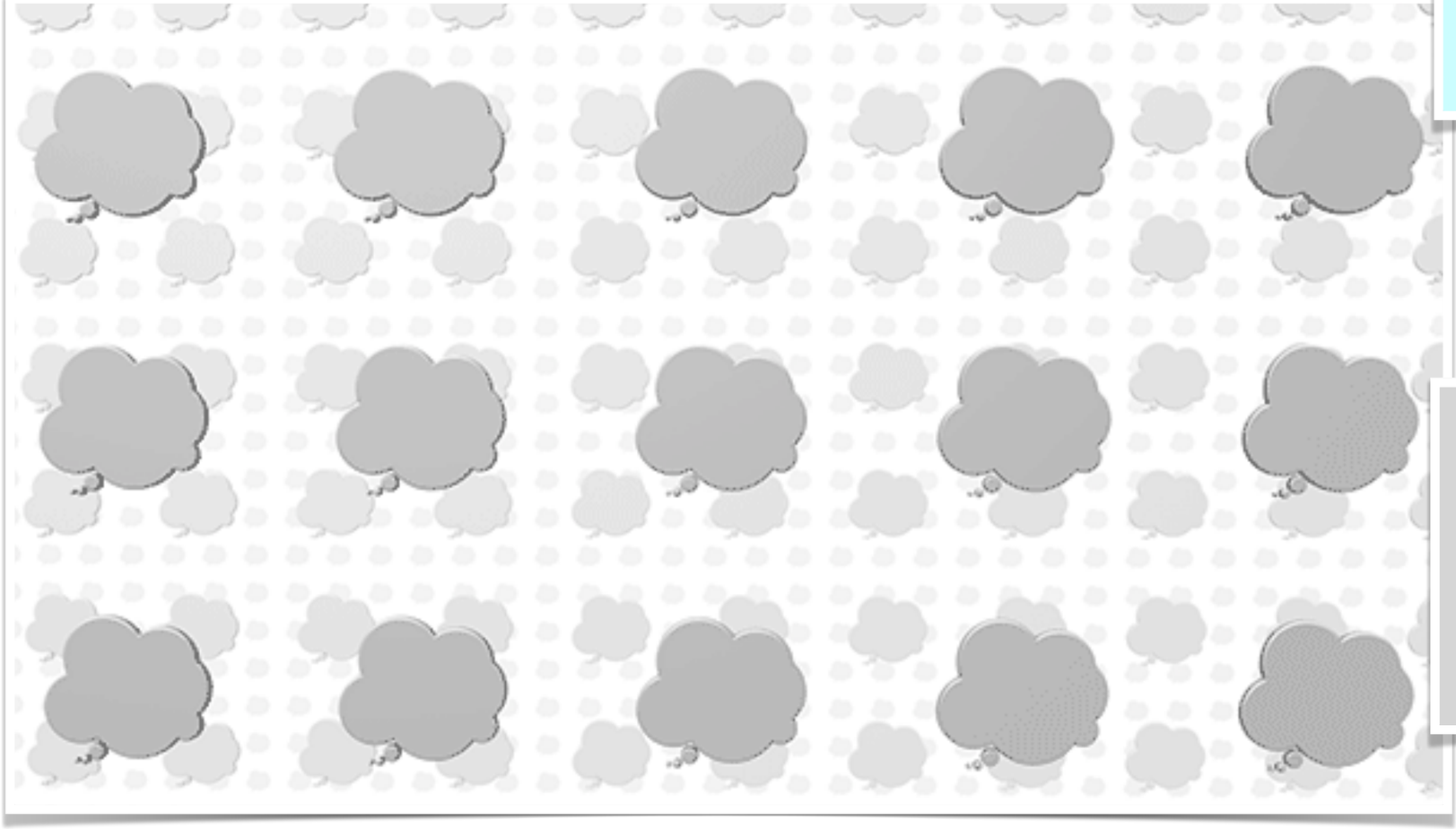
Chapter 5: Categories

undirected graph schema



inv;tgt = src
inv;src = tgt

