MicroBayes

Probabilistic Machines for Low-level Sensor Interpretation

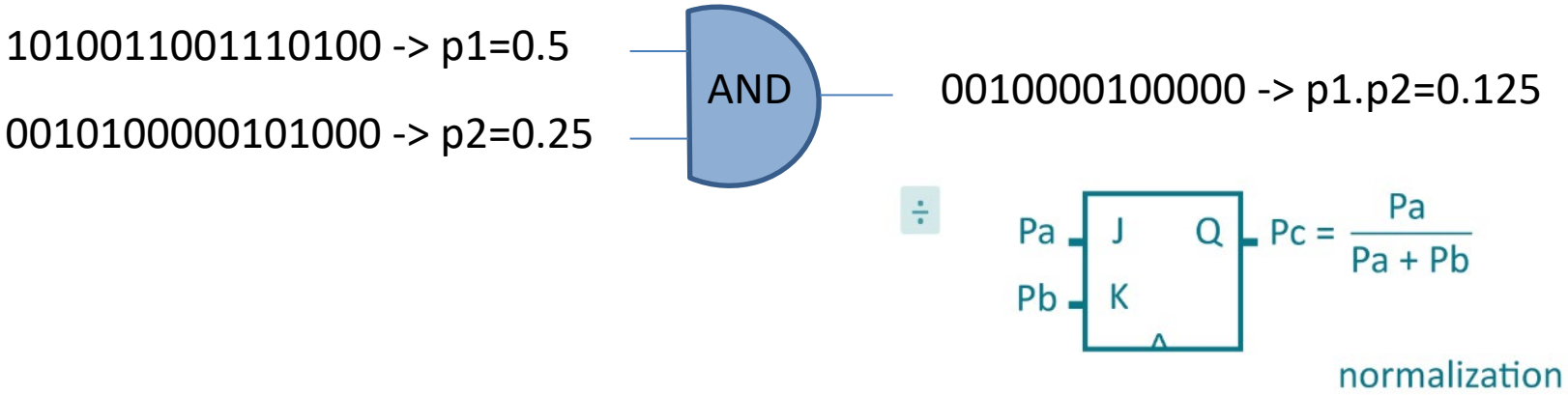
Emmanuel Mazer Didier Piau Laurent Fesquet Laurent Girin

Agenda

- Context
  - Rebooting Computing
  - Bambi
- Project description
  - Scientific challenges
  - Envisioned approaches
  - Expected results
  - Dissemination & valorization

Overall objectives

- Use a radically different approach to perform computation : stochastic computing



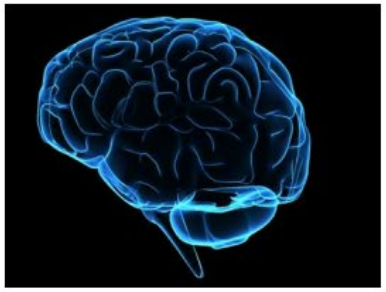
- Outperform standard computer and GPU in term of speed and energy efficiency for Bayesian inference problems

