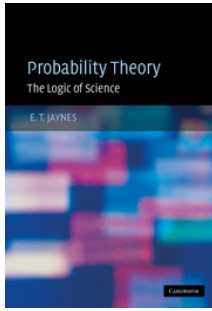
Bayesian programming and Bayesian hardware

Bayesian-Programming.org

Pierre Bessière, 2021

Probability as an extension of Logic



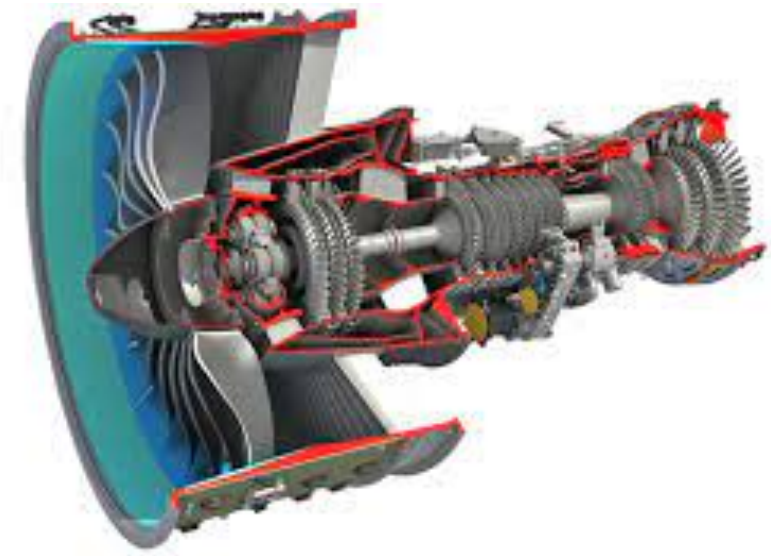
Probability is an extension of Logic

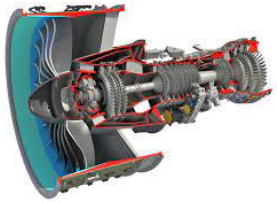
to model rational reasoning

with incomplete (and uncertain) knowledge

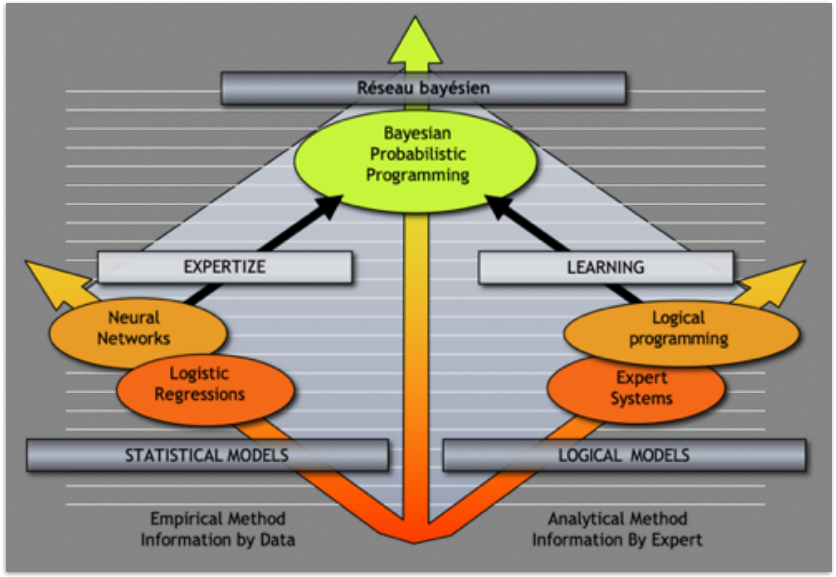
- A subjectivist epistemology of probability
- A discrete approach of probability
- A new cognitive paradigm
- A new computing paradigm
  - New machines and hardware

