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Mathematical Storytelling

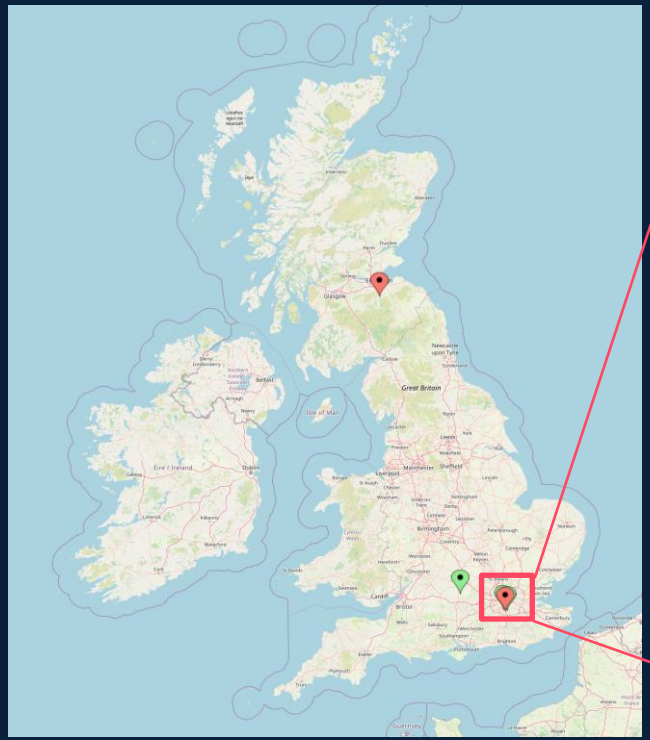
Using narrative to build trust in technology

Dr Madeleine Hall (with visuals assisted by DALL·E 3)

PiWORKS Seminar, 25th June 2024

Introduction

- BSc: Maths, Edinburgh 2013-17
- MSc: Bioinformatics, Imperial 2017-18
- PhD: Mathematical biology / fluid dynamics, Imperial 2018-22
- Intern software developer: Quaisr, 2022
- Science writer: London Institute for Mathematical Sciences 2022-23
- Mathematical consultant: Smith Institute, Oxford 2023-



