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Looking under the hood of Artificial Intelligence: About cookies, blood, language, and some mathematics

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What does the little girl is asking to the little boy that he took from a jar on a shelf in the kitchen while his mother is washing dishes unaware that the sink is overflowing? And, while I am at it, what is this little twisted tube moving weirdly with a wire inside that suddenly disappear out of view provoking great despair for those who were looking?

The first sentence of this abstract describes a common test used to detect dementia and the answer is in the title of this presentation. The second one is the partial description of a cardiac catheterization surgery on newborns using contrast agent. These two sentences themselves are also quite obvious examples of why it is still difficult for computers to understand natural languages (although I am sure you struggled a bit too). They are also examples of two research projects using Artificial Intelligence (AI).

Where are the mathematics? They are, of course, under the hood of AI, and its application to solve these problems here at ÉTS. I don't want to sell the punchline so I will throw at you two images and two formulas here.

$$Coverage(R, S) = \frac{\sum\limits_{p \in \{R\}} \alpha_p MaxSim(p, S)}{\sum\limits_{p \in \{R\}} \alpha_p} \tag{1}$$

Formula (1) (taken from [1]) is an asymmetric coverage measure (inspired by [2]) used to distinguish the discourses of patients during the "Cookie Theft Picture Description Task" [3]. *MaxSim* is a function that measures the similarity between a referent, R (healthy population) and a subject, S (with cognitive decline). The parameters α_p are used to associate a weight to each simplified linguistic pattern, p, that we identified as relevant for the task.

Figure 1 illustrates a Principal Component Analysis (components 1 and 3) of patients' discourses evolving through time (10 years). The label near each point indicates the participant

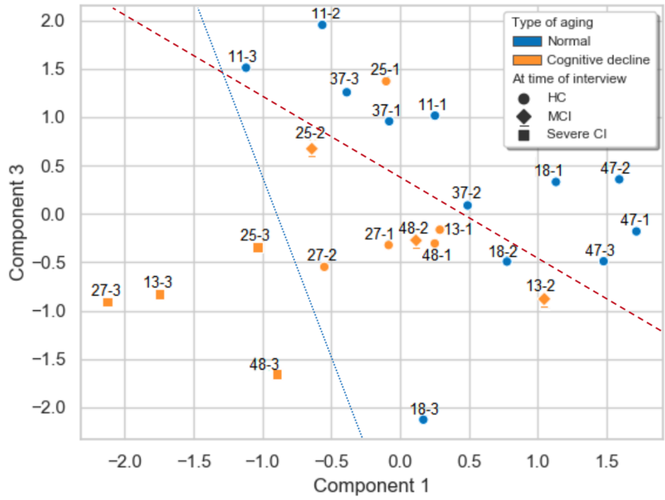

Figure 1: Patients' discourses evolving through time [4]

ID-interview number. Interviews 1, 2 and 3 were held in 2005, 2012 and 2015, respectively (see [5, 6] for the data). The hue difference indicates normal or cognitively declined aging processes. Circle, square and rhomboid markers indicate healthy control (HC), mild cognitive impairment (MCI) and severe CI, respectively, at the time of the interview.

$$C_n = \frac{1}{n+1}\binom{2n}{n} \tag{2}$$

Formula (2) points to the well-known difficulty of analyzing symbolically natural languages by associating binary trees to sentences (= parsing trees). On this account (presented in [7] for natural languages), our first sentence can theoretically produce an extravagant number of syntactic trees; while humans discard most of them without even thinking, computers find the task phenomenally troublesome.

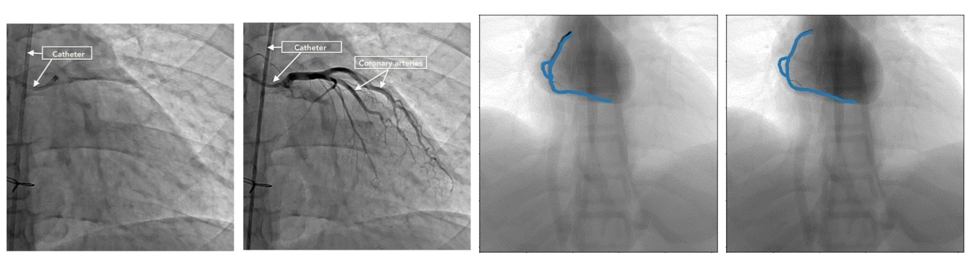

Figure 2: Left: X-ray frame without (1) and with (2) contrast agent (from [8]). Right: Tracking of cardiac artery during movement (from [9]).

Finally, figure 2 illustrates the challenges of tracking coronary arteries to help surgeons during cardiac catheterization. There are two challenges here. First, as in the case of sentences analysis, you must be able to recognize the real vessel within the noise surrounding it (two figures on the left, from [8]). Second, the patient is breathing and his heart is beating (hopefully!), so that twisted tube is moving (two figures on the right, from [9]).

My intention is to use these applications to introduce you to natural language processing and machine learning. We will finish our journey pointing to a sample of research themes related to AI at ÉTS, and why education in mathematics and ethics is so important in this new world obsessed with AI.

Artificial Intelligence
Matrix algebra, Neural networks, Natural language processing, Medical image processing

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