

What are we tracking? How category theory puts thinking on rails

David I. Spivak



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Outline

1 Introduction

- Why am I here?
- Tracking values systematically
- What values does CT track?
- Plan for the talk

2 Three accounting systems

3 Applying category theory: what to do and expect

4 Conclusion

Why am I here?

In 2007, I read *The Moment of Complexity* by Mark C. Taylor

- It explained that the world was getting increasingly complex.
- More would be different: Anomalies would become the norm.
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- And these are quite different than the database schemas found in orgs.
- Yet we are able to communicate! How??
- For the world to solve big problems, we must communicate better.

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I'm here to help improve coordination between ACTs and SMEs.

- ACT mathematizes world systems and relationships between them.
- Our work cashes out in improved abilities of subject-matter experts.
- This tutorial is about how I think we can improve the interaction.

Tracking values

Our values are what we care about.

- A company may value its profits and/or making a quality product.
- A person may value their comfort or child's well-being.
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But the word value also means something like observable datum.

- This company is valued at \$5B. This product breaks after ~ 2 years.
- The temperature is 70° . My child just got straight A's.
- There is too much war, the rate of fraud in elections is small.
- What "value" do you put into a certain field in the database?

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We pursue our values by tracking certain observables.

- If you care about something, you keep track of relevant observables.
- If profits slip or the room temp. drops, we need to figure out why.
- We produce narratives, accounts, for why things are the way they are.
- These let us focus our energy on what we can and should change.

Accounting systems

We solve big problems together by coordinating our activity.

- When my efforts and yours conflict, it causes friction and loss.
- When we coordinate, we stop stepping on each others' toes.
- To work collectively, our activities must align, like a golfer's body.
- The parent explains to the child, the SME explains to the programmer.
- We give [accounts](#). We explain our activity in terms of the collective.

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As the collective matures, its internal accounts become more systematic.

- There is friction every time I misinterpret your account of something.
- Or if your account hides key variables, externalities that I must handle.
- We get more systematic, so that we can regulate each other.
- These language games become regular and “grammatical”.

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If the system sufficiently crystalizes, it becomes a mathematical field.

Mathematical fields as accounting systems

I think of mathematical fields as crystalized [accounting systems](#).

- Arithmetic accounts for the flow of quantities, as in finance.
- Hilbert spaces account for the states of elementary particles, as in QM.
- Probability distributions account for likelihoods, as in game theory.
- Each is crystalized: hardened and coherent. Think laws of arithmetic.

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We obtain a conceptual overlay: the phenomena are abstracted as types.

- In finance, we have the type **dollar (\$)** and the type **quantity (#)**.
- We can add and multiply #'s by #'s: $5 \text{ boxes} \times 20 \text{ widgets} = 100$.
- We can add \$'s, and we can multiply \$'s by #'s: $100 * \$3 = \300 .
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Math is a high-fidelity language for systematically tracking our values.

- The language articulates the relevant type-differences ...
- ... and provide operations that correspond with their interactions.
- The rules let us regulate each other: check each others' work.
- The regularity lets the collective share accounts w/o interpretive loss.

Where are we in the story?

- Every person, company, etc. has values it's tracking.
- It is also a collective, and hence its parts must coordinate.
- This is done by internally sharing accounts of “what's happening”.
- To reduce internal loss, the accounts become systematic and regular.
- If they crystalize, the resulting system becomes a kind of math.

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Questions, comments, examples, or concerns?

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Questions, comments, examples, or concerns? Consider:

- Do you care about yourself, society, your company achieving its goals?
- Do you think this involves coordination of different parts?
- Do you think accountability is important for coordination?
- Do you ever wish the accounts were more systematic and regular?
- Are any of your systems crystalized into something like math?

How Applied Category Theory fits in

Category theory is a kind of math; what sort of phenomena is it tracking?

- It tracks a meta-level phenomenon.
- Namely, that different systems are somehow able to work together.
- To tackle big problems, we need to coordinate between entire systems.
- The finance, engineering, and safety departments must coordinate,...
- ...even though they track their values in entirely different systems.

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Category theory has crystalized what it means to connect different systems.

- Each crystalized accounting sys. is captured as a structured **category**.
 - It tracks the types and relations as “objects” and “morphisms”.
 - It tracks operations as monoidal structures, closures, limits, etc.
- Each translation between two systems is captured as a **functor**.
 - Every translation involves some preservation and some loss.
 - We've worked hard to crystalize the types, relations, operations.
 - So we consider the extent to which our functors preserve these.
 - A functor can be “faithful”, “monoidal”, “limit-preserving”, etc.