CONTEXT

High energy consumption

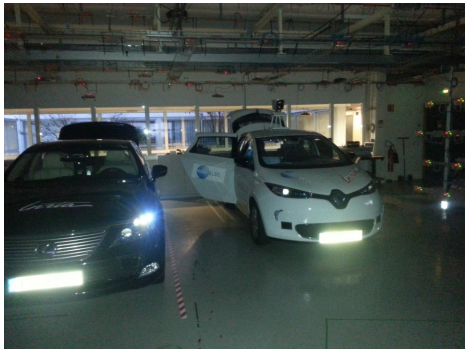
~ 200 kW
$\sim 3,9$ m^3

VS



~ 20 W
$\sim 1,3$ l

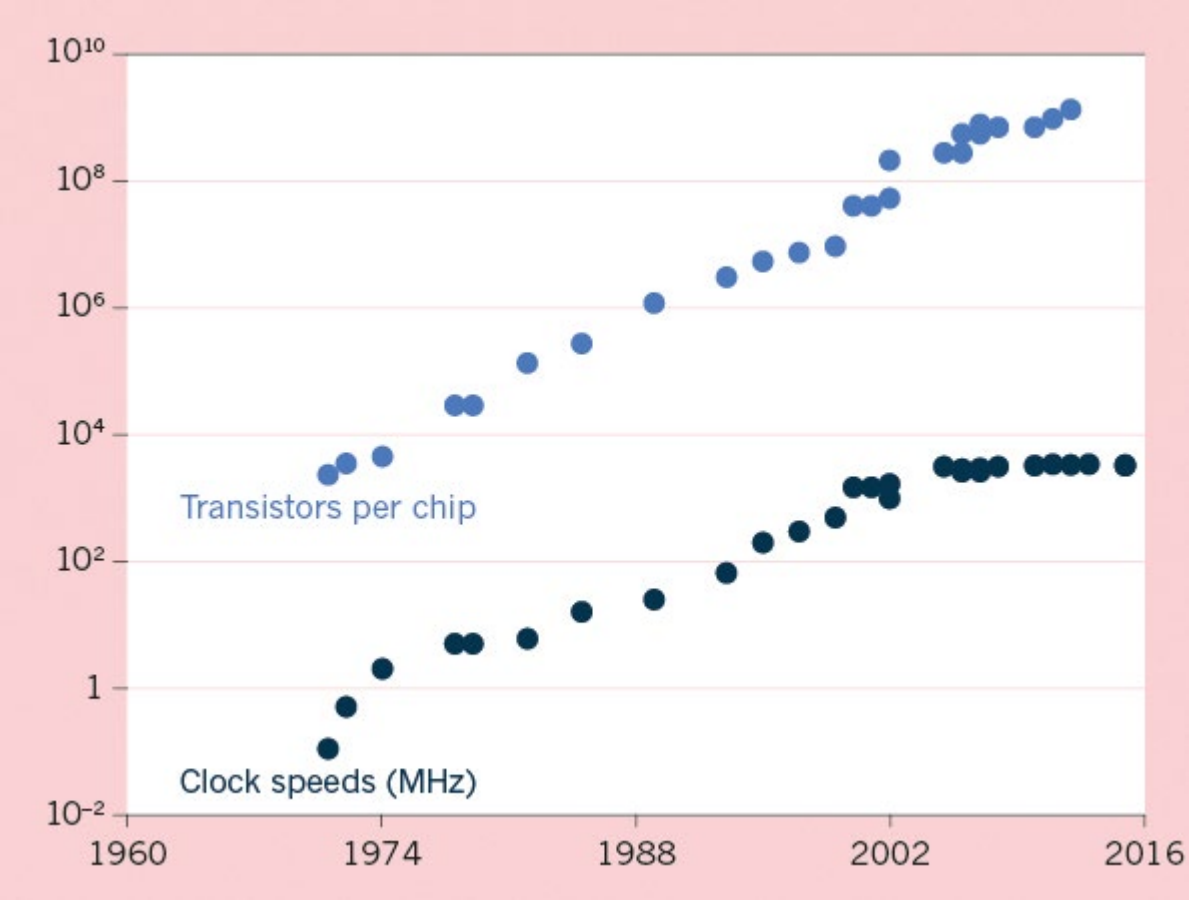
1 Stéréo Camera
+
2 lidars



$\approx 0.5M^3$

$\approx 1KW$

Moore's Law limits



Rebooting Computing

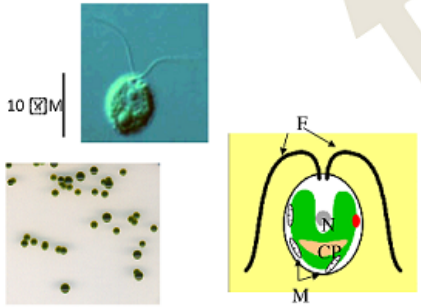
http://rebootingcomputing.ieee.org/rc-summits/rcs4/presentations

BAMBI

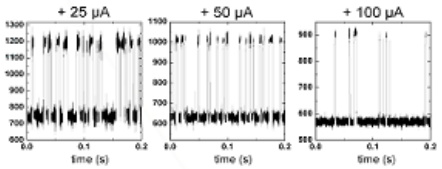
Bottom-up Approaches to Machines dedicated to Bayesian Inference

FET Project BAMBI FP7-ICT-2013-C

«bio study chlamydomonas»



New hardware thinking:
- Telegraphic signal
- new device



Soft evidence

$P(MDL)$: *def*

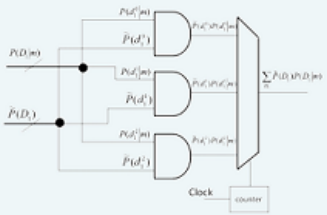
$\widetilde{P}(D_i)$: soft evidence input

$$P\left(M \middle| \prod_i \widetilde{P}(D_i)\right) = \frac{1}{Z(D)} \sum_{D_1} \widetilde{P}(D_1) \cdots \sum_{D_k} \widetilde{P}(D_k) \sum_{L} P(MDL)$$

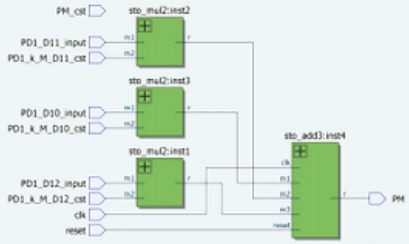
Bayesian model description

$$Pr\left\{ Ds \left\{ \begin{array}{l} Va : D_1, D_2, M \\ Dc : \{P(MD1D2) = P(M)P(D_1|M)P(D_2|M) \\ Sp(\pi) \\ Fo : \left\{ \begin{array}{l} P(M)\text{Uniform} \\ P(D1|M)\text{Histograms} \\ P(D2|M)\text{Histograms} \end{array} \right. \\ Identification \end{array} \right. \right. \\ Qu : P(M)$$