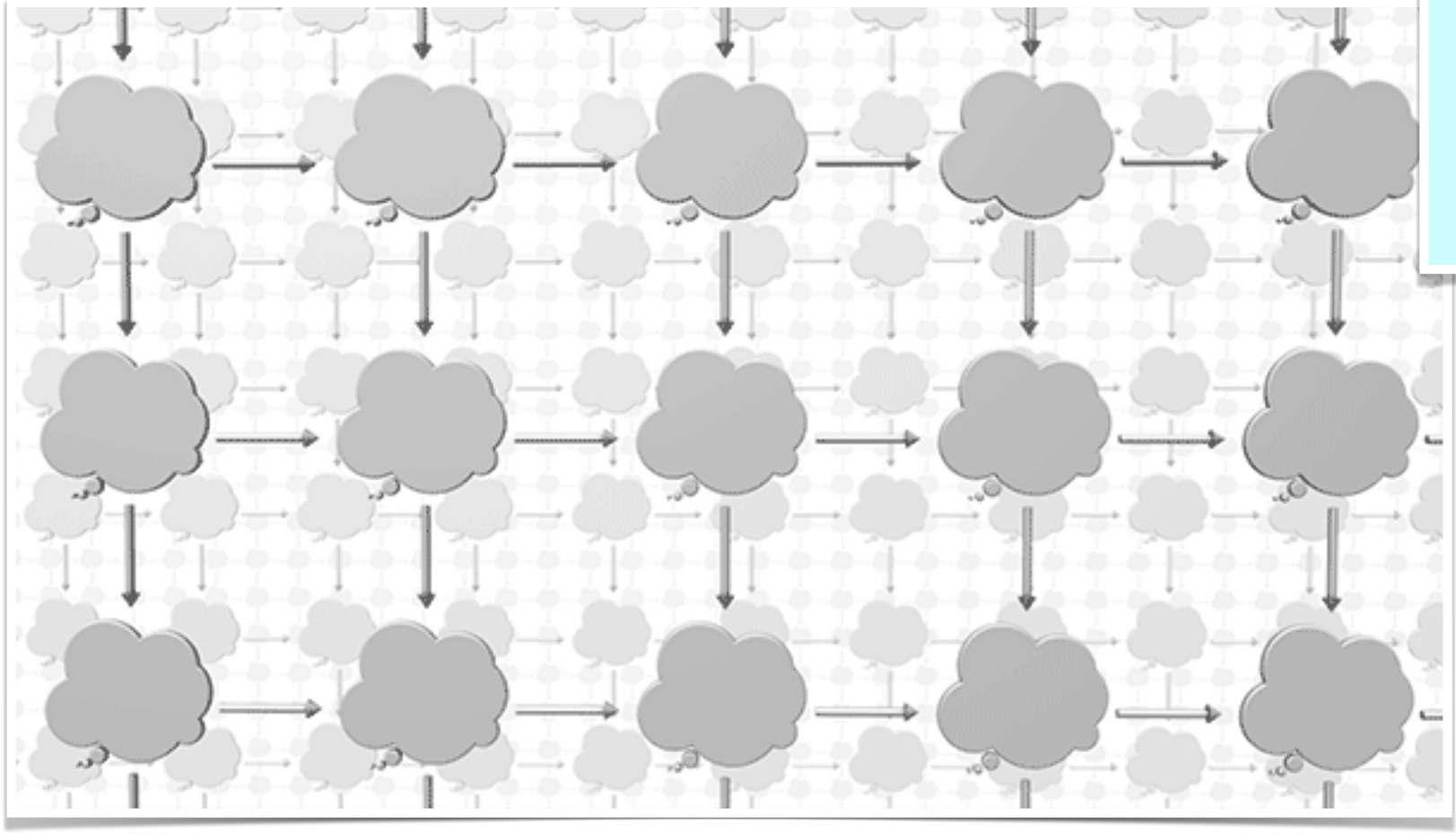
inv;inv = id



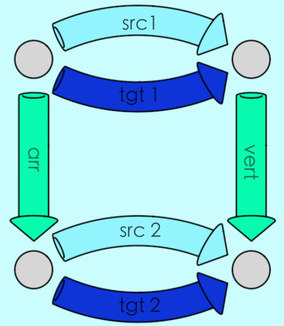
A universe of all possible graphs generated by ag raph schema