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CT lets you create & relate *custom accounting systems* for tracking values.

Plan

The plan for the rest of the tutorial is:

- Consider three different accounting systems as categories.
- Consider some principles for interaction between ACTs and SMEs.
- Consider what you get when you use CT.
- Conclude with a summary.

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- Finance: Accounting for resource flows
- Recipes: Accounting for procedures
- Heterogeneous communities: accounting for perspectives

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ACT: "Now you're getting the hang of what I need from you!"

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What does finding this abstraction do for anyone?

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Let's explore the idea of conceptual neighbors with more dialogue.

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ACT: Right, but there's a 2-dimensional vector space of \$ and £

SME: First, we don't do that. Second, you could just convert both to \$.

ACT: Oh, right: That conversion is a linear transformation $V \rightarrow \mathbb{R}$!

SME: I'm not following. Or maybe you're not listening..?

ACT: Sorry. I'm listening, but I'm following a trail.

SME: What is it? Vectors?

ACT: Question: do you ever do accounting for different sorts of widgets?

How an ACT-SME dialogue might proceed

SME: This is cool, I never thought about how you can't multiply \$'s before.

ACT: I have a question. \$'s is kinda "one-dimensional".

SME: How so?

ACT: Well, do you ever have, like, different sorts of dollars?

SME: We don't really deal with other currencies at our company.

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ACT: I bet they form a vector space too. This is starting to come together.

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SME: Cool, because this is exactly what I wanted to tell you about next.

Summarizing and concluding this example

What happened here?

- The ACT was looking for the right mathematical object.
- Having found it, the idea of multiple dimensions suggested itself.
- Multiple currencies was the first idea; it works, but isn't relevant.
- Multiple sorts of widgets was the second idea.
- The ACT and SME are now vibing: they agree on what's relevant.
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What happens from here?

- Every collaboration takes its own turns.
- Maybe they invent a souped-up spreadsheet that type checks formulas.
- Maybe the SME explains the *accounting equation*,

$$\text{Assets} = \text{Liabilities} + \text{Equity}$$

- The ACT considers why it's so central to financial accounting today.
- They create a new ACT account of the firm, grounded in this equation.

What is a recipe?

Turn to your neighbor. Consider together: what is a recipe?

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- What is it tracking? What sort of account is it?
- What types (of actions, objects, structures) are involved?
- What operations can you do on these types. (Combine actions?)

Meta: The role of questions and answers

Soon, I will give you my answers to the above questions.

- This will have positive and negative aspects. Why?
- Questions “open” the conversation, answers “close” it.
- When we *jump* to conclusions, we prematurely close.
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The ACT-SME interaction seeks to temporarily reopen closed questions.

- Traditional methods are in use but closed. (e.g. ZFC, UML)
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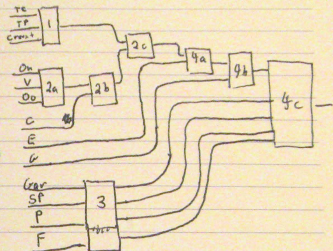
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Can we find any structure to recipes?

Joey Hirsch's Shakshuka recipe

Joey's Shakshuka (serves 6-8)

- E. Eggs (2 per person)
- On. Onion (1 big)
- TP. Tomato Paste (4-6 oz)
- TC. Canned tomatoes (56 oz)
- On. Olive oil
- F. Feta cheese
- G. Cookable green (spinach, swiss chard, etc.)
- V. Egg plant and/or other veggie
- C. Cumin
- Par. Parsley/Cilantro/Lemon
- SP Fresh serrano pepper
- P Pita



1. Tomato sauce: if TC are whole, mash them. Add TP. Put in "Crouset" - casserole pan.
2. Sauté onion (On) and Veggies (V) in olive oil. When almost cooked, add Cumin (C). Add to crouset. Simmer for ≈ 40 mins.
3. Prepare garnishes: cut parsley, cilantro, lemon (Par), cut serrano pepper (SP) and

4. About minutes before eating, add eggs (E) uncooked to crouset, when they'll poach. A few minutes later, add greens (G). Serve when cooked.

Recipe structure: parallel, series, and nesting

A recipe tracks resources and ways they're combined.

- Each step in the recipe takes many inputs and produces an output.
- Some steps must be done sequentially, others can be done in parallel.
- Each step in the recipe could be seen as a whole recipe.
 - You can zoom into the step and take it apart.
 - To mix the eggs into the flour, get a whisk and stir vigorously.
 - To get a whisk, open the drawer on the left and then....
- Maybe we should say: a recipe is the free operad on some signature.
 - Fix a set of all possible resources; call them *types*.
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But what if someone objects that a step can produce many outputs.