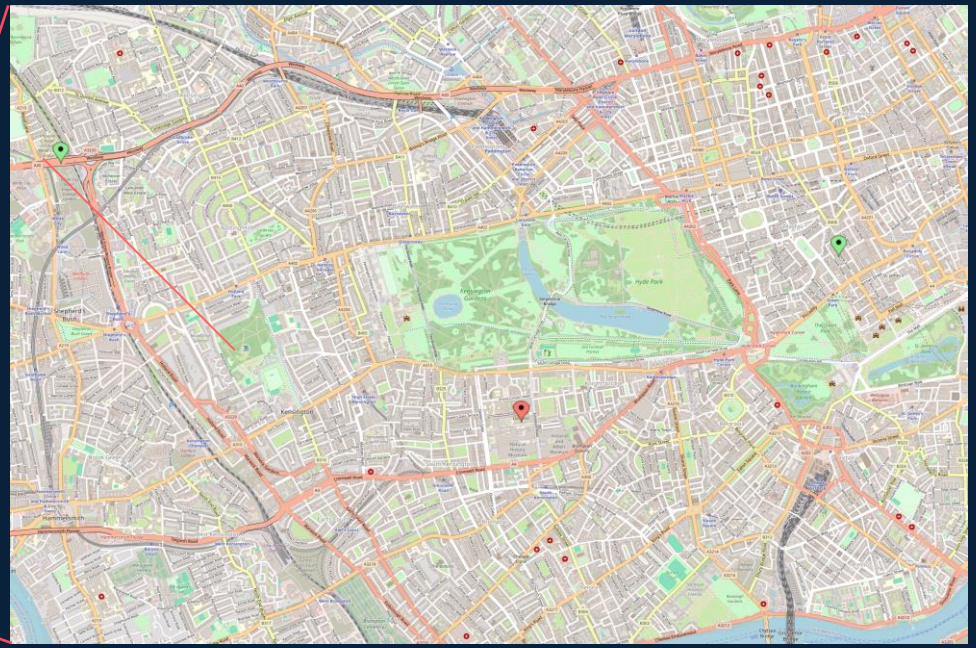


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Fig. 0 from my thesis

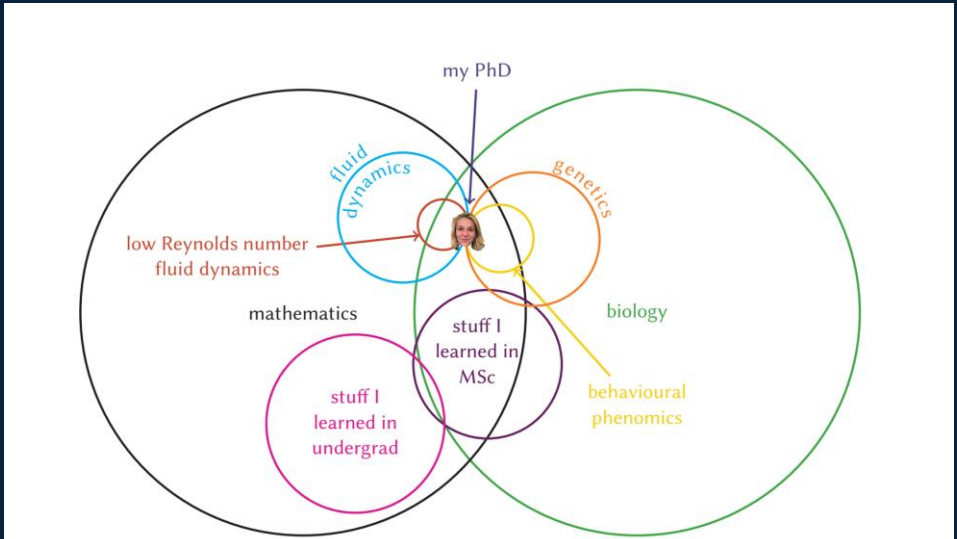

Figure 0

v2.0

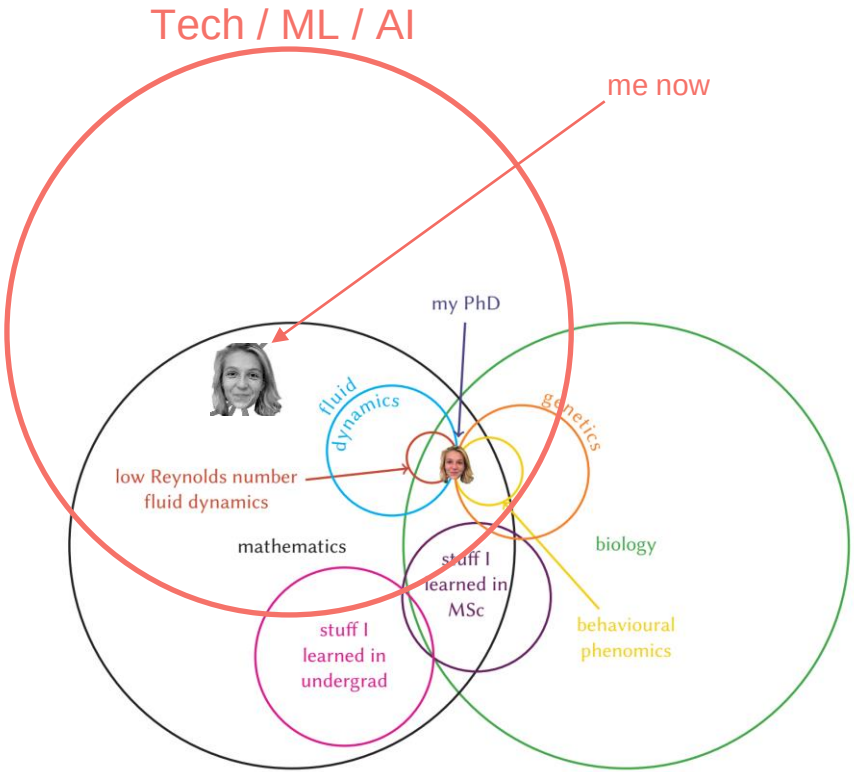

Figure 0

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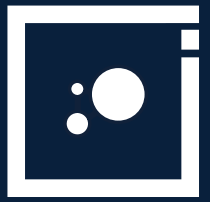
What does Smith Institute do?