Rung 4: Categories

Chapter 5: Categories



graph morphism schema



src 1 ; vert = arr ; src 2

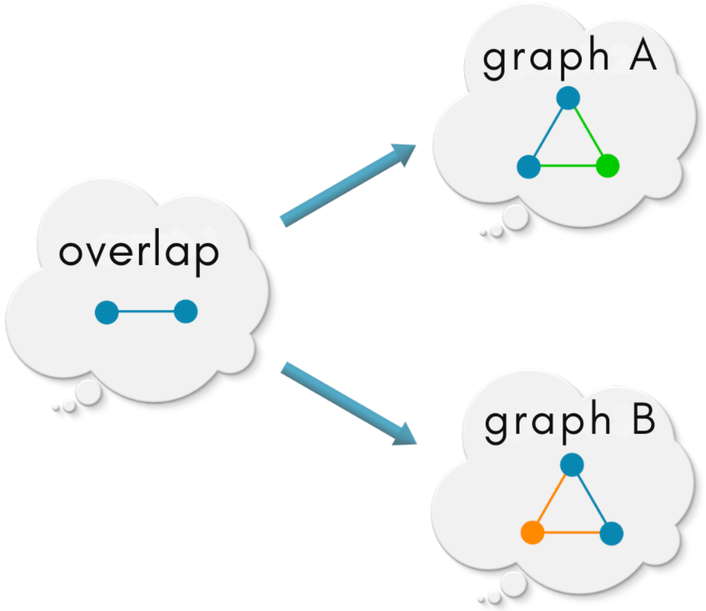
tgt 1 ; vert = arr ; tgt 2

A universe generated by a graph morphism schema

Thinking about graph pushouts

Chapters 5: Combining graphs

How would you explain the universal property of pushouts
of without using the words categories, functors, natural transformations?



Thinking about graph pushouts

Chapters 6: Combining graphs

How would you explain the universal property of pushouts

of without using the words categories, functors, natural transformations?

Imperative vs Declarative solution

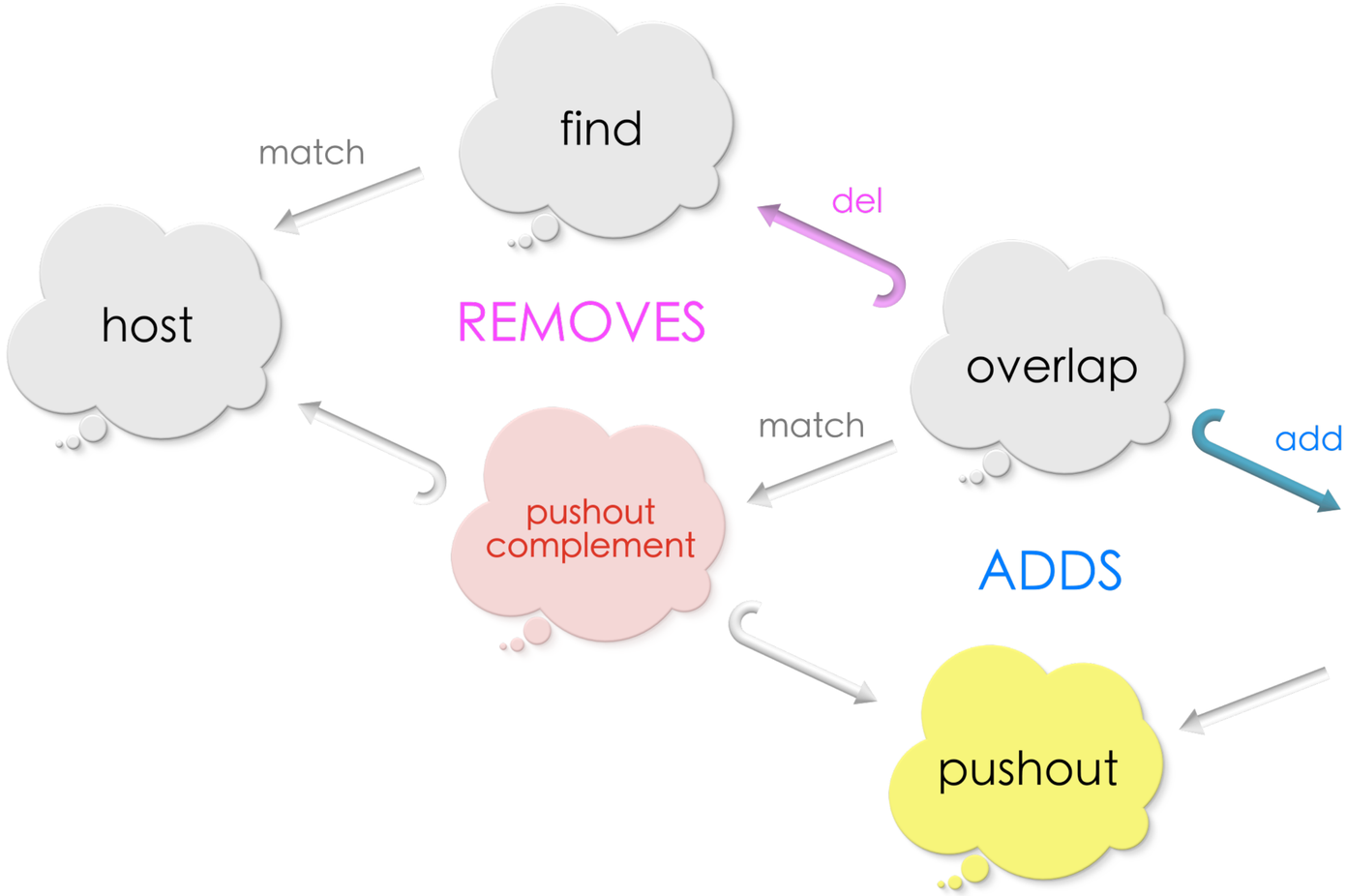
The idea is that a solution graph already exists in this universe of graphs. We find that solution by describing what must be its relationship with the other relevant graphs a.k.a. Universal property!