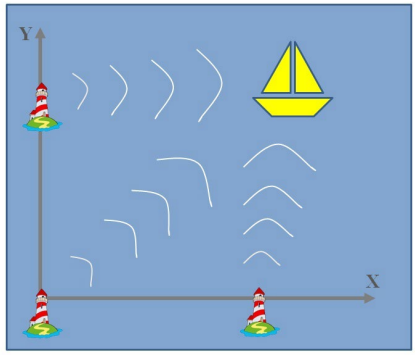
high level circuit simulation



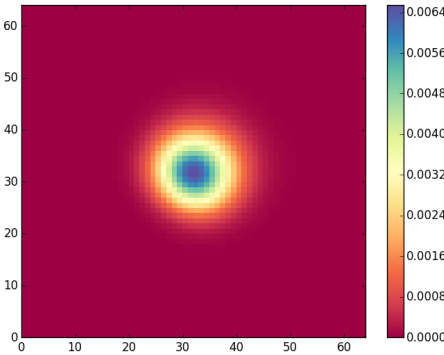
mapping on FPGA



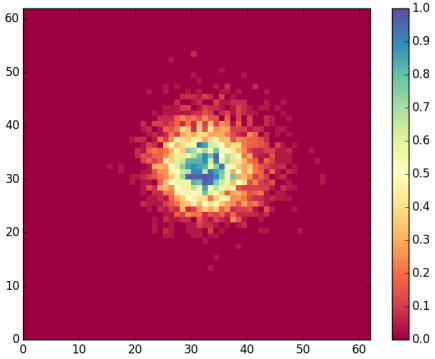
Good results with minimal hardware



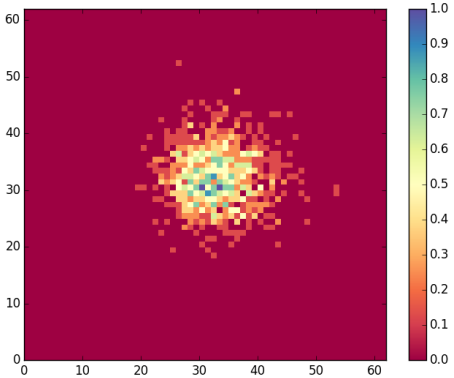
Exact inference



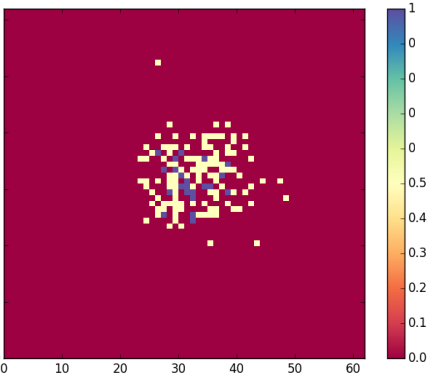
N=200: ε <0.01%



N=10: ε < 0.1%



N=1: ε <2%



ε: mean location precision

N: length of the bit stream used for the priors

MicroBayes Challenges

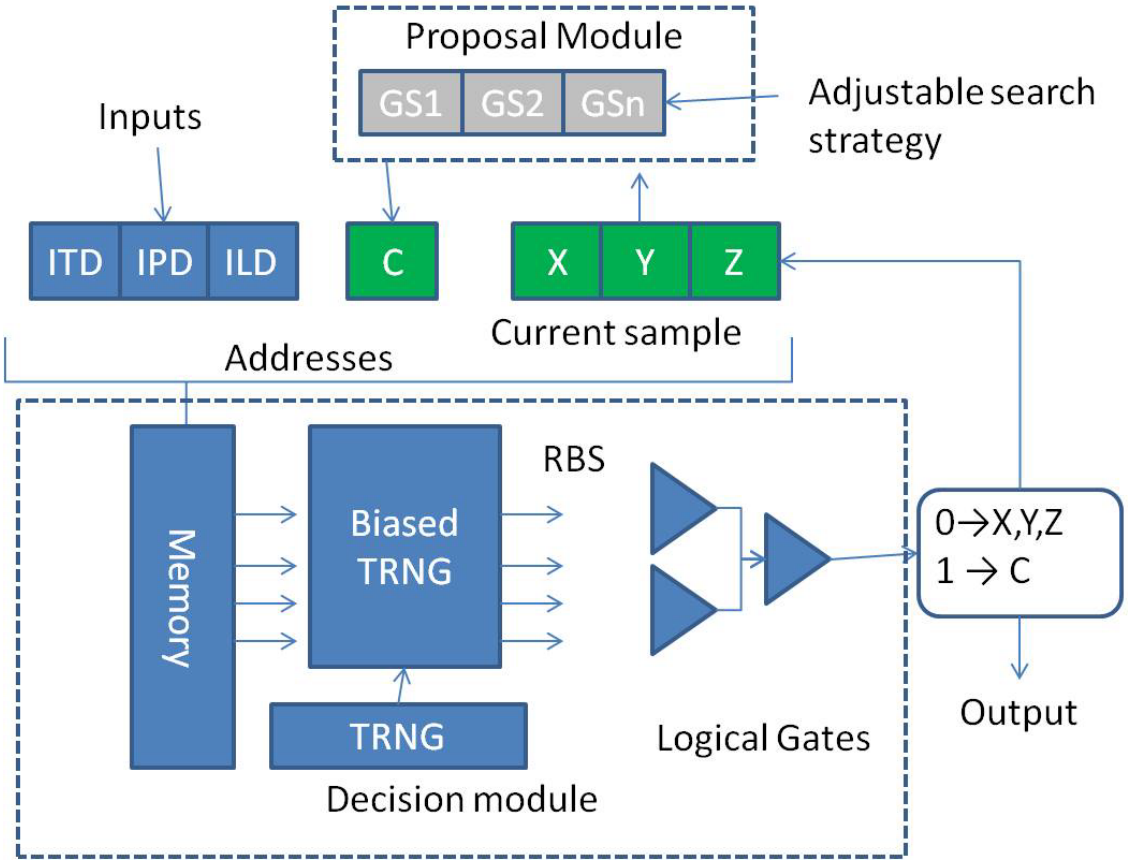
(a) To design non von Neumann architectures dedicated to the processing of stochastic bit streams.

(b) To study new algorithms for stochastic inference based on generating sets.

(c) To evaluate stochastic machines on difficult Bayesian inference problems related to low-level sensor fusion.

