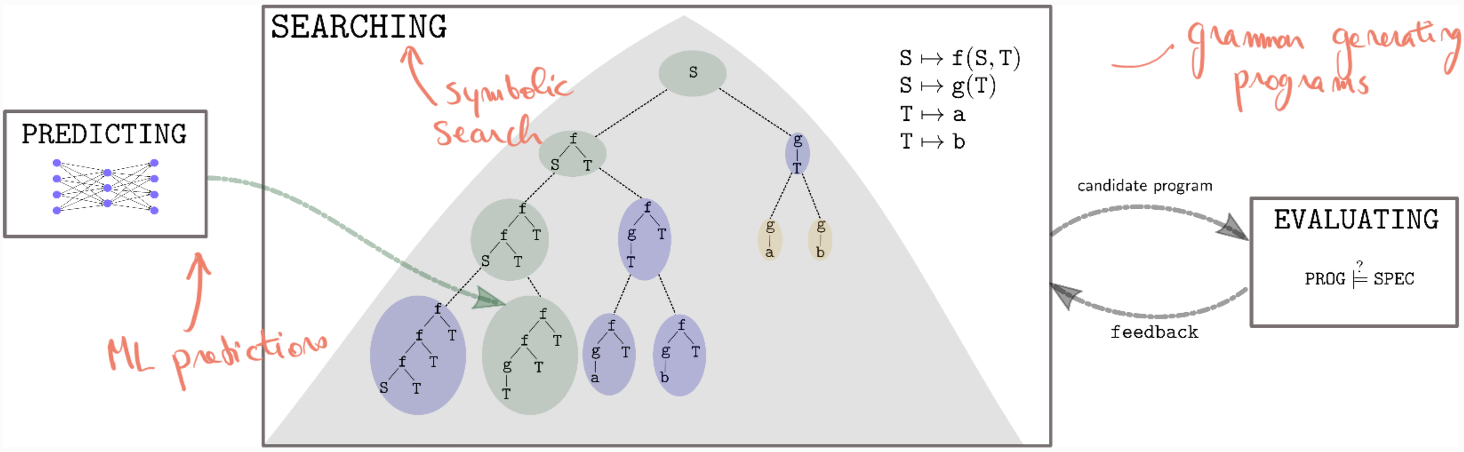
PART III :

