An Adventurer's Guide to Rheology Simulations

The Magic of Models

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Thanks to the Society of Rheology and our educational consultants Victoria Russell and Kelsey Briselli.

Glossary of **terms** in the back.

For more rheology, check out Rheology of Cats
rheologycomics.github.io/comic1-english

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What does a scientist use a computer for?

All scientists use computers for a lot of things...

...and some do their experiments on a computer, too!

In a **computer simulation** researchers use math and computer code to control what happens in an experiment.

Even though simulations aren't "real," they are still useful for testing theories and making predictions. Especially because real-world experiments can get messy.

Even when you're very careful most measurements are a little unclear. Common problems are:

SIZE

What size party hats do you need, Elvish size S or Dwarvish size L? Does it matter if the hat size is 3.142 instead of 3?

MOTION

It's easy to see a slow moving dragon turtle arrive at the party, but the phoenix is on fire and flying fast! You might not see it come through the door.

NUMBER OF PARTS

Tracking two gnomes dancing is easy. Tracking many interactions is more confusing!

TYPE OF EXPERIMENT

Some things are just better behaved than others. It's hard to measure what you don't expect!

Researchers call these problems **error**. This error isn't a mistake, it tells you how accurate your information is.

To keep error from ruining our results, we need data from many repeated experiments. That's why scientists focus on **averages** (*what is the most balanced result?*) and **probability** (*how likely do we think that result is?*).

With enough real-world data, we can build a **model** that describes how something works. This model can then be used in simulations.

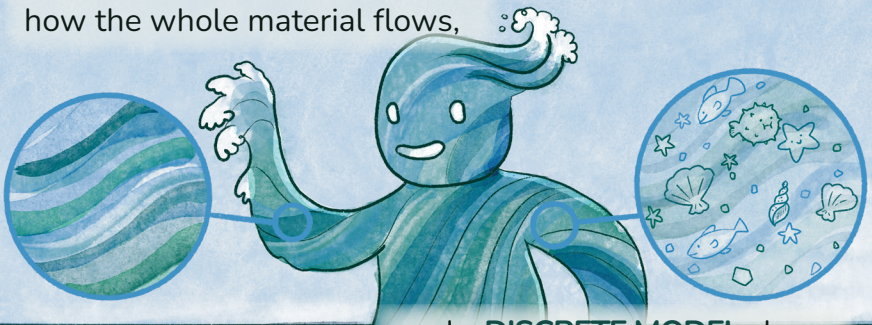
Running simulations on a computer can be much faster and easier than doing experiments by hand!

For example, in **rheology** researchers use models to understand how a material will flow. These models help predict what will happen to new materials in new situations. Especially if it's hard to test them in real life...

A good model lets you use simulations to predict how a material flows and changes over time, without having to test real materials in new experiments.

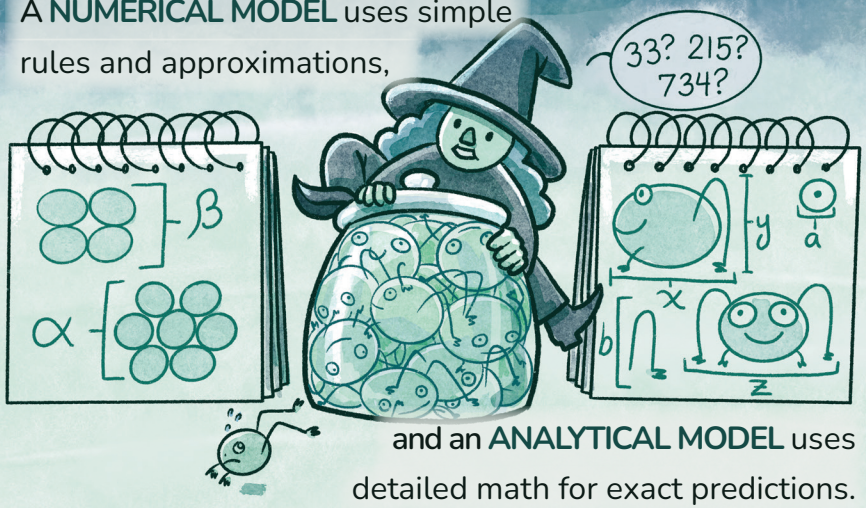
There are many types of models:

A **CONSTITUTIVE MODEL** shows how the whole material flows,



and a **DISCRETE MODEL** shows how its pieces fit together.

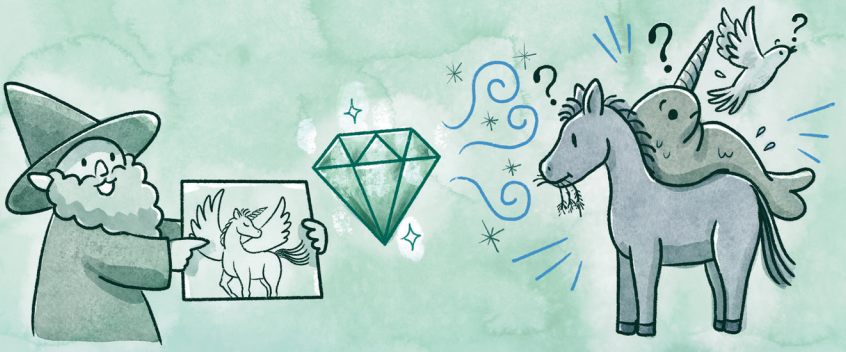
A **NUMERICAL MODEL** uses simple rules and approximations,



and an **ANALYTICAL MODEL** uses detailed math for exact predictions.

Sometimes you can build faster, more accurate models by combining different methods.

Most models try to simplify things as much as possible. It's easier to understand how a simple model works. But you don't want to simplify too much...