- A single egg can produce two resources: egg white and egg yolk.
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- Either viewpoint works; we get a functor from that one to this one.

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We're still connected if two developers try out different approaches.

Another ACT-SME dialogue

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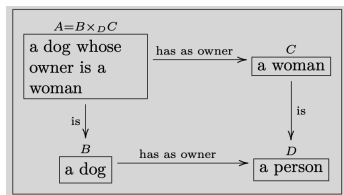
SME: Why do you call it a manifold?

ACT: I'll explain later. For now, can you show me a sample "page"?

Ologs and databases

Ologs were my way of bringing SMEs and ACTs together.

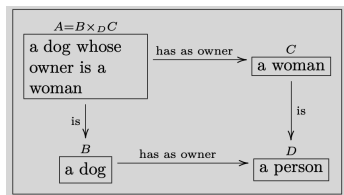
- An olog is a mix between math and natural language.
- The math is just that of categories, or perhaps “sketches”.
- Each object is assigned a noun phrase, indicating a set.
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Ologs form database schemas. An *instance* fills your olog with data.

- For each box, you record examples. You connect them along arrows.
- E.g. every example of “a woman” is an example of “a person”.

How do ologs connect to our use-case?

There may be way more appropriate ACT systems for cybersecurity.

- But in our dialogue, the SME needed to weave together perspectives.
- This comes up a lot, not just in cybersecurity.
- Different engineers, safety experts, programmers, finance people...
- ... need to understand each other's lingo and form a working whole.

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As categories, ologs can be connected by functors.

- This allows you to migrate data between different worldviews.
- For the “atlas of worldviews” idea, use spans of injections.
- You can then put everything together as a *colimit*.
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- Allow movement between worldviews without making “urban sprawl.”

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Often, the ACT comes to understand deeper aspects by making an olog.

- The discipline of creating ologs with SMEs can lead to clarifications.
- This can lead to a crystalizing insight into “the real thing”.

Outline

- 1 Introduction
- 2 Three accounting systems
- 3 Applying category theory: what to do and expect**
 - Best practices, according to me
 - Value proposition of ACT
- 4 Conclusion

Best practices for the interaction

Again, this is all my perspective. Take everything with a grain of salt.

- Work in person for a few full days, as often as possible.
- Work at a board, drawing pictures, making marks, pointing.
- Make every step obvious. Don't let the other lead without following.
- Interrupt when you don't understand.
- Regularize notation; notation can be a great guide; make use of it!
 - If X and P are the same type of thing, use X , X' or X_1 , X_2 .
 - Serge Lang: "The notation must be functorial with respect to the ideas!"
- Move back and forth between abstraction and concrete example.
- If something's difficult to explain, slow down; don't try to skip over it.

Best practices for the ACT

Applied category theorists:

- Do not impress them; help them see.
 - It's easy to move a little too fast, to jump to the next thing.
 - Make sure they're really following. Match their speed.
- Make your abstractions relevant.
 - Abstractions should feel right in terms of their prime example.
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 - Explain everything. If they think it's hard, do more examples.
 - Don't say "oh, this is easy" but never show them.
 - Their confidence comes from being able to do it themselves.
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I felt sheepish when I introduced ologs.

- They are not even math, they are not complex, they are not fancy.
- But they worked for what I wanted. They make sense to people...
- ...and they connect to real math in a relevant way.

Best practices for the SME

Subject matter experts:

- Do not flood them with complexity.
- Clarify the very most basic things first.
 - The ACT may not know very basic things.
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 - I remember watching a building being built from my dorm room.
 - The bulldozers spent literally six months moving dirt around.
 - Then a 10-story building went up in like a month.
 - Getting the foundation right is the hardest part.

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 - Draw your own pictures and ask if they look right.
 - Explain your understanding of the math, and be ready to learn.
- Expect clarity and interoperability, not magic.
 - CT is like information plumbing. It's not grand, but...
 - ...plumbing has saved more lives than doctors.

What is the value proposition of ACT?

To some degree this is an open question. Here are some thoughts.

- For computer implementation:
 - ACT is generally quite good at seeing the “corner cases”.
 - The math gives a complete spec. No technical debt.
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- Information hygiene: get the plumbing right to reduce disease.
- Compositionality: everything works really well together.

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- It puts thinking on rails.
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- These tools will help everyone. A rising sea that lifts all boats.
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We're ready for the first big step in laying down information infrastructure.

- Everything is in place: the right problems, people, and institutions.
- It's now just a matter of investing resources in it.

Thanks! Comments and questions welcome...