Turbofan

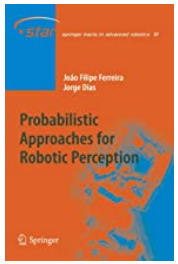


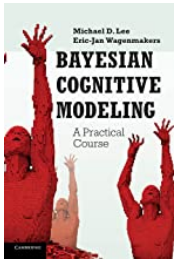


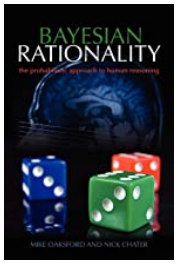
A subjectivist epistemology

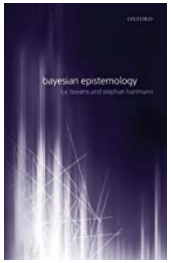


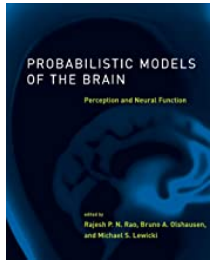
A new cognitive paradigm

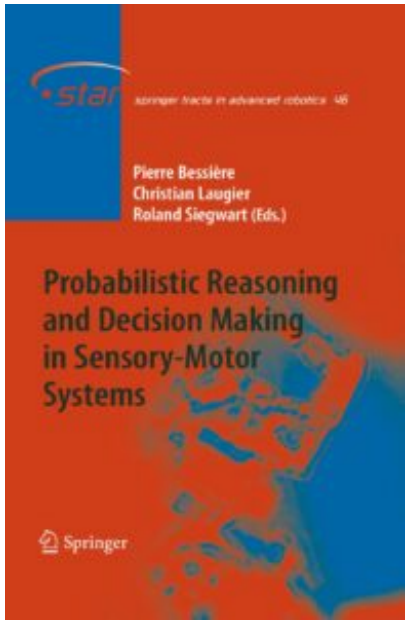


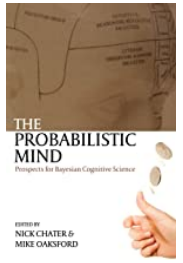


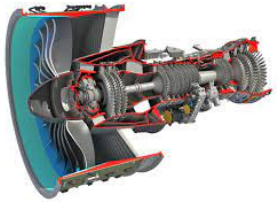




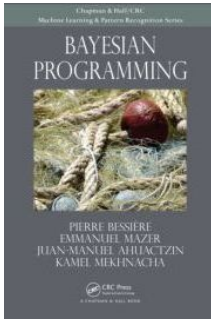




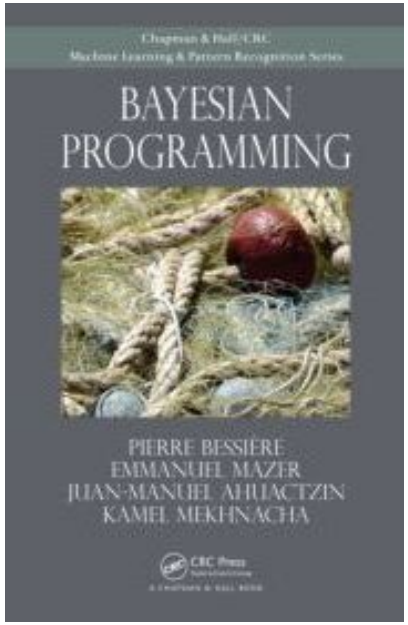


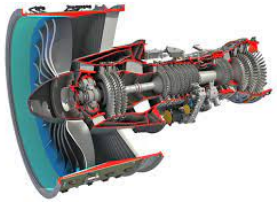


A new computing paradigm

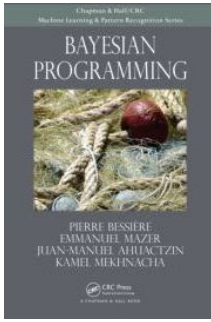


- New modeling methodology
- New programming languages
- New inference algorithms
- New hardwares





New modeling methodology: Bayesian Programming



BAYESIAN PROGRAM

DESCRIPTION

SPECIFICATION

- VARIABLES

$$S^0, \ldots\ldots, S^t, O^0, \ldots\ldots, O^t$$

- DECOMPOSITION

$$\mathbf{P}(S^0 \wedge \ldots\ldots \wedge S^t \wedge O^0 \wedge \ldots\ldots \wedge O^t) = \mathbf{P}(S^0) \times \mathbf{P}(O^0 \mid S^0) \times \prod_{i=2}^{t} [\mathbf{P}(S^i \mid S^{i-1}) \times \mathbf{P}(O^i \mid S^i)]$$