We can’t help but wonder

Chapters 7: Evolving graphs

We can’t help but wonder

Chapters 7: Evolving graphs

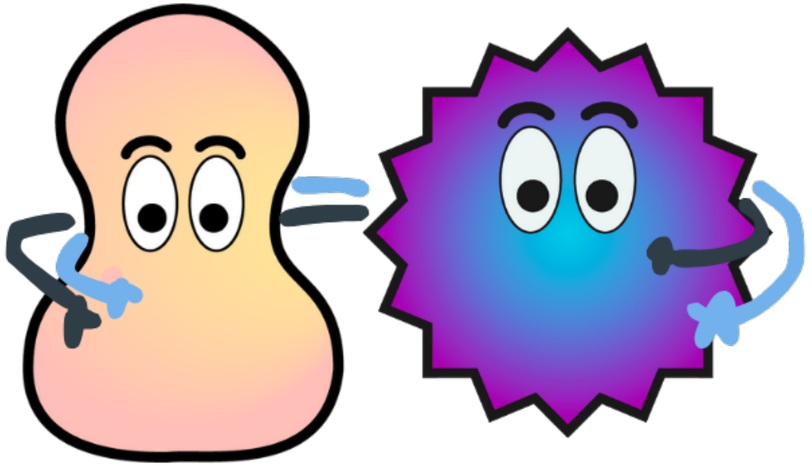


A common saying in software engineering:
There is no way to avoid edge cases, so keep them simple!

A solution with no edge cases!!!

We were convinced that..

