

GAME 2025

—Generative AI Modeling for Extreme Events—

Prof. Miguel de Carvalho

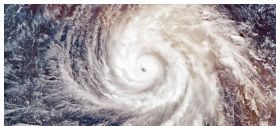


THE UNIVERSITY of EDINBURGH
Generative AI Laboratory



Introducing Myself

- Chair of Statistical Data Science.
- Co-Director of Edinburgh Centre for Financial Innovations.
- Fellow of Generative AI Laboratory (GAIL).
- Leading research field: Extreme Value Theory (EVT).



- Other interests include: Bayes; Interfaces between Statistics & AI.
- Current funding: Aberdeen Investments, GAIL, Royal Society of Edinburgh.

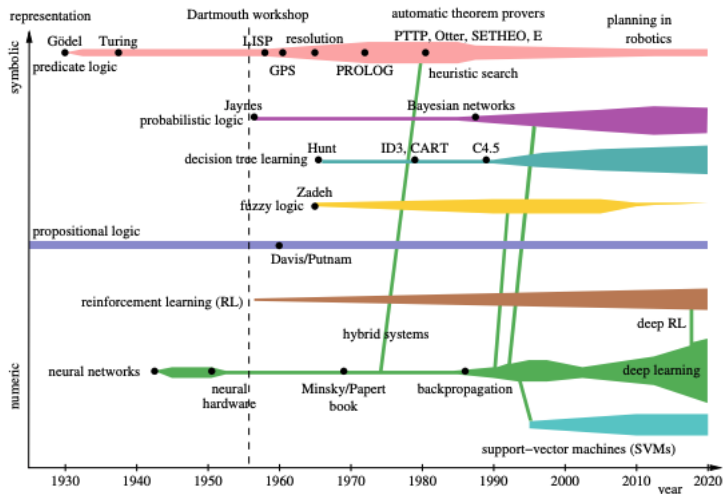
Goal

Mission

- This workshop aims to stimulate discussion on generative AI models for extreme events and to promote the exploration of novel directions in this emerging area.
- **Extreme Value Theory** provides a robust mathematical framework to estimate the risk of extreme events by extrapolating into the tails of a distribution—beyond the limits of available data.
- **Generative AI** refers to a class of artificial intelligence models designed to produce novel content and ideas, including but not limited to text, images, audio, and video.

Selected Comments on the History of AI

Ertel (2025)



History of various subfields of AI.

Parallel Beginnings

Fisher & Tippett (1928)

180 *Messrs Fisher and Tippett, The frequency distribution of*

Limiting forms of the frequency distribution of the largest or smallest member of a sample. By R. A. FISHER, Sc.D., Gonville- and Caius College, and L. H. C. TIPPETT, M.Sc.

[Received 24 November, read 5 December, 1927.]

1. *Introductory.*

In a previous paper on the subject of the distribution of the largest member of a sample from a normal population, one of the authors has given constants involving the first four moments for samples up to 1000. In this paper, possible limiting forms of such distributions in general are discussed. It will appear that a particular group of distributions provides the limiting distributions in all cases, and that the case derived from the normal curve is peculiar for the extreme slowness with which the limiting form is approached.

2. *The possible limiting forms deduced from the functional relation which they must satisfy.*

Since the extreme member of a sample of mn may be regarded as the extreme member of a sample of n of the extreme members of samples of m , and since, if a limiting form exist, both of these distributions will tend to the limiting form as m is increased indefinitely, it follows that the limiting distribution must be such that the extreme member of a sample of n from such a distribution has itself a similar distribution.

If P is the probability of an observation being less than x , the probability that the greatest of a sample of n is less than x is P^n , consequently in the limiting distributions we have the functional equation

$$P^n(x) = P(a_n x + b_n);$$

the solutions of this functional equation will give all the possible limiting forms.

If a is not equal to unity, then

$$x = ax + b,$$

when

$$x = \frac{b}{1-a},$$

and at this point

$$P^a = P,$$

$$P = 0 \text{ or } 1,$$

consequently the solutions fall into three classes:

$$\text{I. } a = 1, \quad P^n(x) = P(x + b_n),$$

$$\text{II. } P = 0 \text{ when } x = 0, \quad P^n(x) = P(a_n x)$$

Gödel (1931)

Some metamathematical results on completeness and consistency,

On formally undecidable propositions of Principia mathematica and related systems I,
and

On completeness and consistency

KURT GÖDEL

(1930b, 1931, and 1931a)

The main paper below (1931), which was to have such an impact on modern logic, was received for publication on 17 November 1930 and published early in 1931. An abstract (1930b) had been presented on 23 October 1930 to the Vienna Academy of Sciences by Hans Hahn.