- PARAMETRIC FORMS

$$\mathbf{P}(S^0) \equiv \mathbf{G}(S^0, \mu, \sigma)$$
$$\mathbf{P}(S^i \mid S^{i-1}) \equiv \mathbf{G}(S^i, A \bullet S^{i-1}, Q)$$
$$\mathbf{P}(O^i \mid S^i) \equiv \mathbf{G}(O^i, H \bullet S^i, R)$$

IDENTIFICATION

- LEARNING FROM INSTANCES

QUESTION

$$\mathbf{P}(S^t \mid O^0 \wedge \ldots\ldots \wedge O^t)$$

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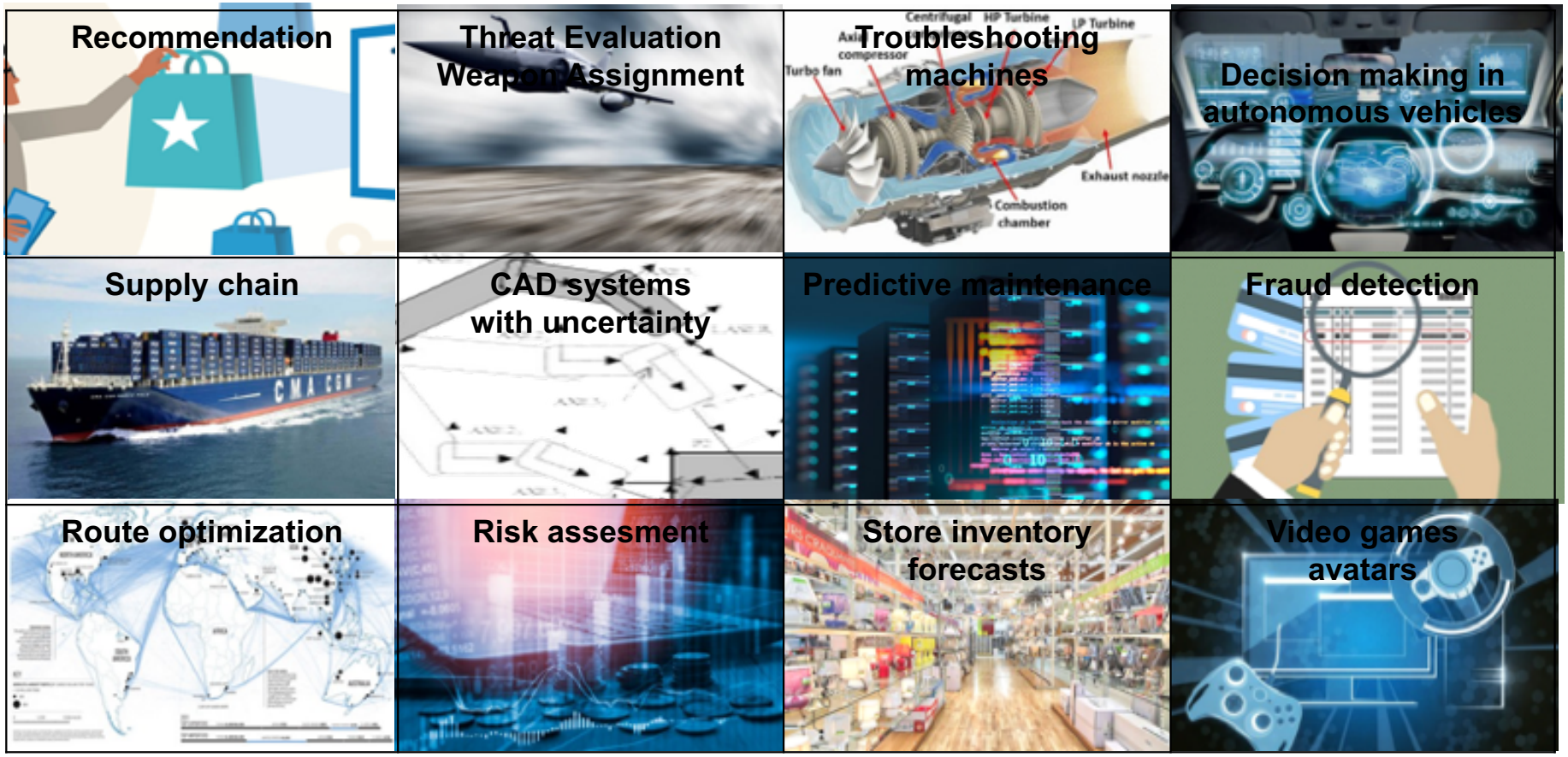
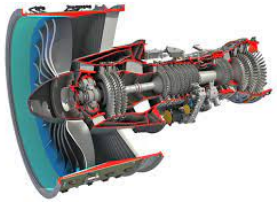
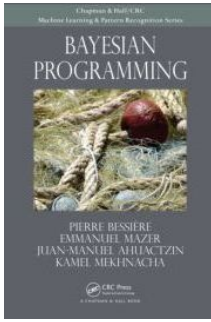
L'IA sur-mesure