Data Analysis
& Visualisation

Forecasting
& Prediction

Optimisation

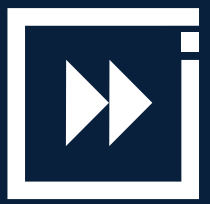


Machine Learning
& AI

Model Verification
& Validation

AI Assassurance
& Safety

Simulation



Future Systems
Design

Open to
applications!

The AI revolution

AI isn't going anywhere, but many people don't understand it / fear it. Why?

Complicated, Technical, Mathsy, Stigmatised, Abstract, Opaque, Intimidating, Rapidly-evolving, Specialised, Misunderstood, Inaccessible

AI literacy needs to grow ASAP

Experts (you!) are responsible

AI is people all the way down

- People **define the problem**
- People **collect and pre-process data**
- People **select & build models**
- People **decide how models are trained**
- People **evaluate how well models perform**
- People **interpret model outputs** (high-risk scenarios: healthcare, law-enforcement)

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Explainability can remove opacity

More on explainability:
smithinst.co.uk/insights

- **Prediction accuracy:** measure how well model predictions match true outcomes
- **Traceability:** build models that are intrinsically transparent, by design, parameter weightings that are assessable
- **Decision understanding:** **educate people** who interact with AI, i.e., everyone

Education relies on **effective communication from experts** (again, that's you) in **AI, technology, maths, …**

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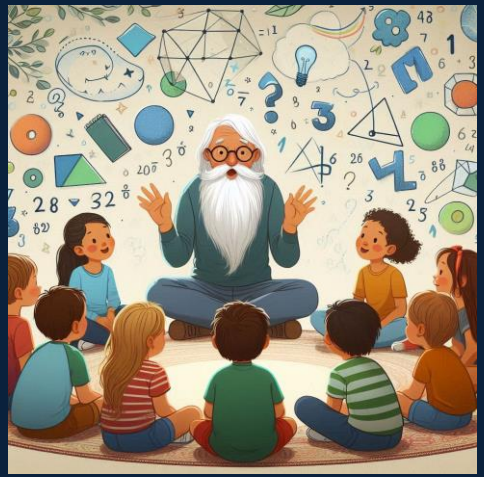
Is storytelling the answer?

- **Maths is powerful**, also beautiful and fun
- **But it's commonly perceived as inaccessible** and hard to understand
- **Can we use storytelling** to make it engaging, relatable and understandable?



Science is a newcomer

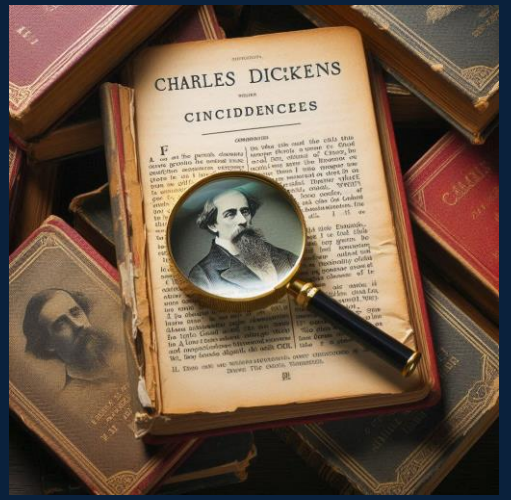
- **We've been telling stories for a long time.**
  Connection, entertainment and survival
- **Science is a newcomer** - “doing science” for only ~400 years
- **The way we do science is evolving rapidly** - technology cycles are shrinking
- **With great pace comes great responsibility.**
  People that understand it are responsible for building trust

Scientists love complexity

- **Academic papers don’t sound like novels**
  Endless lists of facts, very technical, information dense
- **IMRAD** structure: consistent, efficient, helps with peer review, reproducibility
- But it’s a barrier to engagement outside a small academic niche
- Story dynamics **thrive on simplicity**

Statistics tangent: Dicken's coincidences

Andrew Gelman, Columbia -



- **Charles Dickens** novels are criticised for the nortorious coincidences, but **coincidences are necessary**

- **In maths:** random sampling nodes in a network can't capture overall architecture (depends on complexity / characteristics)
- We can sample local, specific scenarios, instead of averaging arbitrary random sample
    - What a coincidence – my data verifies/challenges my implicit model of the world

- "In statistics, stories should be **anomalous** (push against your implicit model) and **immutable** (checkable)"

- This creates a **paradox**: stories should be anomalous but statistics loves representative samples
    - Also, many textbooks follow the 'penicillin model' of science, but nobody does science like this anymore

- Solutions? Better exploration? Better data visualisations?