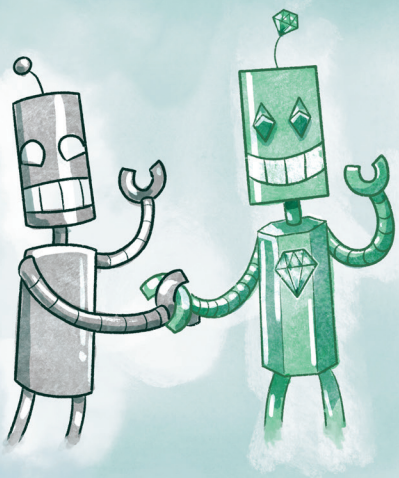
For complicated situations, **Artificial Intelligence (AI)** and **Machine Learning (ML)** are great at making predictions without oversimplifying.

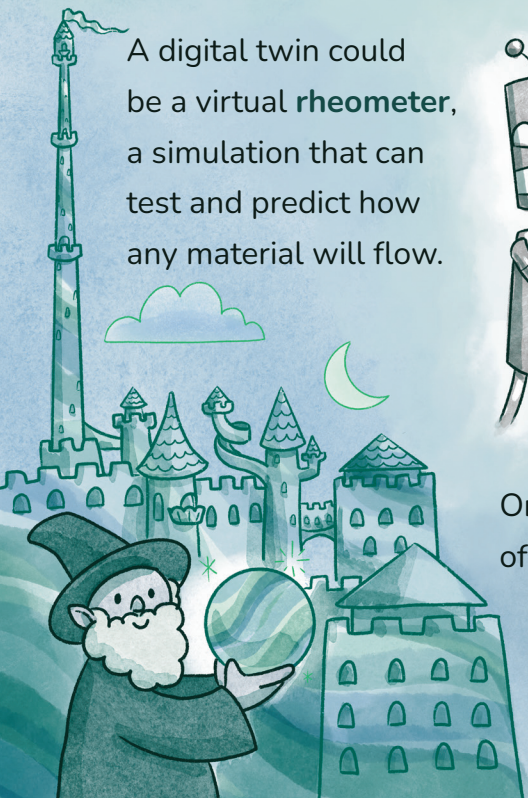
Using the power of probability and advanced computer hardware, AI and ML can quickly try out many possibilities and "learn" complex relationships. Adding these to a model can help you find the answer you're looking for, as long as you have the right data to train it.

In the end, each model has a special ability. One model can't do everything, so researchers try to combine models to get the best parts of each one.

The ultimate combination is a **digital twin**: a simulation that matches everything about a machine or material.

A digital twin could be a virtual **rheometer**, a simulation that can test and predict how any material will flow.





Or it could be a virtual copy of a complicated material, like a special mixture of mud or concrete used to 3D print a building.

Like a wizard taking time to learn new spells, you may need to spend many hours writing and testing computer code to get a model working... but the magic is worth it!

What will your model's specialty be?

Think about what your model can and can't do, and what type of data you need to build it.

Check out these coding and AI resources to get started!

https://scratch.mit.edu/

https://code.org/

https://code.org/minecraft

https://girlswhocode.com/programs/code-at-home

https://www.youtube.com/BlackGirlsCode

https://www.joshfunkbooks.com/how-to-code-a-sandcastle

https://machinelearningforkids.co.uk

https://tinyurl.com/algorithms-as-opinions

GLOSSARY

COMPUTER SIMULATION - a virtual experiment that researchers build with math and computer code.

ERROR - a description of how accurate a measurement is. Ex: if your ruler only has marks every 1 inch, and you measure a leaf that is between 2 inches and 3 inches long, you can't measure exactly how long it is. Your best measurement still has a possible error of 1 inch.

AVERAGE - the most balanced result. Ex: how tall is a typical giant? If you measure 2 giants, and one is 8 feet tall and one is 10 feet tall, then their average height is (10 + 8) / 2 = 9 feet. This average might not match a specific giant, but it tells you about the typical height in this group of giants.

PROBABILITY - how likely is a result. Ex: you have a 20-sided die. When you roll it, there is an equal chance of getting any of the numbers. So the probability of rolling a 17 is a 1/20 chance (1/20 = 0.05 = 5%).

MODEL - a simulation or math equation that is a good representation of something in the real-world. You need real-world data to prove it makes sense, and then you can use it to make predictions.

RHEOLOGY - the study of how things flow, especially materials in between solid and liquid.

CONSTITUTIVE MODEL - a model that describes an entire material (ex: ocean currents, a landslide, pudding).

DISCRETE MODEL - a model that uses pieces of a material to describe it's behavior (ex: droplets of water in the ocean, each rock in a landslide, the fats and sugars in a pudding).

NUMERICAL MODEL - a set of simple and general rules that can approximate what a material does.

ANALYTICAL MODEL - a detailed math equation that can make an exact prediction of what a material does.

ARTIFICIAL INTELLIGENCE (AI) - a new way to use probability and statistics to help solve complex problems or make decisions.

MACHINE LEARNING (ML) - a new way to make models that "learn" complex relationships from training data, like how a student studies for a test by doing practice problems.

DIGITAL TWIN - a virtual copy of a real machine or material (ex: a rheometer, an airplane engine, a 3D printed material, a battery, a pudding).

RHEOMETER - a machine that scientists and engineers use to test how a material flows.

Rheology Comics #3

A simulation is more than just fantasy!

Computer simulations are an important part of rheology research, whether you're studying how something flows or designing a brand new material. But why? And what actually are they?

Fear not, adventurer! Whether facing monstrous mathematical models, "messy" experiments, or other-worldly AI, this comic will help you explore how researchers use simulations to study rheology, and how you can join the adventure.

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Learn more about rheology by following the QR code.

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