New programming languages: ProBT





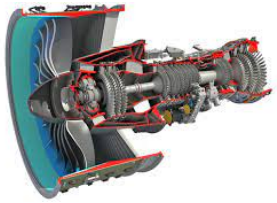
A discrete approach



$$P(S|k) \propto \sum_{F} \left[\prod_{d=1}^{D} \left[P(L_d|R_d) \right] \right]$$

$$\mathbf{P}(S^t \mid O^0 \wedge \ldots\ldots \wedge O^t)$$

$$\mathbf{P}(S^0 \wedge \ldots\ldots \wedge S^t \wedge O^0 \wedge \ldots\ldots \wedge O^t) = \mathbf{P}(S^0) \times \mathbf{P}(O^0 \mid S^0) \times \prod_{i=2}^{t} [\mathbf{P}(S^i \mid S^{i-1}) \times \mathbf{P}(O^i \mid S^i)]$$



New inference algorithms

$$P(S|k) \propto \sum_{F} \left[\prod_{d=1}^{D} \left[P(L_d|R_d) \right] \right]$$

BMF Machine

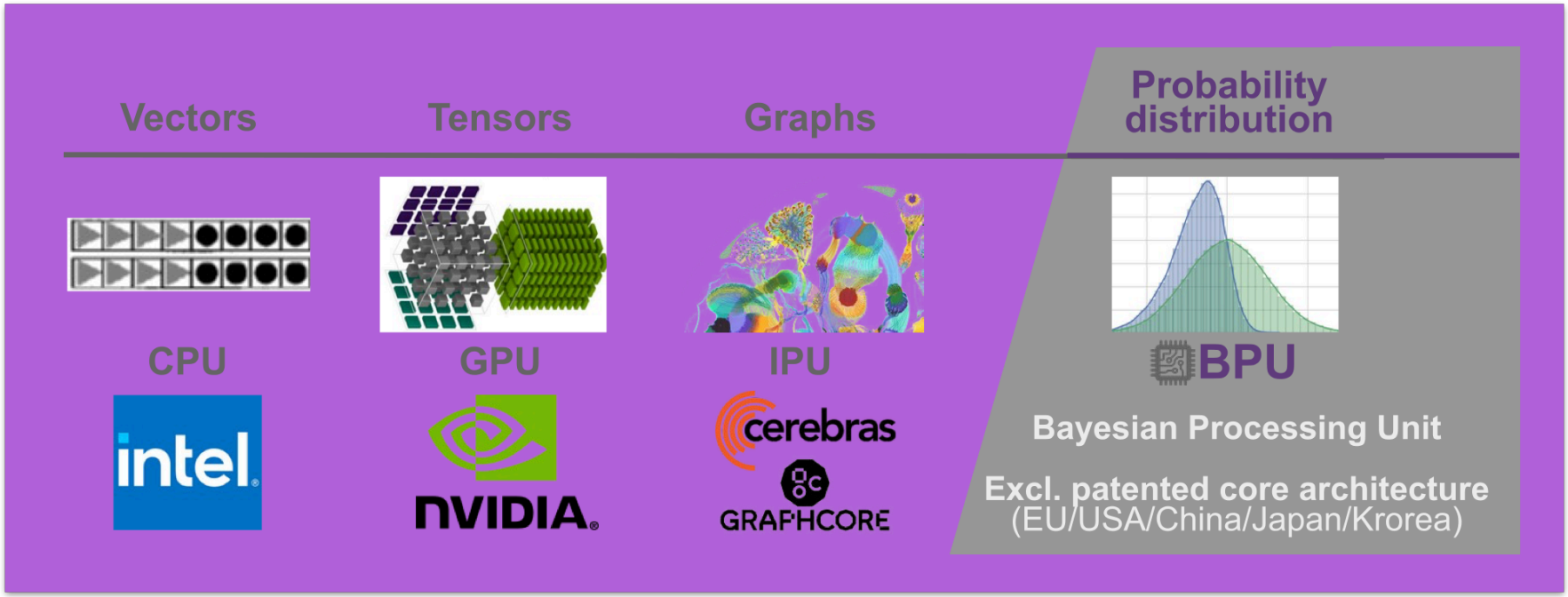
Sampling Machine

Memory-centric Machine

Spintronic Machine

New hardwares

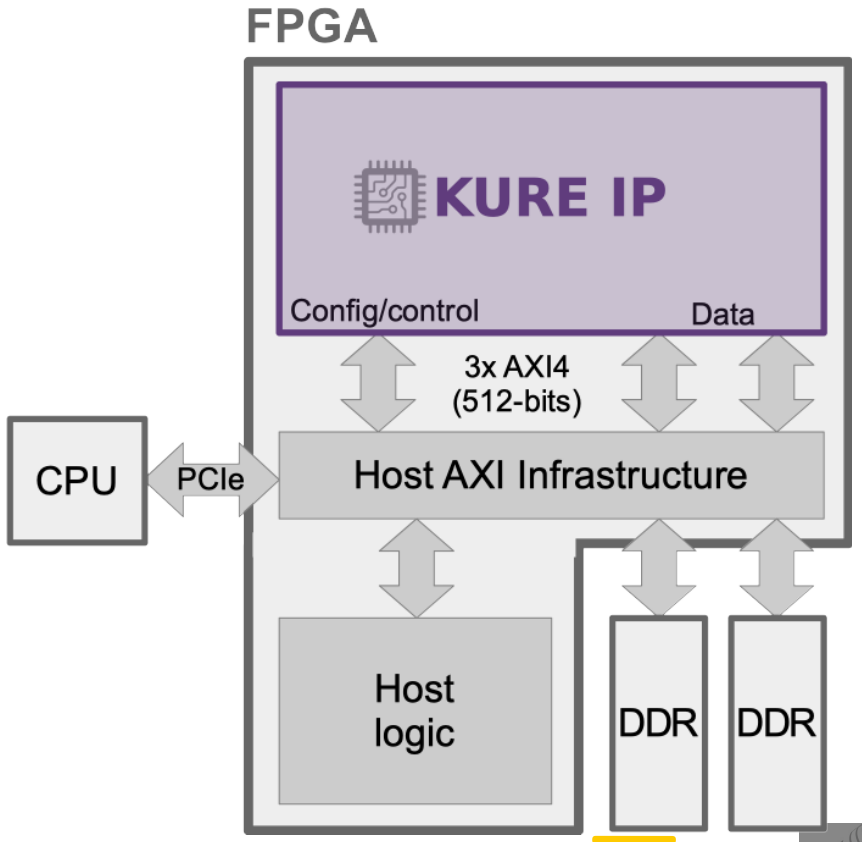
CPU / GPU / IPU / BPU

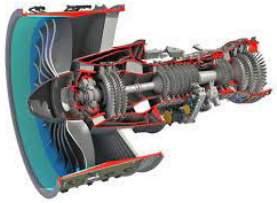


BMF Machines

$$P(S|k) \propto \sum_{F} \left[\prod_{d=1}^{D} \left[P(L_d|R_d) \right] \right]$$

BMF Machine





Sampling machines

$$P(S|k) \propto \sum_{F} \left[\prod_{d=1}^{D} \left[P(L_d|R_d) \right] \right]$$