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Optimising narrative

- **Our brains need narrative**

Hard for our brains	**Fun for our brains**
Back-to-back **Number Theory** lectures with no narrative structure	Binge watching episodes of **Breaking Bad**
Reading paper after paper on **Finite Element Methods**	Reading chapter after chapter of **Lord of the Rings**

- **How can we optimise narrative for communication?**
  Introducing**:** The narrative spectrum…

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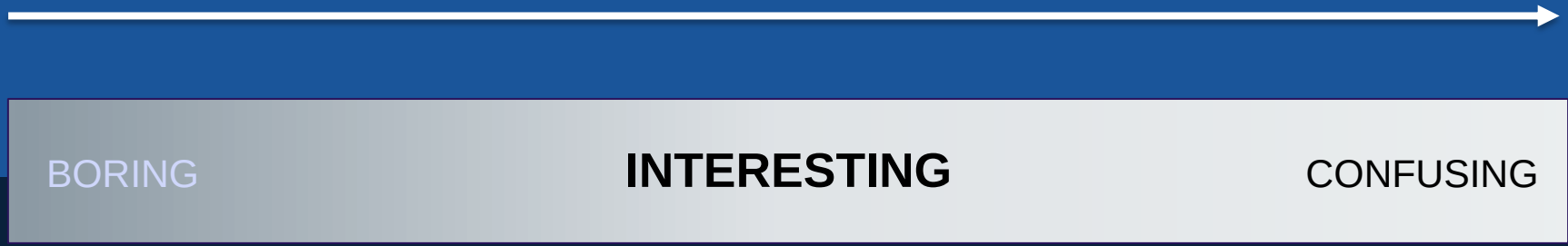
Science

Information density

Technical detail



Non-narrative	Narrative	Overly narrative
Rainday Antiques Goodnight Moon	Breaking Bad LOTR	Inception Ulysses

Storytelling

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The optimal narrative structure

- Aristotle's poetics 335 BCE: prologue, episode(s), exodus
- Hegelian Dialectic, early 1800s: thesis, antithesis, synthesis
  - **using confrontation to reach an ultimate truth**

(Drumroll)…the **three-act structure** (popularised 1970s)

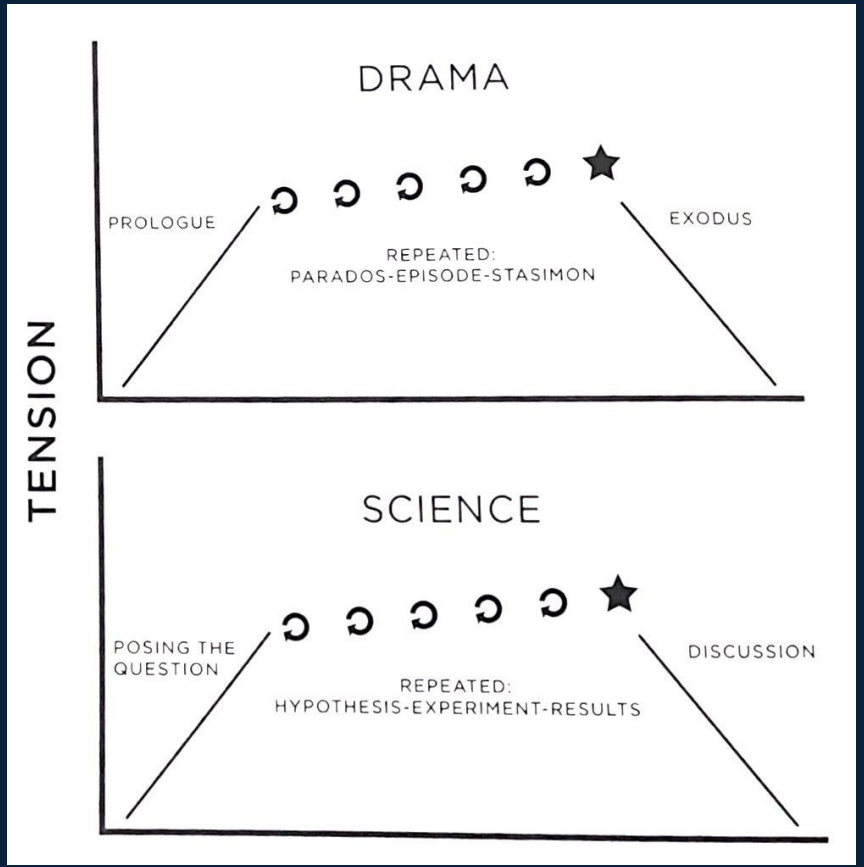
- **Act 1: Setup (Thesis)** – introduce the setting, establish the status-quo
- **Act 2: Confrontation (Antithesis)** – present the challenge, conflict, build tension
- **Act 3: Resolution (Synthesis)** – climax to the solution, resolve the tension