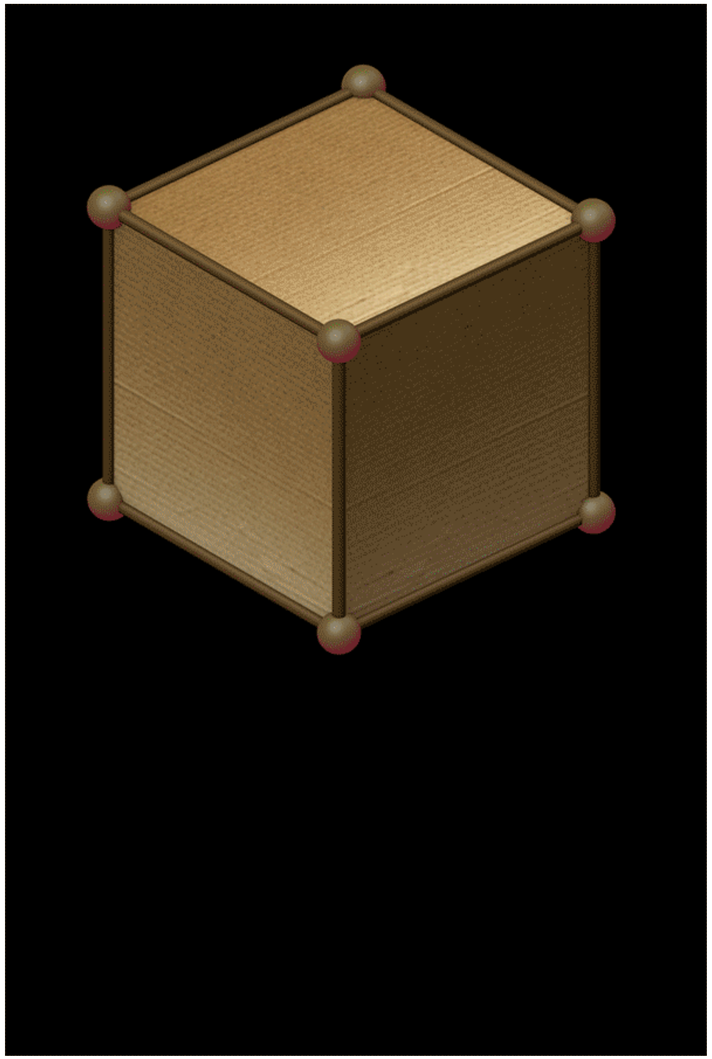
Relational thinking



is good thinking!

Some serious applications

Chapter 8
A look beyond: Evolving world models



Opening a cake box
Without dropping the cake

Some serious applications

Chapter 8
A look beyond: Evolving world models

Making a cheese sandwich

“Simplicity is the key”

Provide the experience of Algebraic Julia

without expecting the reader to program

2. Technology

Infrastructure of the book

An environment to build publication-quality books and documents from computational content

Supports Markdown and its special flavor myST markdown

Compiled locally and viewed in web browser

Your book can be published in Github pages or Netlify easily

`_config.yml` has all the configuration

Computing environment for the code

Open source computing environment for Python, R, and Julia

Too good to believe but its true!!

Binder provides a sandbox of 2GB of RAM

Automatic installation of the kernel for the user

Ideal for small-scale projects

It was a test of our patience in getting Julia going!

A lot of our troubles were because we asked too much from Binder.

Thebe: Live code execution

- Thebe connected to Binder enables live code execution in JupyterBook.
- Very simple to configure Thebe in JupyterBook
- Specifying the right kernel name for Julia was the hardest part
- Thebe is quite easy to use

```
kernelOptions:
  kernelName: "julia-1.10"
```

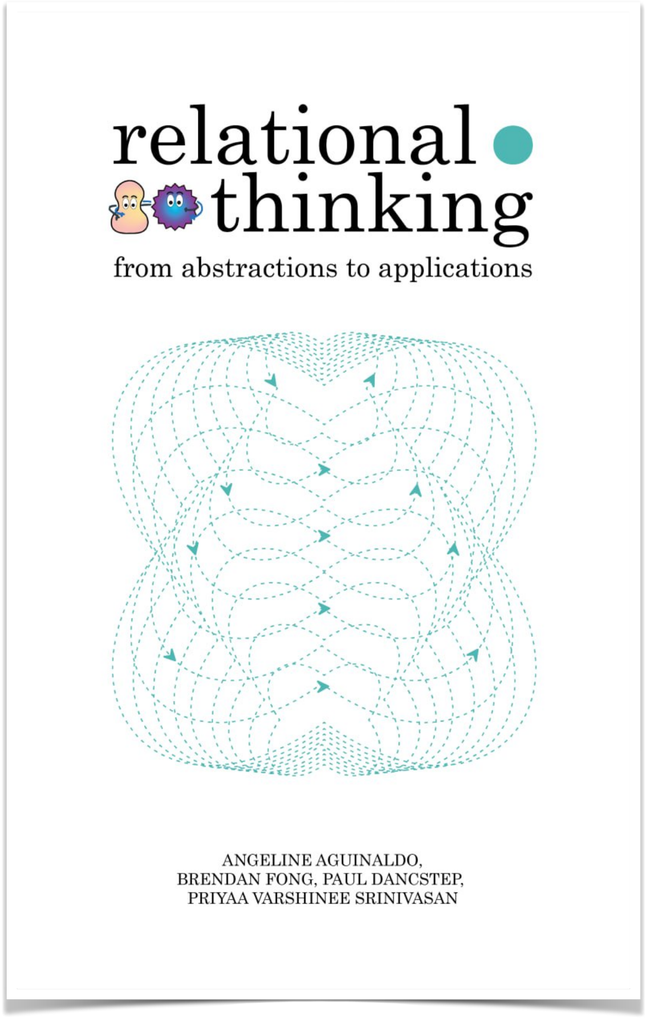
```
launch_buttons:
  thebe         : true
  binderhub_url: "https://mybinder.org"  # The URL for your BinderHub (e.g., https://mybinder.org)
```