ALGORITHMS

NEURAL GUIDED PROGRAM SYNTHESIS

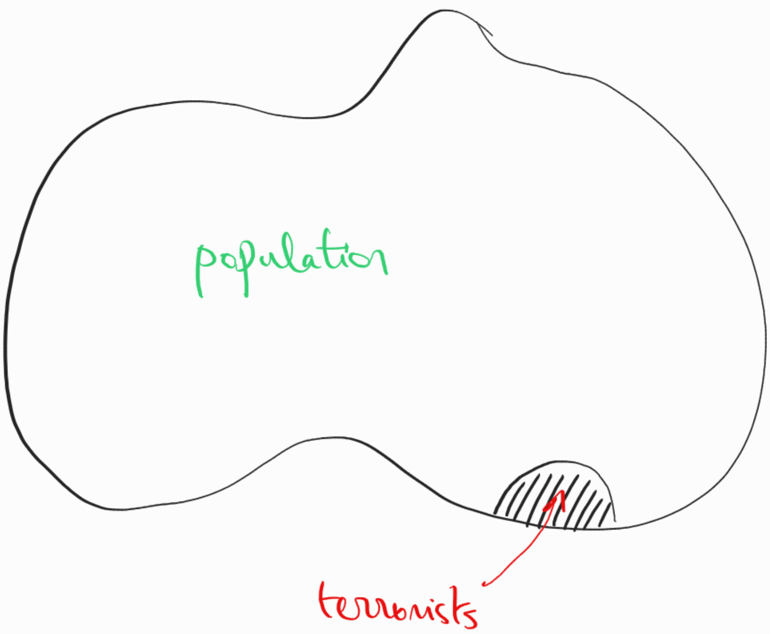


Focus of this part : SYMBOLIC SEARCH

AIRPORT SCREENING

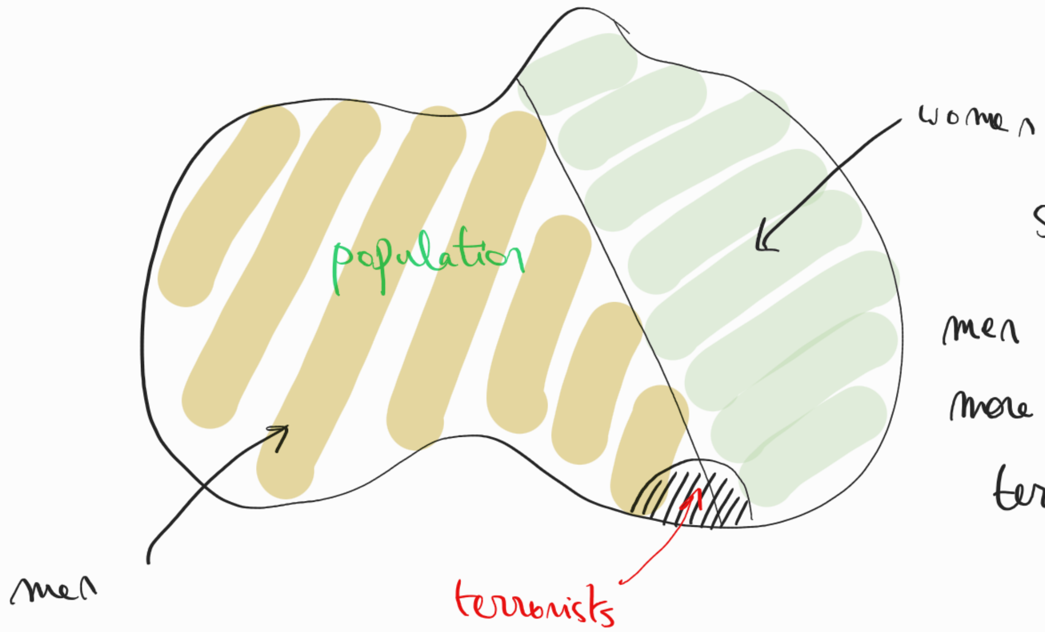
The following example is REAL
BUT does NOT reflect in any way
the speaker's political views

Problem :



Who to scan in order to catch terrorists ?

Assumption: prior (think Baysesian)



Say:
men are 9 times more likely to be terrorists

Mathematically:

$\mathcal{D}$ distribution over X population

We want to do sampling with replacement

Objective: minimise

$\mathbb{E}$[# Scans before catching a terrorist]

we call that the loss

Naive : $\mathcal{D}$

Optimal : $\sqrt{\mathcal{D}}$

defined by $\sqrt{\mathcal{D}}(x) \propto \sqrt{\mathcal{D}(x)}$:

$$\sqrt{\mathcal{D}}(x) = \frac{\sqrt{\mathcal{D}(x)}}{\sum_{x' \in X} \sqrt{\mathcal{D}(x')}}$$

Theorem : Let $\mathcal{D}$ a distribution over X.

Either :

(1) $\sum_{x \in X} \sqrt{\mathcal{D}(x)} < \infty$, then

$\sqrt{\mathcal{D}}$ minimises the loss

(2) $\sum_{x \in X} \sqrt{\mathcal{D}(x)} = \infty$, then

$\forall \mathcal{D}' \quad \mathcal{L}(\mathcal{D}, \mathcal{D}') = \infty$

Simplest instance of the SQRT sampling theorem:

$\mathcal{D}$: $p \cdot$ HEAD $+$ $(1-p)$ TAIL $\qquad X = \{\text{HEAD}, \text{TAIL}\}$

$\mathcal{D}'$: p' HEAD $+$ $(1-p')$ TAIL

$$\min_{p'} \alpha(\mathcal{D}', \mathcal{D}) = \min_{p'} \frac{p}{p'} + \frac{1-p}{1-p'}$$

$$p' = \frac{\sqrt{p}}{\sqrt{p} + \sqrt{1-p}}$$

SOLUTION OF THE AIRPORT SCREENING RIDDLE

If men are 9 times more likely to be terrorists they should be scanned 3 times more often

BACK TO PROGRAM SYNTHESIS:

HOW TO DEPLOY THE PREDICTION MODEL?

↳ how to search using $\mathcal{D}$ given as a PCFG

EXAMPLE

$X = \mathbb{N}_{\geq 1}$ $\qquad \mathcal{D}(n) = \frac{1}{2^n}$ $\qquad \left(\sum_{n \geq 1} \frac{1}{2^n} = 1 \right)$

A_1: enumerate $1, 2, 3, 4, \dots$

$$\mathcal{L}(A_1) = \sum_{n \geq 1} \frac{n}{2^n} = 2$$

A_2: sample with $\mathcal{D}$ with replacement

$$\mathcal{L}(A_2) = \sum_{n \geq 1} \frac{2^n}{2^n} = \infty$$

A_3: sample with $\sqrt{\mathcal{D}}$: $\quad \sqrt{\mathcal{D}}(n) = \frac{\sqrt{2}+1}{2^{n/2}}$

$$\mathcal{L}(A_3) = (\dots) \simeq 5{,}83$$

FAMILIES OF ALGORITHMS

SAMPLING

- SQRT is optimal
- How can we avoid repetitions? Unique Randomiser
- Many algorithmic ideas: Alias methods, ...

ENUMERATION (COMBINATORIAL SEARCH)

- Best First Search algorithms enumerate programs in the optimal order: large space requirements!
- Trade off between efficiency and relevance?

CONSTRAINT-BASED SOLVING

CVC4 / CVC5

DEDUCTIVE BACKPROPAGATION

FlashFill / FlashMeta

GENETIC PROGRAMMING

PushGP

REINFORCEMENT LEARNING

BAYESIAN INFERENCE

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