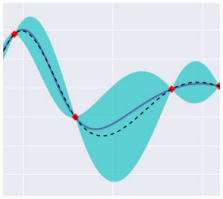
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Session 5: Probabilistic Programming



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Probabilistic Model

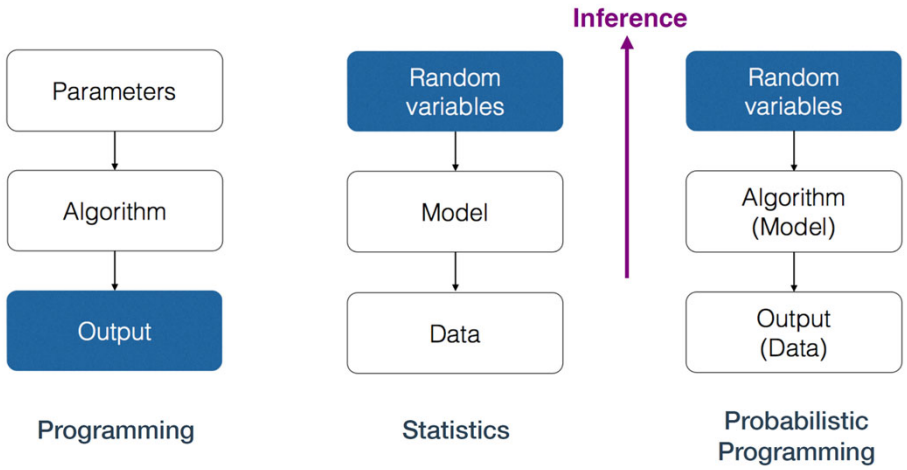
- Probabilistic models incorporate random variables and probability distributions into the model
  - Deterministic model gives a single possible outcome
  - Probabilistic model gives a probability distribution
- Used for various probabilistic logic inference (e.g. MCMC-based inference, Bayesian inference…)

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Intuitive View of Probabilistic Programming

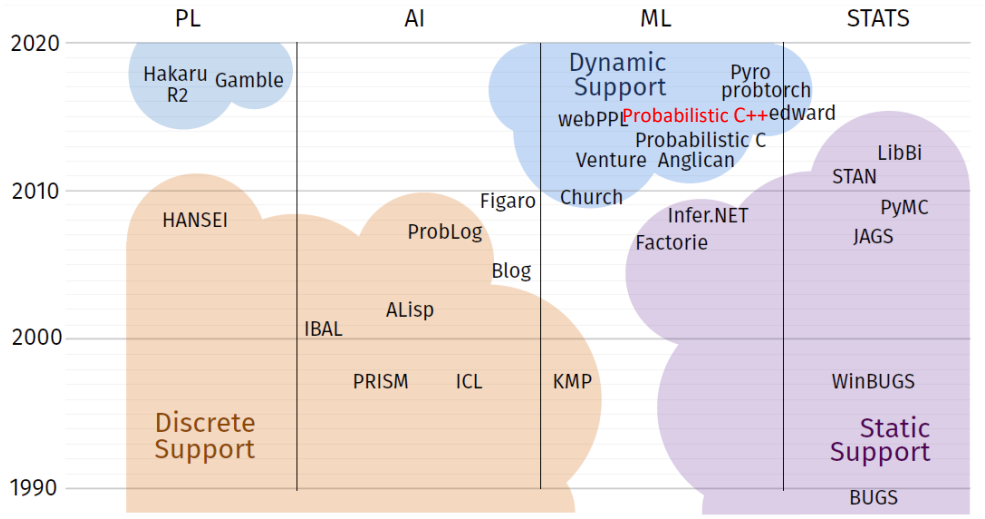


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Probabilistic Programming Languages



B. Paige

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Computer systems using probabilistic models with PPL

- **Stan (probabilistic programming system)**
  Widely used for Bayesian modelling and statistical inference in applications like epidemiological modelling, recommendation systems, and time-series forecasting.
- **Pyro (Uber AI Labs)**
  A deep probabilistic programming language built on PyTorch, applied in large-scale machine learning tasks such as probabilistic forecasting, personalization, and causal inference.
- **Edward2 (Google/TFP)**
  A probabilistic programming system integrated with TensorFlow Probability, applied in Bayesian neural networks, uncertainty quantification, and scientific modelling.
- **Infer.NET (Microsoft Research)**
  Originally developed for probabilistic graphical models, deployed in applications such as natural language processing, computer vision, and healthcare (e.g., genetic data analysis).
- **Gen (MIT CSAIL)**
  A flexible probabilistic programming system designed for probabilistic inference in AI systems, applied to problems like 3D scene understanding, robotics, and program synthesis.