Gödel's results are now accessible in many publications, but his original paper has not lost any of its value as a guide. It is clearly written and does not assume any previous result for its main line of argument. It is, moreover, rich in interesting details. We now give some indications of its contents and structure.

Section 1 is an informal presentation of the main argument and can be read by the nonmathematician; it shows how the argument, by dealing with the proposition that states of itself "I am not provable", instead of the proposition that states of itself "I am not true", skirts the Liar paradox, without falling into it. Gödel also brings to light the relation that his argument bears to Cantor's diagonal procedure and Richard's par-

adox (Herbrand, on pages 626–628 below, and Weyl (1949, pp. 219–235) particularly stress this aspect of Gödel's argument; see also above, p. 439).

Section 2, the longest, is the proof of Theorem VI. The theorem states that in a formal system satisfying certain precise conditions there is an undecidable proposition, that is, a proposition such that neither the proposition itself nor its negation is provable in the system. Before coming to the core of the argument, Gödel takes a number of preparatory steps:

(1) A precise description of the system P with which he is going to work. The variables are distinguished as to their types and they range over the natural numbers (type 1), classes of natural numbers (type 2), classes of classes of natural numbers (type 3), and so forth. The logical axioms are equivalent to the logic of *Principia mathematica* without the ramified theory of types. The arithmetic axioms are Peano's, properly transcribed. The identification of the individuals with the natural numbers and

Parallel Beginnings

Gnedenko (1943)

ANNALS OF MATHEMATICS
Vol. 44, No. 3, July, 1943

SUR LA DISTRIBUTION LIMITE DU TERME MAXIMUM D'UNE SÉRIE ALÉATOIRE

PAR B. GNEDENKO

(Received February 8, 1943)

Introduction

Considérons une suite

$$x_1, x_2, \dots, x_n, \dots$$

de variables aléatoires mutuellement indépendantes et assujetties à une même loi de distribution $F(x)$. Formons une autre suite de variables aléatoires

$$\xi_1, \xi_2, \dots, \xi_n, \dots,$$

en posant

$$\xi_n = \max(x_1, x_2, \dots, x_n).$$

On voit facilement que la fonction de distribution de ξ_n est

$$F_n(x) = P\{\xi_n < x\} = F^n(x).$$

L'étude de la fonction $F_n(x)$ pour les grandes valeurs de n offre un intérêt notable. Beaucoup de travaux ont été consacrés à cette question. En particulier, M. Fréchet [1] en 1927 a trouvé les lois qui peuvent être limites pour $F_n(a_n x)$ pour un choix convenable des constantes positives a_n .

Cette classe de lois limites est formée des lois de types¹ suivants

$$\Phi_\alpha(x) = \begin{cases} 0 & \text{pour } x \leq 0 \\ e^{-x^\alpha} & \text{pour } x > 0 \end{cases}$$

et

$$\Psi_\alpha(x) = \begin{cases} e^{-(-x)^\alpha} & \text{pour } x \leq 0 \\ 1 & \text{pour } x > 0 \end{cases}$$

où α désigne une constante positive.

En 1928 R. A. Fisher et L. H. C. Tippett [2] ont établi que les lois limites pour $F_n(a_n x + b_n)$, où $a_n > 0$ et b_n sont des constantes réelles convenablement choisies, se réduisent aux lois de types $\Phi_\alpha(x)$, $\Psi_\alpha(x)$ et la loi

McCulloch & Pitts (1943)

BULLETIN OF
MATHEMATICAL BIOPHYSICS
VOLUME 5, 1943

A LOGICAL CALCULUS OF THE IDEAS IMMANENT IN NERVOUS ACTIVITY

WARREN S. MCCULLOCH AND WALTER PITTS

FROM THE UNIVERSITY OF ILLINOIS, COLLEGE OF MEDICINE,
DEPARTMENT OF PSYCHIATRY AT THE ILLINOIS NEUROPSYCHIATRIC INSTITUTE,
AND THE UNIVERSITY OF CHICAGO

Because of the "all-or-none" character of nervous activity, neural events and the relations among them can be treated by means of propositional logic. It is found that the behavior of every net can be described in these terms, with the addition of more complicated logical means for nets containing circles; and that for any logical expression satisfying certain conditions, one can find a net behaving in the fashion it describes. It is shown that many particular choices among possible neurophysiological assumptions are equivalent, in the sense that for every net behaving under one assumption, there exists another net which behaves under the other and gives the same results, although perhaps not in the same time. Various applications of the calculus are discussed.