Sampling Machine

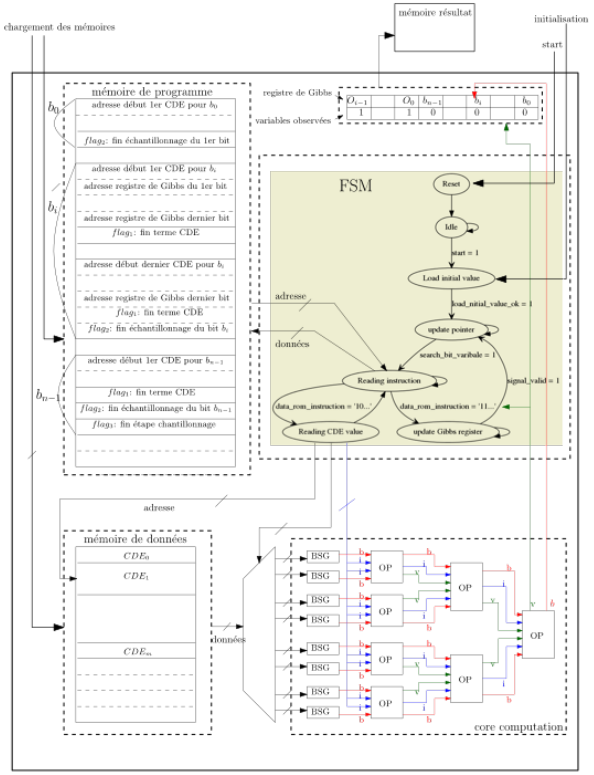
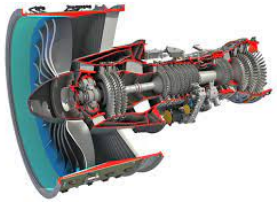


FIGURE 6.1 – Schéma de la machine bayésienne programmable pour l'inférence approchée



Memory-centric machines

$$P(S|k) \propto \sum_{F} \left[\prod_{d=1}^{D} \left[P(L_d|R_d) \right] \right]$$