Other tools uses

Javis, a Julia package - used for visualization of results

Canva, a graphic design tool - https://www.canva.com/

Designed using canva



People

Concept and content

Angeline

Paul

Brendan

Priyaa

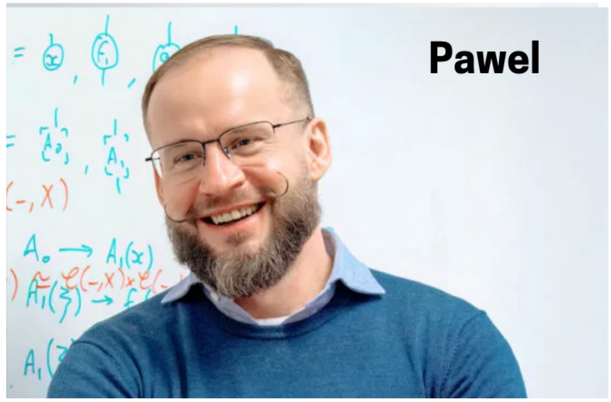
Paul made the illustrations and the animations too!

Technology team

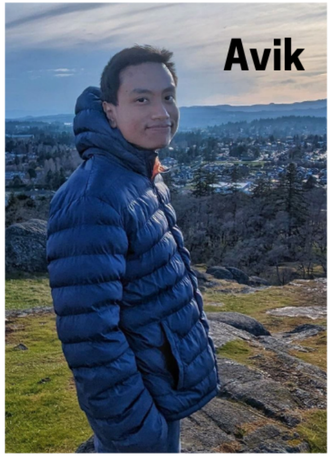
Evan

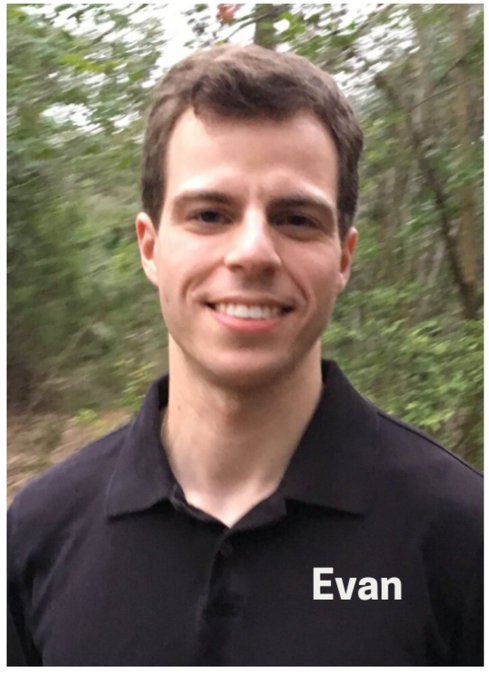
Brendan

Priyaa



Thank you people !!





Some thoughts..