SCIENTIFIC APPROACHES

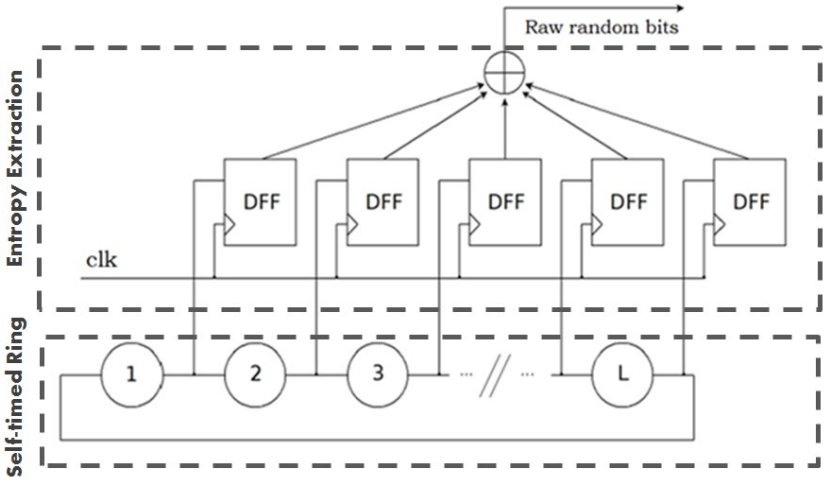
Design of stochastic machines

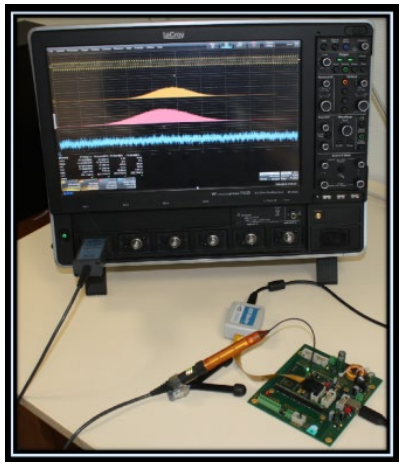


High performance CMOS TRNG

TIMA Self-timed ring based TRNG

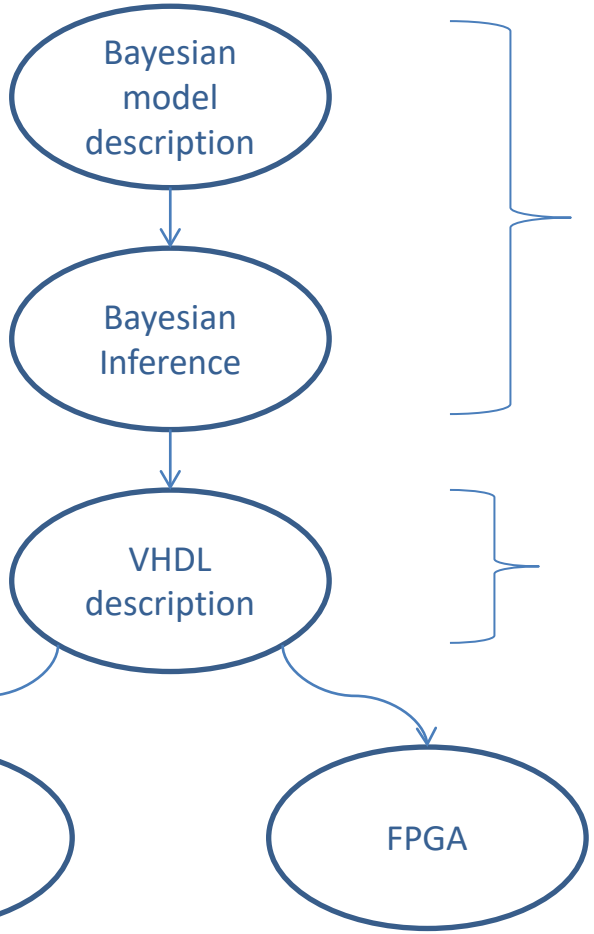
- Extracts randomness from the jitter of a STR, **regardless the jitter magnitude**
- The design is flexible: **area, bit rate and security level can be tuned** with a very low design effort
- Passes AIS31 and NIST tests at high bit rates (**a few hundred Mbit/s**)





Compilation tool chain for stochastic machines

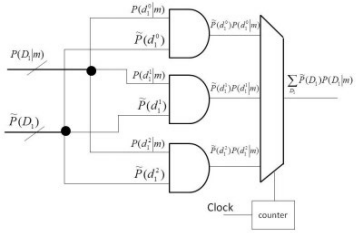
$$Pr\left\{\begin{array}{l} Ds\left\{\begin{array}{l} Sp(\pi)\left\{\begin{array}{l} Va: D_1, D_2, M \\ Dc: \{P(MD1D2) = P(M)P(D_1|M)P(D_2|M) \\ Fo: \left\{\begin{array}{l} P(M)\textbf{Uniform} \\ P(D1|M)\textbf{Histograms} \\ P(D2|M)\textbf{Histograms} \end{array}\right. \end{array}\right. \\ Identification \end{array}\right. \\ Qu: P(M) \end{array}\right.$$

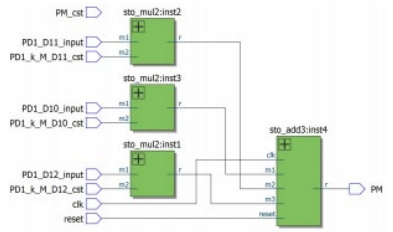


Programming and Algorithmic (ProBT)

Compiler

FPGA:
Field Programmable Gate Array





New algorithms for stochastic inference

- Realistic problems are leaving in high dimension space.

- Stochastic inference is equivalent to explore this space to search for high probability density regions.

MicroBayes : Stochastic Machine with Programmable search strategies

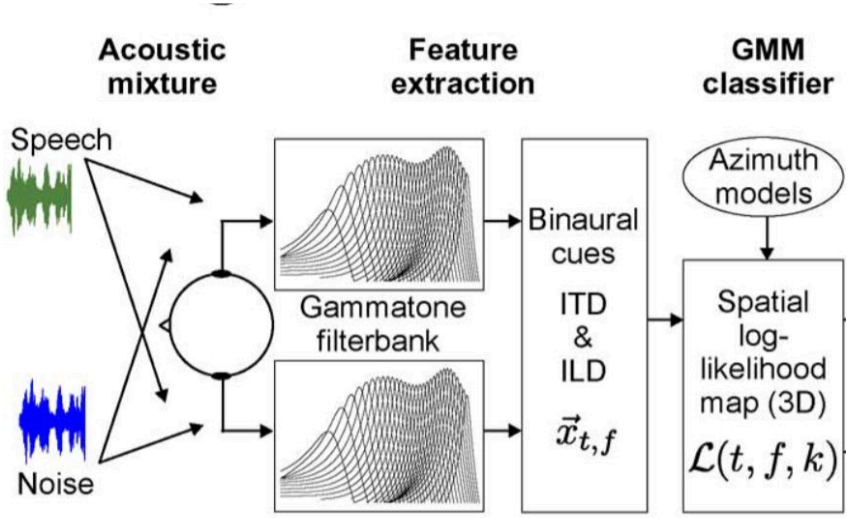
- A generating set is a way to entirely explore a given search space.

- Choosing one generating set is a way to select an exploration strategy: for example low and large grain exploration.

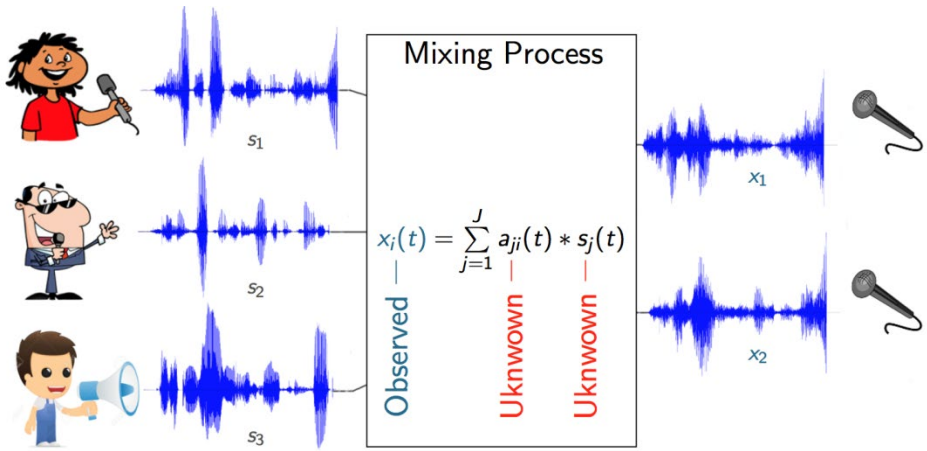
- Exploration strategies may be combined for a particular application.