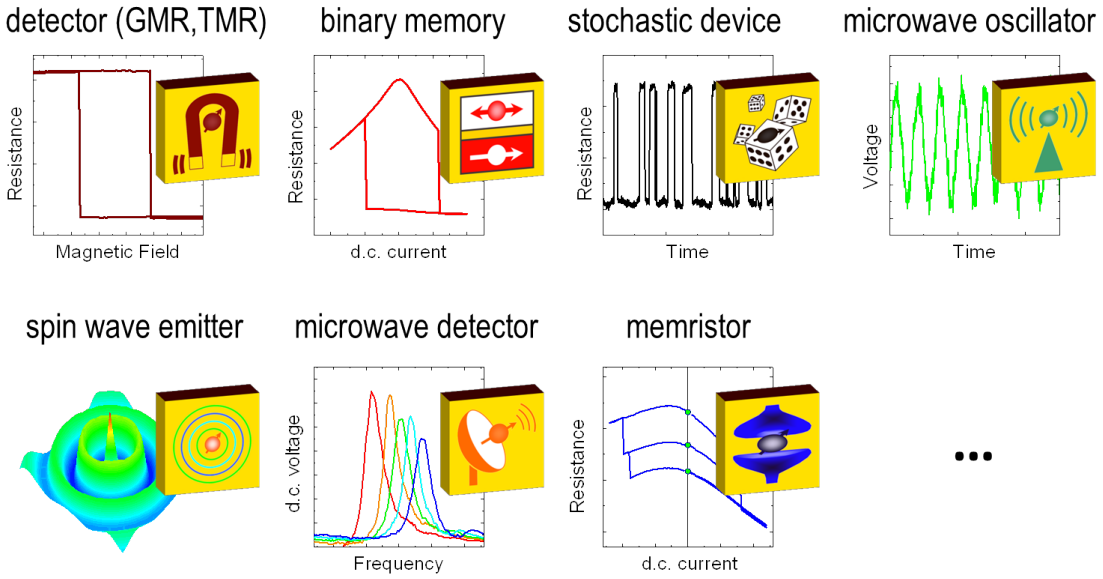
Memory-centric Machine

Patents pending

Spintronic machines

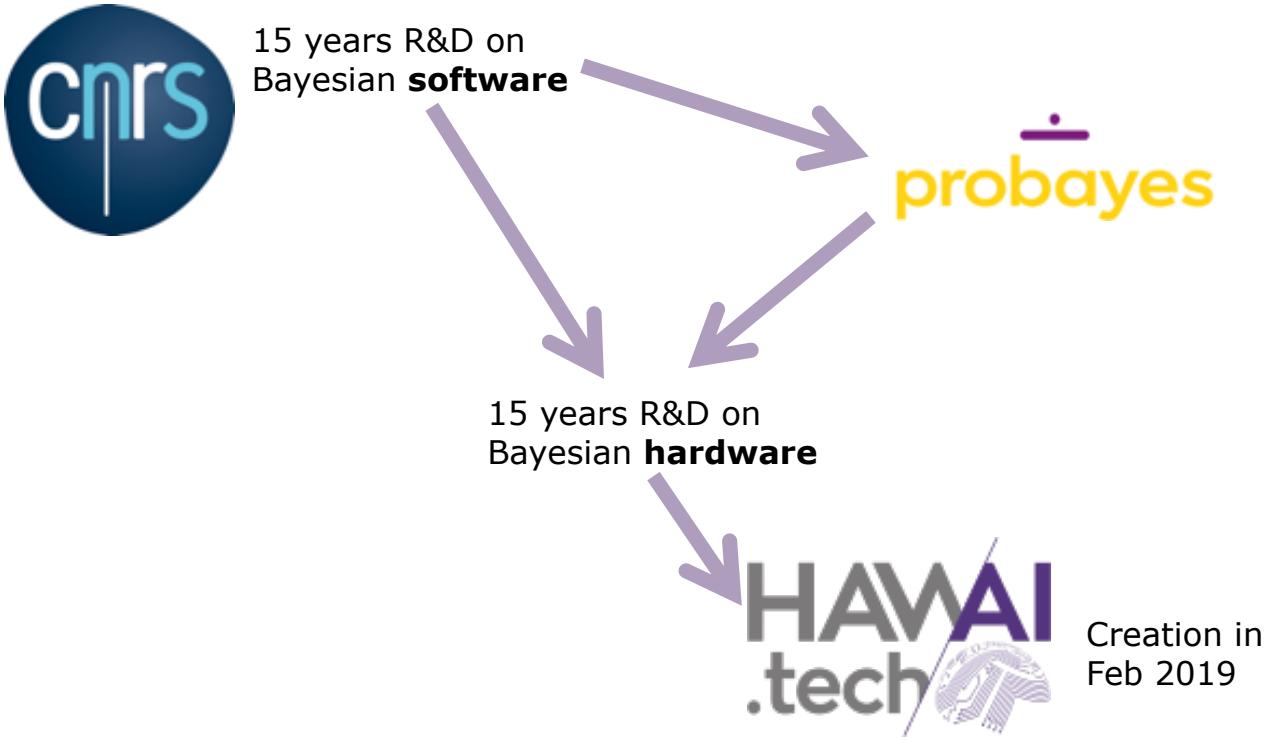
$$P(S|k) \propto \sum_{F} \left[\prod_{d=1}^{D} \left[P(L_d|R_d) \right] \right]$$

Spintronic Machine

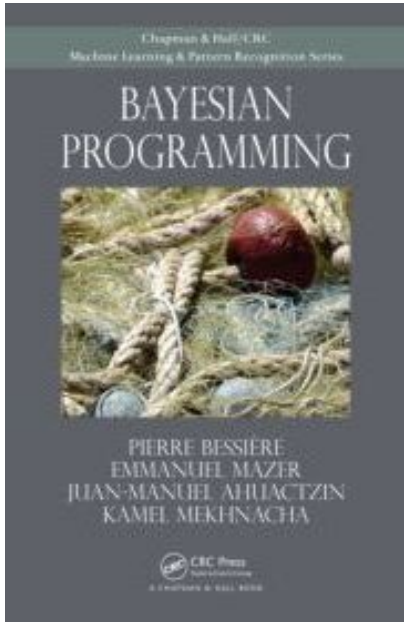


From Julie Grollier web pages – CNRS/Thales lab

happy marriage



Questions ?



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