As luck would have it, mathematics often **is** the resolution!

Parallels in science

The scientific method follows this cycle.

It’s all the same story.



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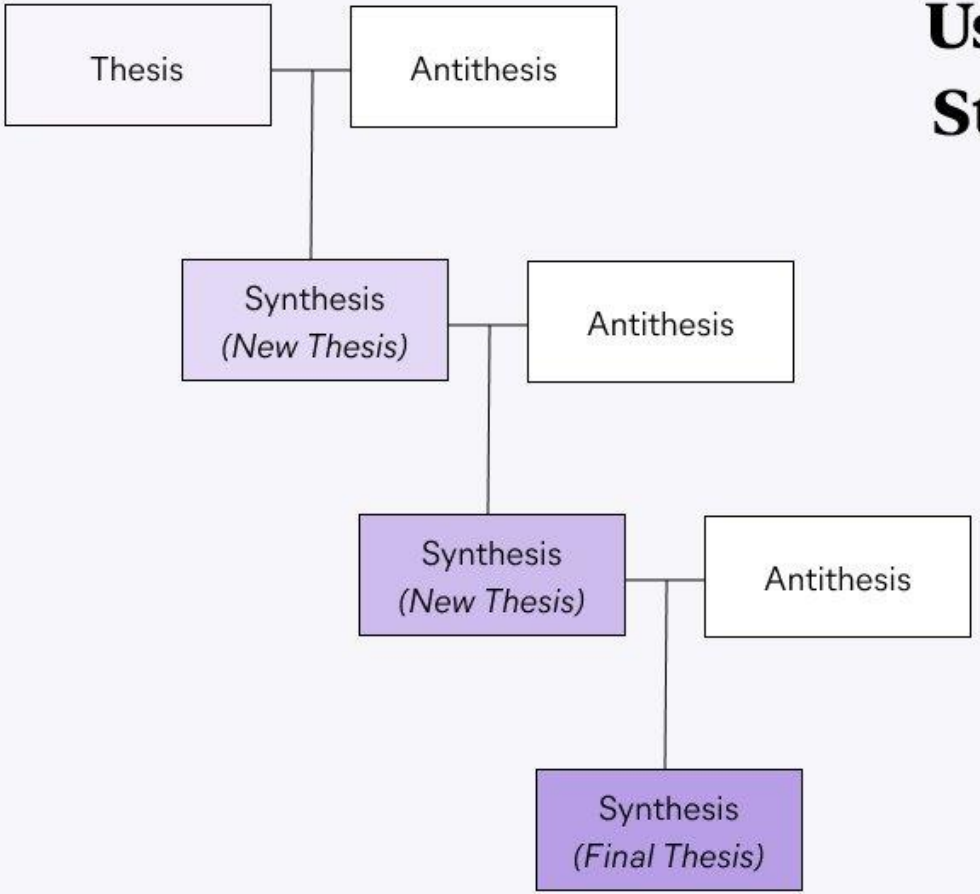


Using Dialectic to Strengthen Ideas

Idea (thesis) is systematically challenged (antithesis).