MicroBayes:
Evaluate stochastic machines on difficult Bayesian inference problems

Sound Source Localization



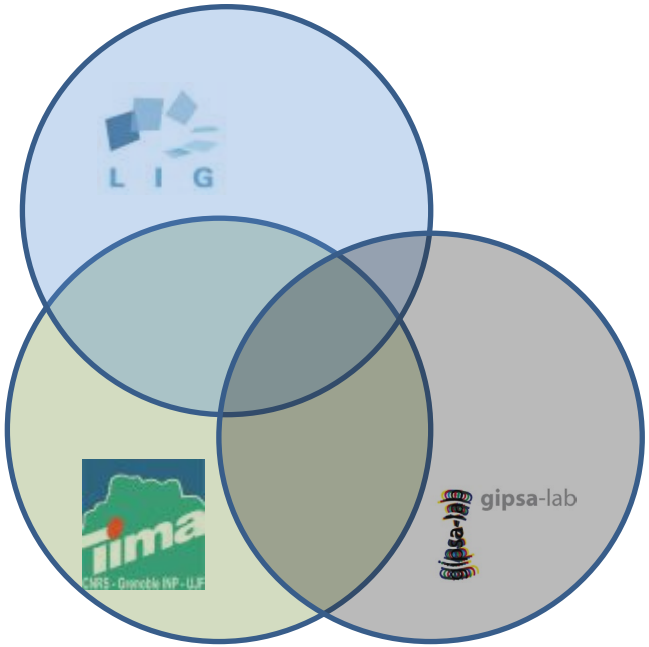
Sound Source Separation



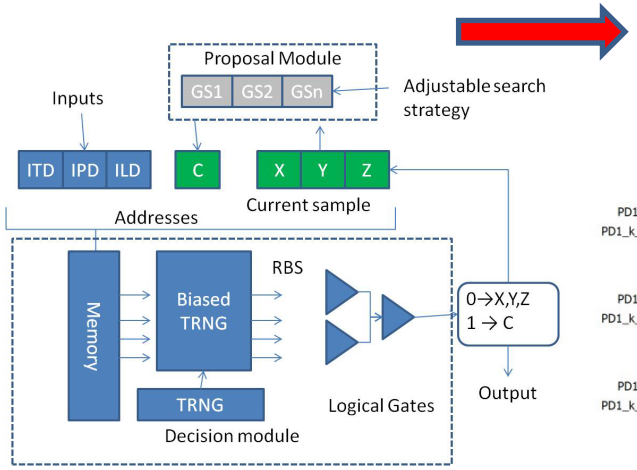
Problem: Recover all $a_{ji}(t), s_j(t)$ given only the $x_i(t)$

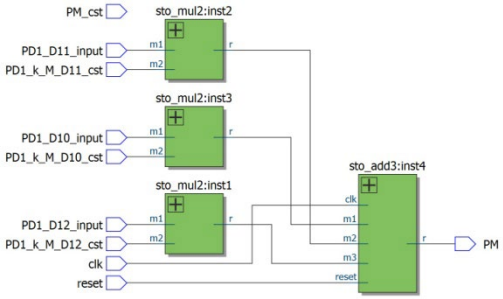
ORGANIZATION

M1 : Architecture and compilers for stochastic machines



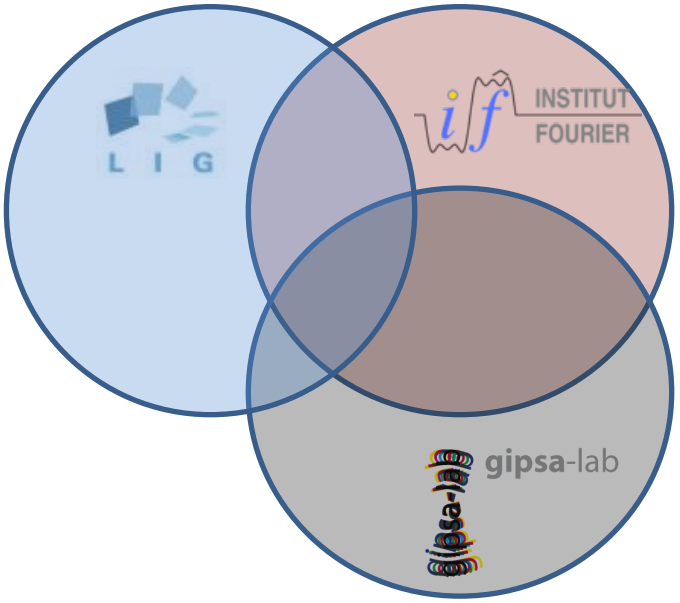
- M1:
  - Circuit Architecture
  - High throughput RNG





- M1:
  - Dimensioning
  - Experimental requirements

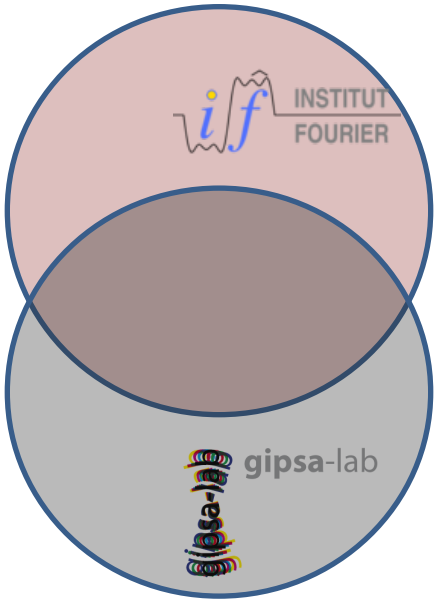
M2: Algorithms for stochastic search



- M2: explore the search space for high probability density regions with generating sets:
  - Theory and formalization
  - Combination to build exploration policies