I. Introduction

Theoretical neurophysiology rests on certain cardinal assumptions. The nervous system is a net of neurons, each having a soma and an axon. Their adjunctions, or synapses, are always between the axon of one neuron and the soma of another. At any instant a neuron has some threshold, which excitation must exceed to initiate an impulse. This, except for the fact and the time of its occurrence, is determined by the neuron, not by the excitation. From the point of excitation the impulse is propagated to all parts of the neuron. The velocity along the axon varies directly with its diameter, from less than one meter per second in thin axons, which are usually short, to more than 150 meters per second in thick axons, which are usually long. The time for axonal conduction is consequently of little importance in determining the time of arrival of impulses at points un-

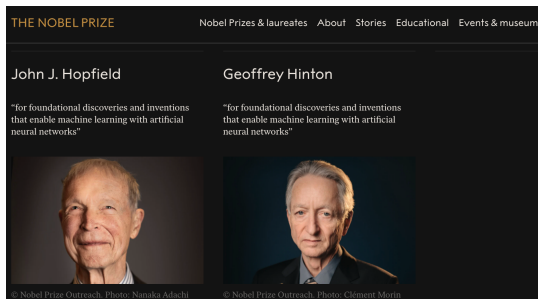
Parallel Beginnings

- Despite these parallel beginnings, it has taken nearly a century for the two fields to begin meaningfully intersecting.



A Lot Has Changed Since Then...

Nobel Prize of Physics 2024



- The press release for the award contains some details on the links between core concepts from physics (e.g., atomic spin, Boltzmann machines, energy) and the neural models that the winners proposed.
- Still, even Geoffrey Hinton himself told the *New York Times* that:
"If there was a Nobel Prize for computer science, our work would clearly be more appropriate for that."

Generative AI

ChatGPT (Nov. 2022)



Other Big Players

IBM

IBM

Research

Focus areas ▾

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Climate and Sustainability

Machine Learning

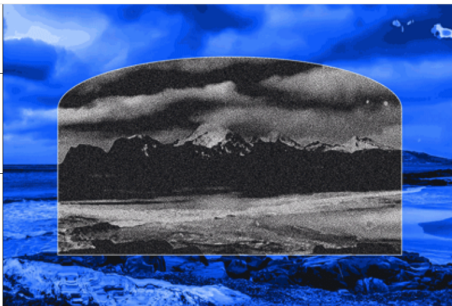
Lab

Brazil

Overview

Publications

Contributors



Generative Machine Learning for Extreme Weather Generation

Overview

As our climate warms, the frequency, duration, and intensity of extreme weather events has been increasing. For example, climate change leads to more evaporation that may exacerbate droughts and increase the frequency of heavy rainfall and snowfall events. That directly impacts various sectors

Agenda

Friday

- 09:30–10:00 Vianey Palacios Ramirez (Newcastle University)
- 10:00–10:30 Michaël Allouche (Kaiko)
- 10:30–11:00 Coffee break
- 11:00–11:30 Emma Simpson (University College London)
- 11:30–12:00 Olivier Pasche (University of Geneva)
- 12:00–13:30 Pizza break
- 13:30–14:00 Miguel de Carvalho (University of Edinburgh)
- 14:00–14:30 Clemente Ferrer (Univ. Técnica Federico Santa María)
- 14:30–15:00 Coffee break (Day 1 Group Photo)
- 15:00–15:30 Jordan Richards (University of Edinburgh)
- 15:30–16:00 Lambert De Monte (University of Edinburgh)
- 16:00–16:45 Brainstorm session

Agenda

Saturday

- 10:15–10:45 Chenglei Hu (Glasgow University)
- 10:45–11:15 Amanda Lenzi (University of Edinburgh)
- 11:15–11:45 Coffee break (Day 2 Group Photo)
- 11:45–12:15 Stéphane Lhaut (Université Catholique de Louvain)
- 12:15–12:45 Luca Trapin (University of Bologna)
- 12:45–12:55 Closing thoughts

Acknowledging the Workshop

Continuing the Impact Together

Attribution

- We kindly encourage participants to acknowledge this workshop in any research outcomes—papers, grant applications, or other scholarly outputs—that have directly or indirectly benefited from it.
- In turn, we would be delighted to feature your work on the workshop website. Please feel free to share links to relevant papers, grants, or projects.

Acknowledgments



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Let the GAME begin!