Incorporating this feedback creates a new thesis (synthesis).

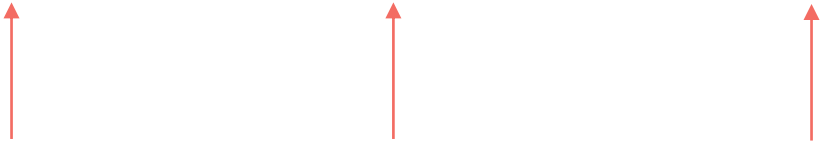
Thesis draws closer to "truth" with every iteration.

Animalz

Doing this in practice: ABT structure

The storyteller's three favourite words:

… **"And"** … **"But"** … **"Therefore"** …



Act 1: Setup	**Act 2: Confrontation**	**Act 3: Resolution**
Create momentum	Introduce conflict	Resolve the problem

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Example: Little Miss Muffet

Little Miss Muffet sat on her tuffet,
(AND) eating her curds and whey
(BUT) along came a spider who sat down beside her
and (THEREFORE) frightened Miss Muffet away.

Generalising

<this happened/this data exists>

AND

<this happened/this data exists>

BUT

<this other data complicates our understanding / these conditions caused a problem>

THEREFORE

<this analysis was performed / this resolution was reached to resolve the problem or understand the circumstances>

Examples from a science writer

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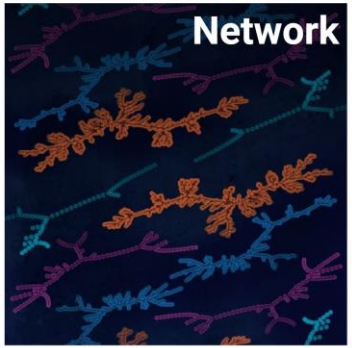

STATISTICAL PHYSICS

Laplacian renormalization group for heterogeneous networks

Nature Physics **19**, 445 (2023)

P. Villegas, T. Gili, G. Caldarelli, A. Gabrielli

The renormalisation group is a powerful tool for examining organisational scales in dynamical systems. But applying it to complex networks presents challenges because of correlations between intertwined scales. We develop a Laplacian renormalisation group approach that can identify proper spatiotemporal scales in complex networks, introducing so-called Kadanoff supernodes to resolve detrimental small-world effects.

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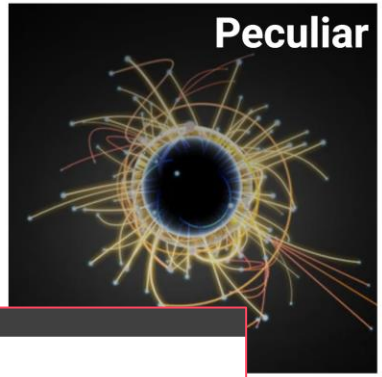

QUANTUM FIELD THEORY

Peculiarities of beta functions in sigma models

Journal of High Energy Physics **2023**, 2023 (2023)

O. Gamayun, A. Losev, M. Shifman

In quantum field theory, beta functions describe the flow of coupling constants, which for sigma models exist as a metric of the target space. Generally, the flow of a metric is expressed by geometric structures. Surprisingly, we find an exception to this in the second order of perturbation theory. The expression we derive has an elegant form in the context of algebraic data, which may be explained by infrared anomalies.

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REPRESENTATION THEORY

Irreducibility of the Koopman representations for the group GL0(2∞,R), acting on three infinite rows

Submitted (2023)

A. V. Kosyak, P. Moree

In representation theory, harmonic analysis for locally compact groups relies on the existence of the Haar measure. This measure exists only if a group is locally compact. Despite the absence of the Haar measure, in this paper we construct representations of infinite dimensional non-locally compact groups. Namely, we construct an analog of quasi-regular representations by using infinite products of Gaussian measures.