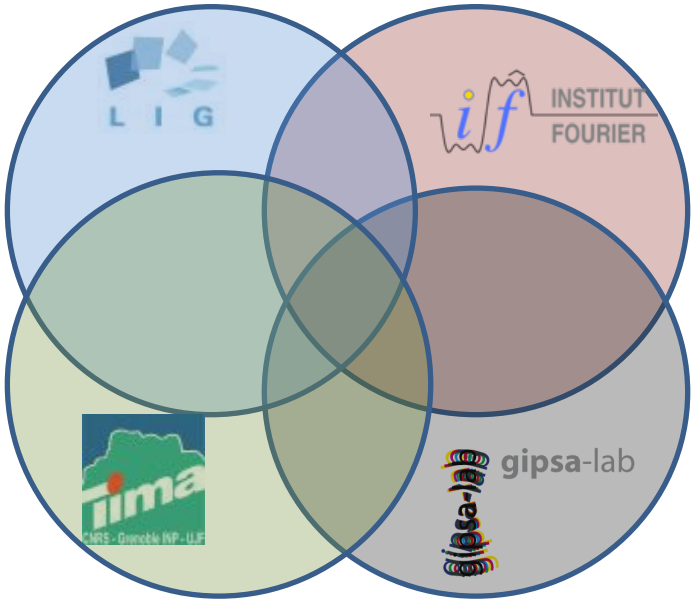
- M2: Define appropriate search strategies in high dimensions (ie: Source separation)

M3: Stochastic algorithms for the localization and the separation of sound sources



- M3
  - Bayesian formalization source localization & separation
  - Specific models for source localization and separation addressing the problem of quantization

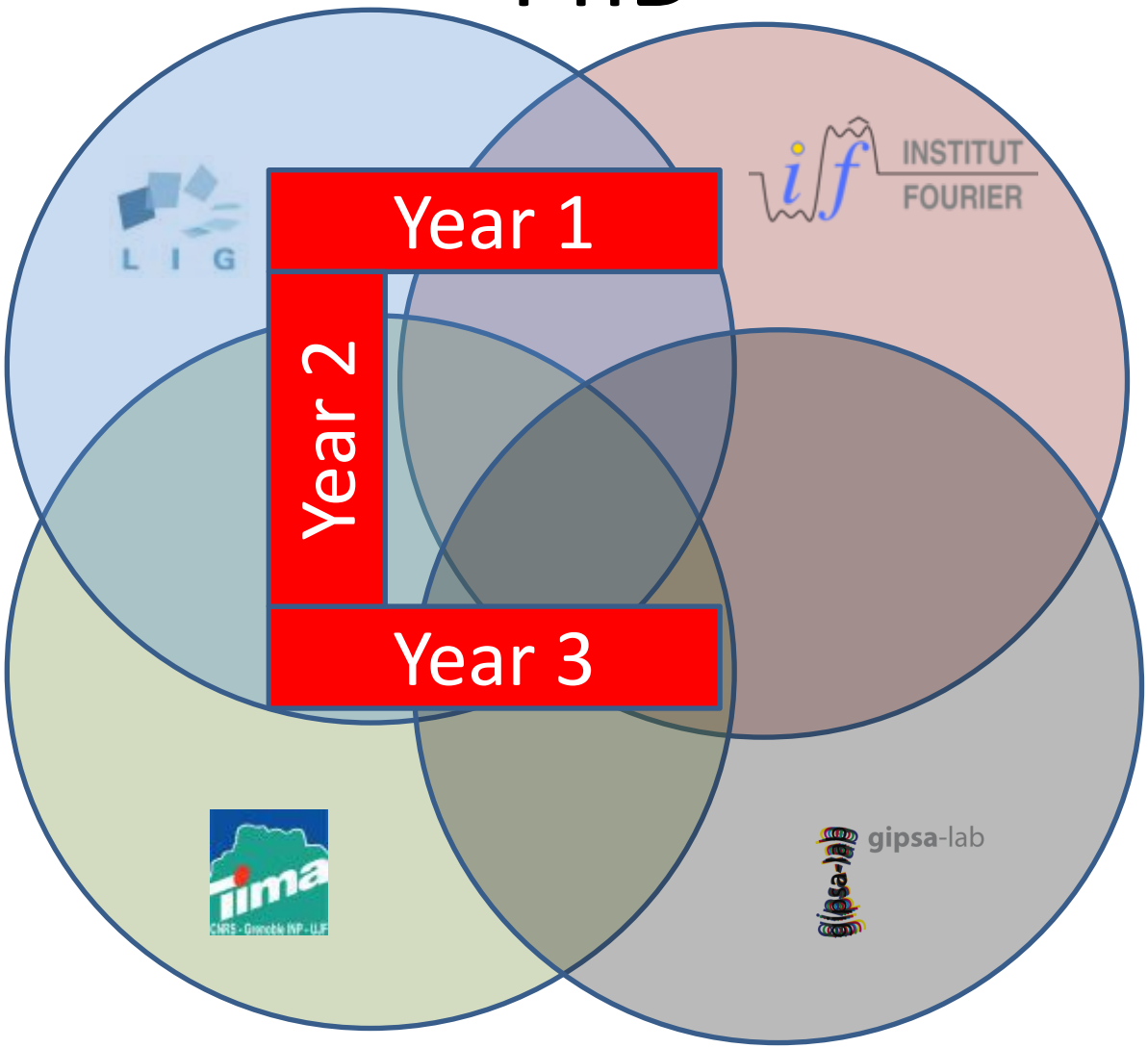
M4: Evaluation on simulated and real-world acoustic signals