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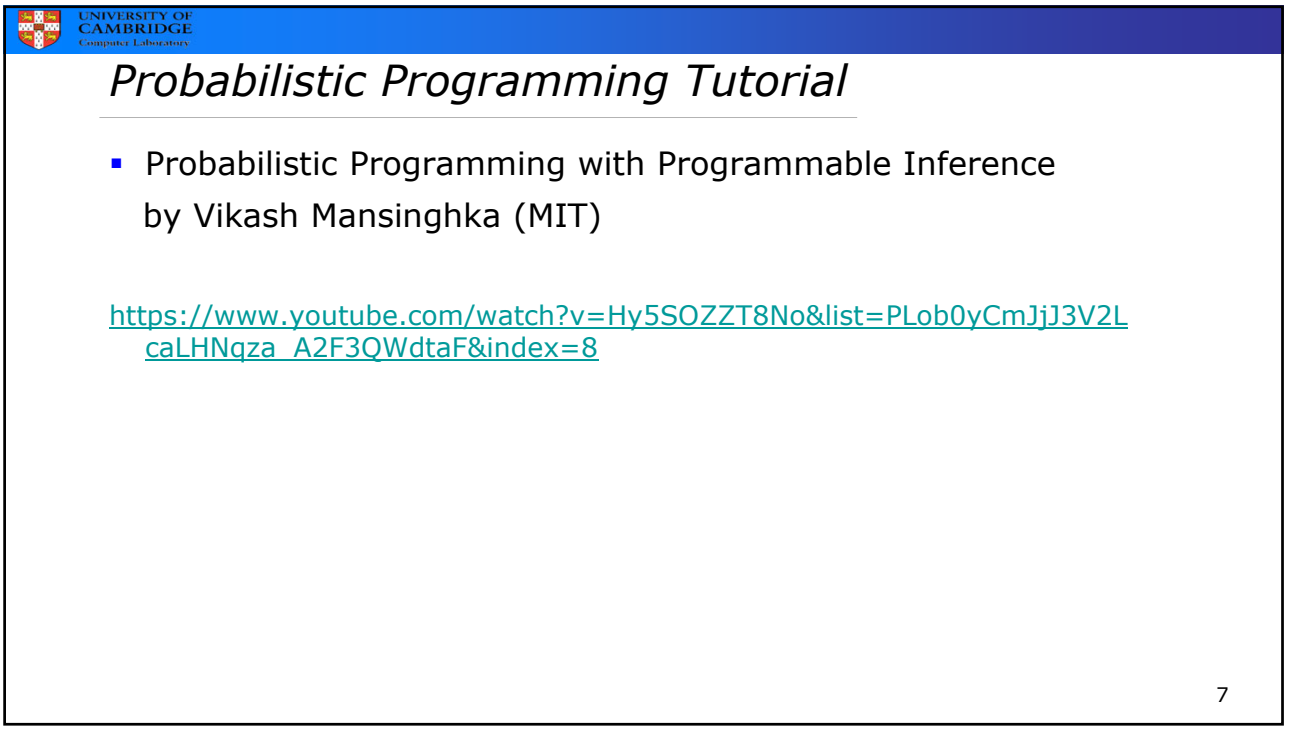
References and Links

- For further knowledge of BO, GP, and PP, read the PhD dissertation by Valentin Dalibard on the following topics. It is well described in concise manner.
  https://www.cl.cam.ac.uk/techreports/UCAM-CL-TR-900.pdf
  - Chapter 2: Bayesian Optimisation including Gaussian Process
  - Chapter 4: Probabilistic models of programs executions including Probabilistic Programming

- Further Bayesian Optimisation
  - Review paper by Shahriari, et al. (2016): Taking the Human Out of the Loop: A Review of Bayesian Optimization. Proceedings of the IEEE 104(1):148-175, 2016.
  - Slides by Ryan Adams (2014): A Tutorial on Bayesian Optimization for Machine Learning. CIFAR NCAP Summer School.
  - Slides by Peter Frazier (2010): Tutorial: Bayesian Methods for Global and Simulation Optimization. INFORMS Annual Meeting.

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Probabilistic Programming Tutorial
Probabilistic Programming with Programmable Inference
by Vikash Mansinghka (MIT)
https://www.youtube.com/watch?v=Hy5SOZZT8No&list=PLob0yCmJjJ3V2LcaLHNqza_A2F3QWdtaF&index=8
7