Arxiv

AND
BUT
THEREFORE

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Examples from a science writer

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MACHINE LEARNING

DeepPavlov dream: platform for building generative AI assistants

Meeting for the Association of Computational Linguistics (2023)

D. Zharikova, D. Kornev, F. Ignatov, M. Talimanchuk, D. Evseev, K. Petukhova, V. Smilga, D. Karpov, Y. Shishkina, D. Kosenko, M. Burtsev

Conversational AI assistants are proliferating, but most of the available tools for dialog system development are proprietary or limited. We present the DeepPavlov Dream Platform, an open-source platform for building complex dialog systems. It features a conversational AI orchestrator which enables asynchronous scalable dialog pipelines, and a library of modern NLP components tailored for multi-skill conversational AI.

Pdf

AND
BUT
THEREFORE

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Other writing tips (quick fixes)

- **Be concise.**
  Choose **short words** over long ones. **Don't write *utilise* if you can write *use***. Use *try* over *attempt*, *get* over *obtain*, *tell* over *notify, help* over *assist*, *show* over *demonstrate.*

- **Be compelling**.
  Use **present tense** wherever possible and use the active voice. Academics use the passive voice in the belief that it conveys impartiality, but it just makes sentences dull.

- **Avoid parentheses**
- Keep paragraphs short
- **Use *et cetera* rarely**. Naming just some elements of a set doesn't deny the existence of the others

Building trust in technology

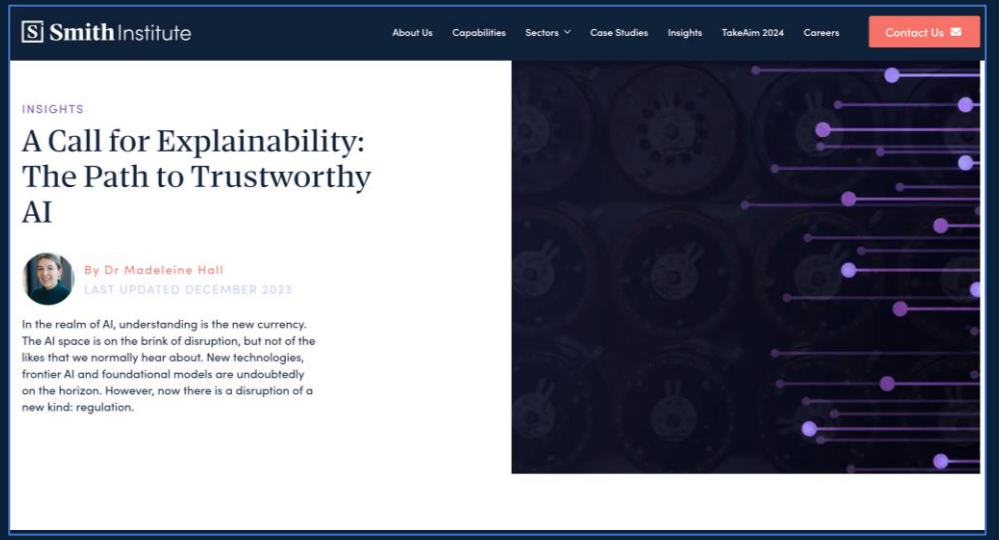
People use what they understand, and also what they don’t

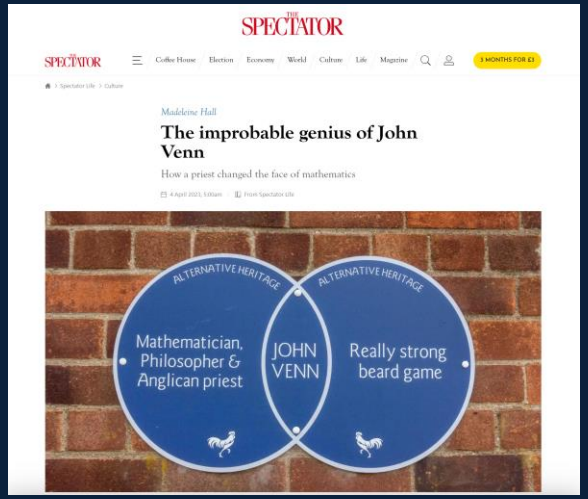
Promoting clarity in tech and AI will build trust and make it safer

Things working against us – degradation of discourse, the algorithm, prolific misinformation, the reproducibility crisis

So, tell your friends!

Further reading





Thanks for your attention

Find me on Linkedin!
Website: madeleinehall.github.io