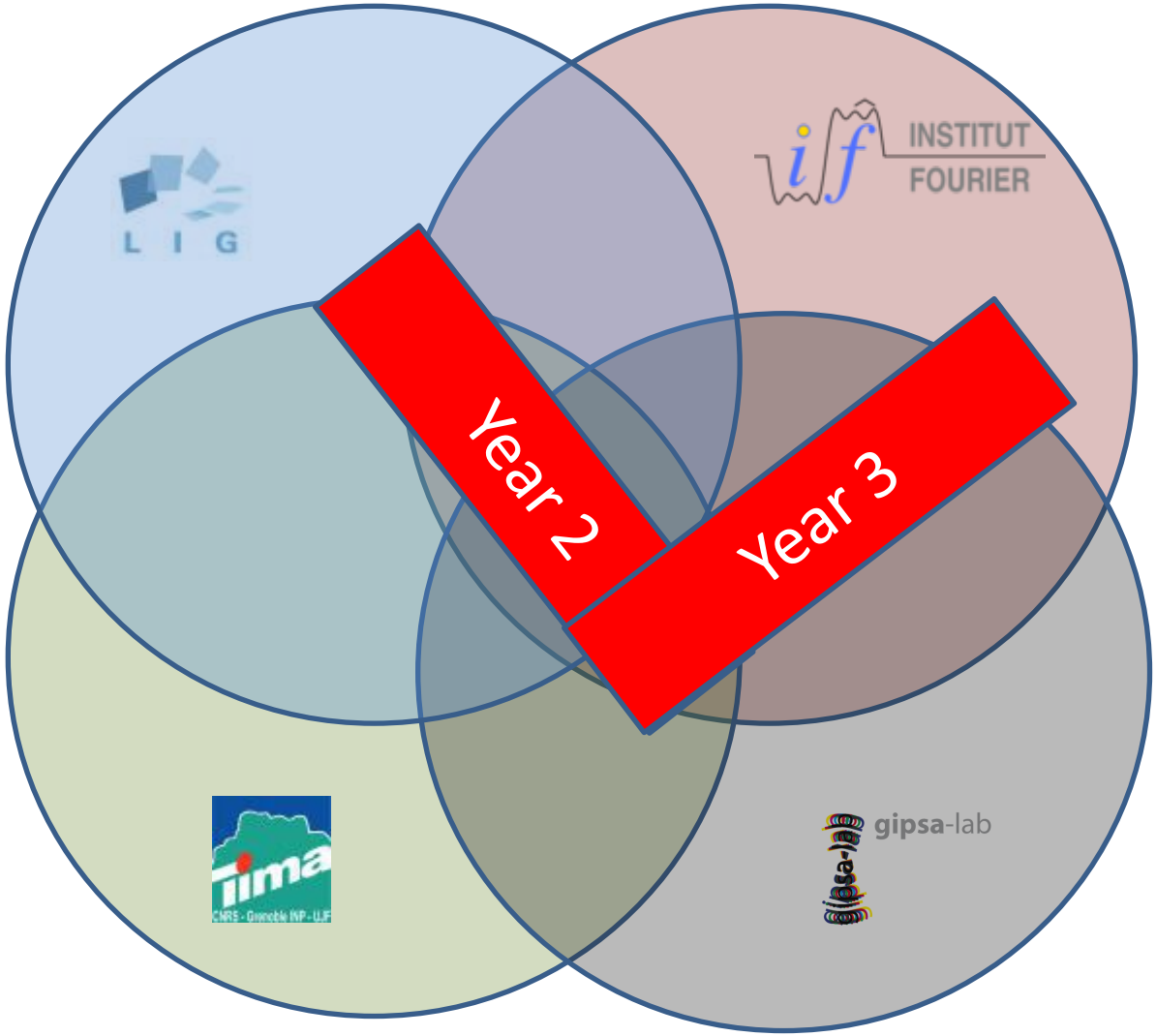
- M4:
  - Experimental setup
  - Quantitative evaluation & discussion