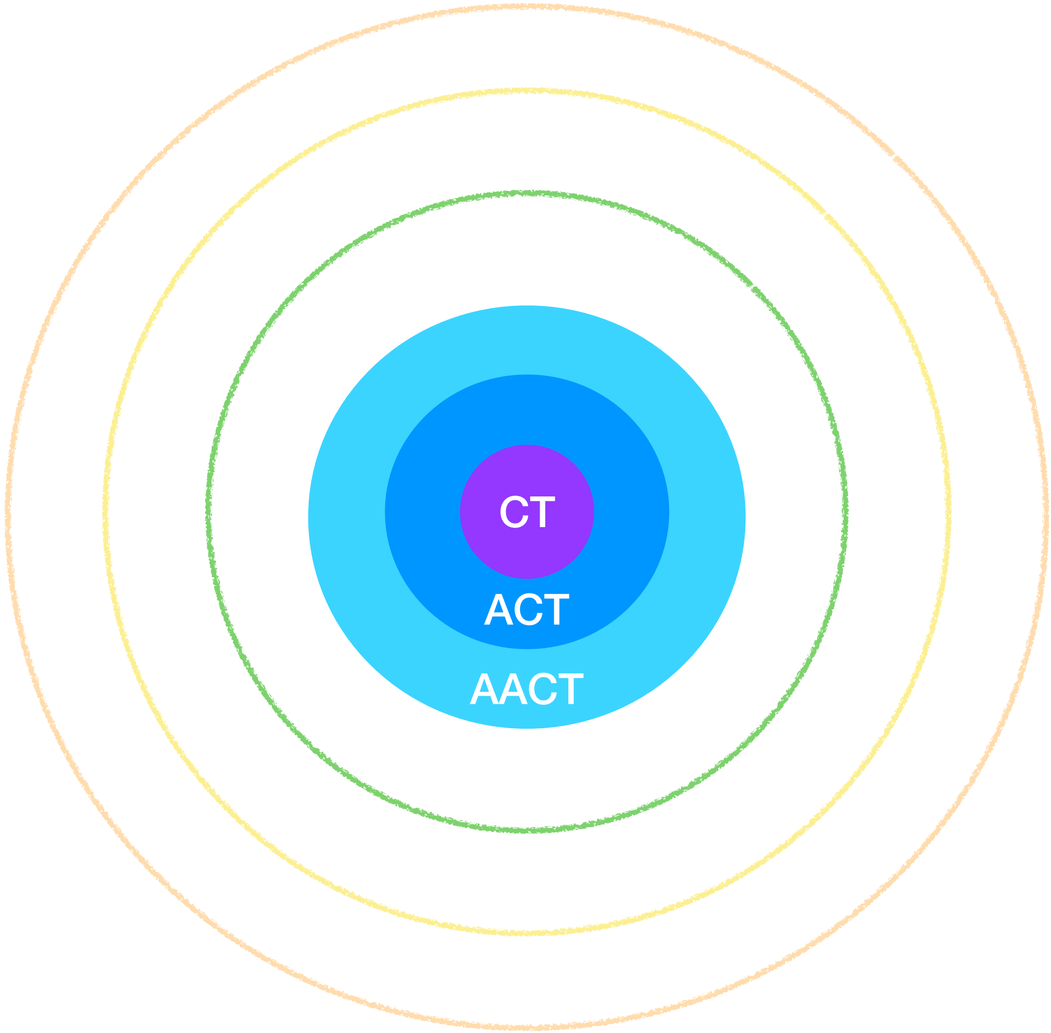
Need for diverse methods and media to communicate category theory

Symbols eliminate ambiguity and create trust

Symbols are easy to document

Utilize technology to find new methods of communication which completes symbols

Together they can give an wholesome presentation of categorical ideas



Resources

Online textbook@

https://toposinstitute.github.io/RelationalThinking-Book/cover.html

Git repositories of the book and the code

https://github.com/ToposInstitute/RelationalThinking-Book

https://github.com/ToposInstitute/RelationalThinking-Code

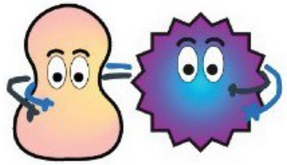
Blog posts outlining the content and the technology

https://topos.site/blog/2024-06-28-fantastic-book-four-months-i/

https://topos.site/blog/2024-07-04-fantastic-book-four-months-ii/

https://topos.site/blog/2024-07-09-fantastic-book-four-months-iii/

relational thinking



from abstractions to applications

Thank you!!

When you are young, you may feel bad because you may not be able to draw skulls or faces as well as that other kid next to you, you may feel bad you can't run as fast as that track runner from your batch,

but boy o boy, will you feel bad in a different way when you realize you cannot understand the language through which the "truth of the world" works.

It makes you feel less than, and it makes you realize that it's something you will have to live with. It's a compounding effect .... So is there a way to change that perception? Can you love something that you found difficult all your life?

– Avik Tripura