- M4:
  - Compiler and Software
  - Algorithms

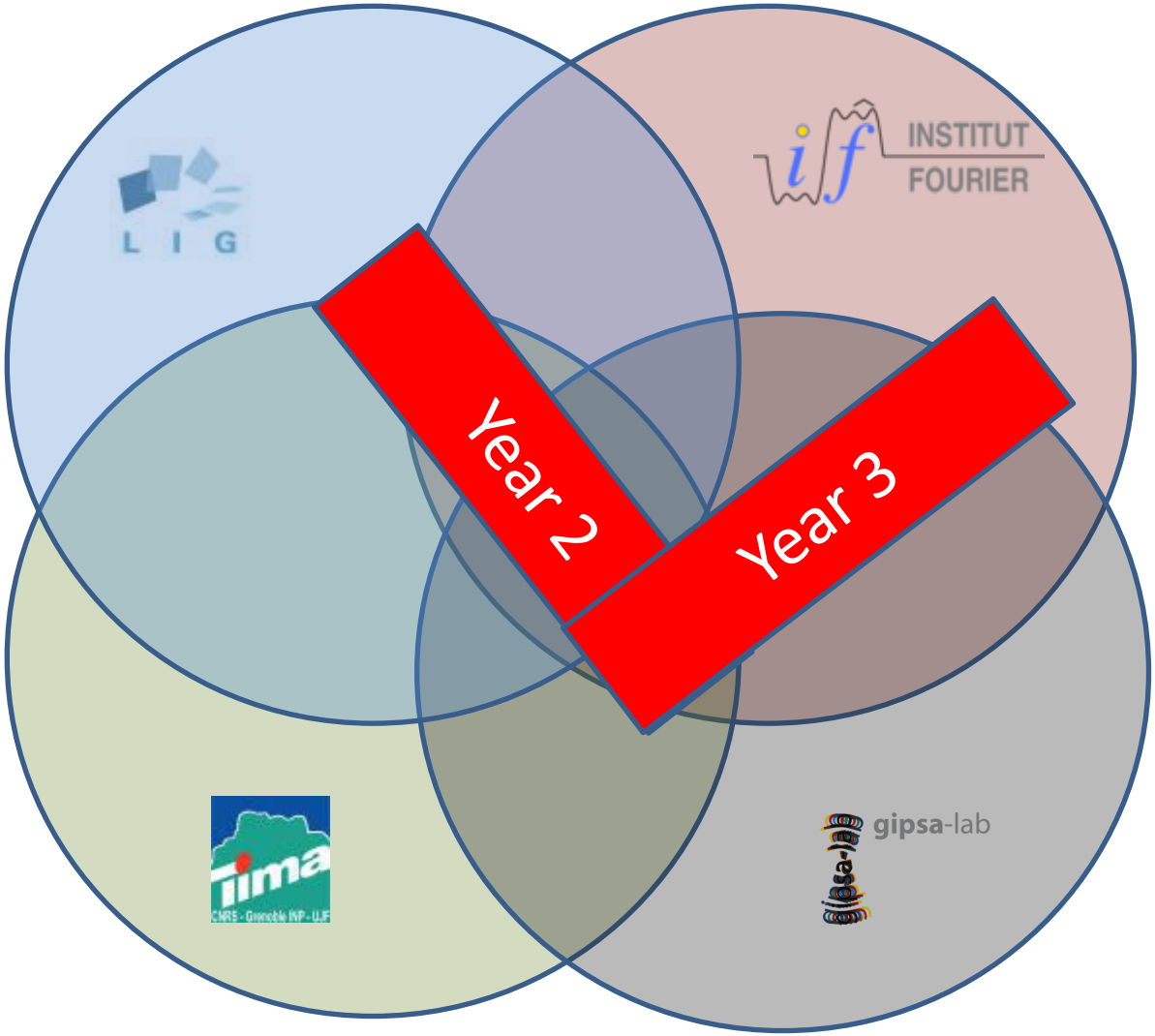
PhD



Postdoc


L I G
INSTITUT FOURIER
Year 2
Year 3
tima
CNRS - Grenoble INP - UJF
gipsa-lab

Postdoc



PERSYVAL-Lab Calls for proposals ANR

Expected Results

- Prototype of a **programmable** stochastic machine
- New algorithms for stochastic inferences allowing to address a variety of applications
- Demonstrations on two difficult tasks

Impact

- Extracting precise information from large amount of noisy data is a general problem.
- A success would lead to high performances devices (speed and energy consumption) for embedded systems:
  - sensor fusion & interpretation
    - Accelerometers , grid based approaches
  - telecommunication
    - PN acquisition
    - Decoding

Architecture for demanding applications

- MicroBayes will lead to the making of a new type of programmable computer that can proactively interpret from large amount of noisy data with a good energy efficiency.
  - ⇨ Patents (architecture – Compilation)
  - ⇨ Stochastic machine kit
  - ⇨ Local collaboration Xerox-CEA-ProbaYes

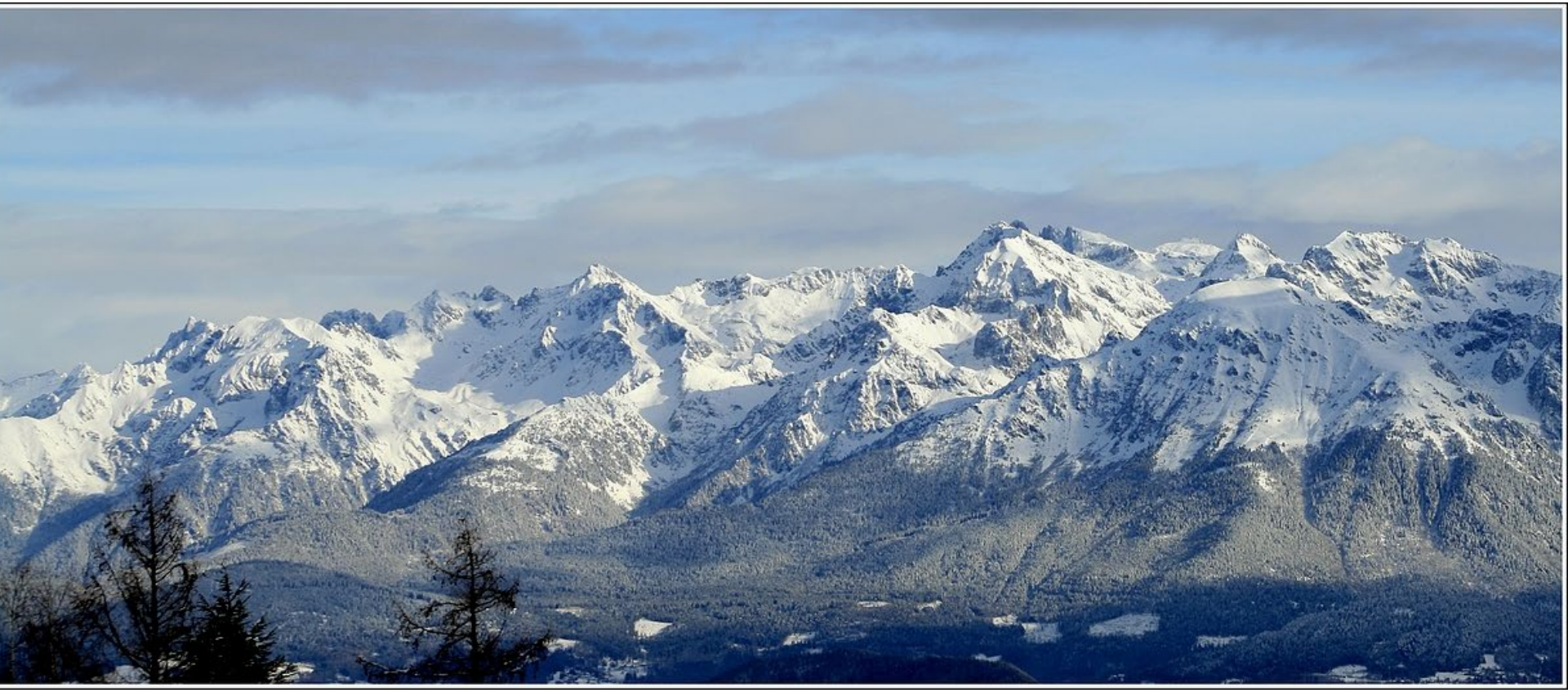
Dissemination

- Scientific Paper and conferences
  - Mathematics
  - Computer science
    - ICC CC: cognitive computing
      Cognitive computing - big data - brain inspired computation
  - Robotics
    - IROS: robotics
      special issue : Special Issue on Unconventional computing for Bayesian inference
  - Signal audio
    - IEEE Transactions on Speech, Audio and Language Processing
    - EURASIP Journal on Advances in Signal Processing
  - Micro electronics
    - Async
    - DATE: Architecture design
      Architectural and Microarchitectural Design : power and energy efficient architectures
    - HPCA: architecture system
      Architectures for emerging technology and applications

MicroBayes

- Four multi-disciplinary Labs
- One PhD
- One PostDoc
- One prototype of a programmable Stochastic Machine
- Two representative demos
- Three scientific challenges
  - Architectures for stochastic machines
  - New inference algorithm
  - Difficult inference problems

The future Bayesian Valley ?



Exact Inference 2^{120}: sums