Machines, Algorithms and Humans:

shall we expect from the third AI wave to reshuffle the cards in the world of engineering and simulation?

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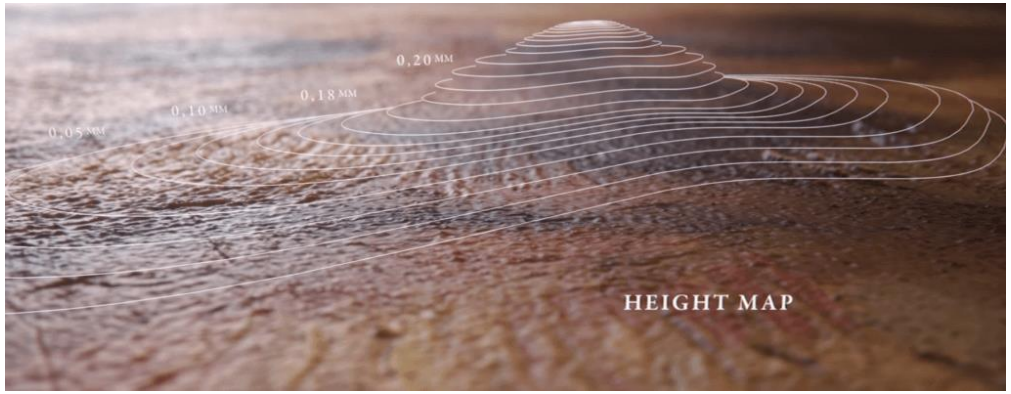
The painter

Work of human or machine?

The cost of the « Next Rembrandt »

- A blend (and intensity!) of expertise:
  - 20 people: art experts, developers, Machine Learning experts, engineers
  - 18 months of collective effort
- Data collection:
  - 150Gb for 160,000 fragments extracted from Rembrandt's paintings
  - 346 paintings studied to determine demographics and presentation of the subject
- Feature engineering:
  - dozens of features for rendering face details
  - more than 500 hundred hours of computation
- 3D Printing
  - Model texture patterns and print layers
  - Build a heigh map of 148m pixels
  - 13 layers of ink



Wisdom

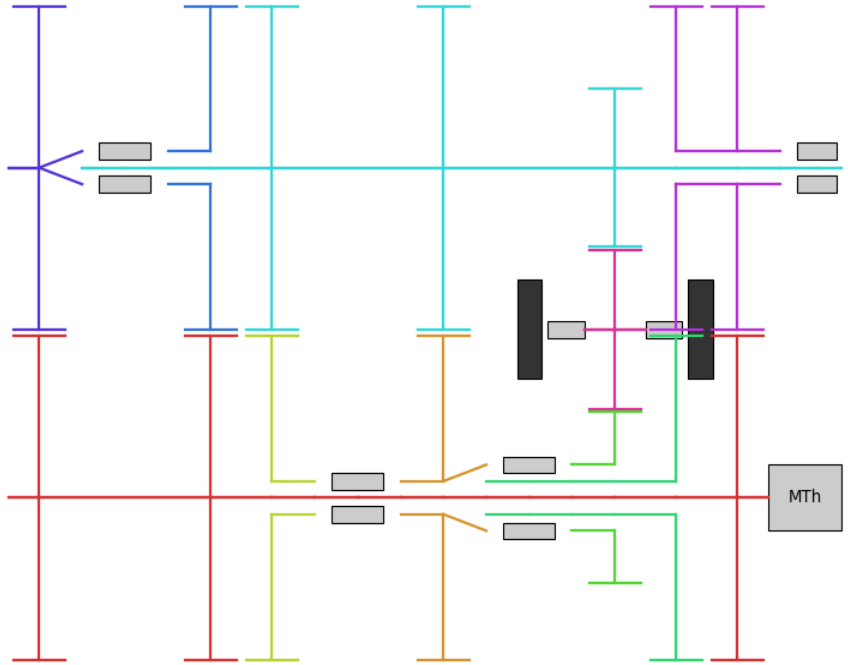
“We're like a father teaching a kid how to write—you still need the father. “

"I think Rembrandt would laugh himself silly if he saw there was a team of 20 people, really clever people, working for 18 months and this is what they come up with.“

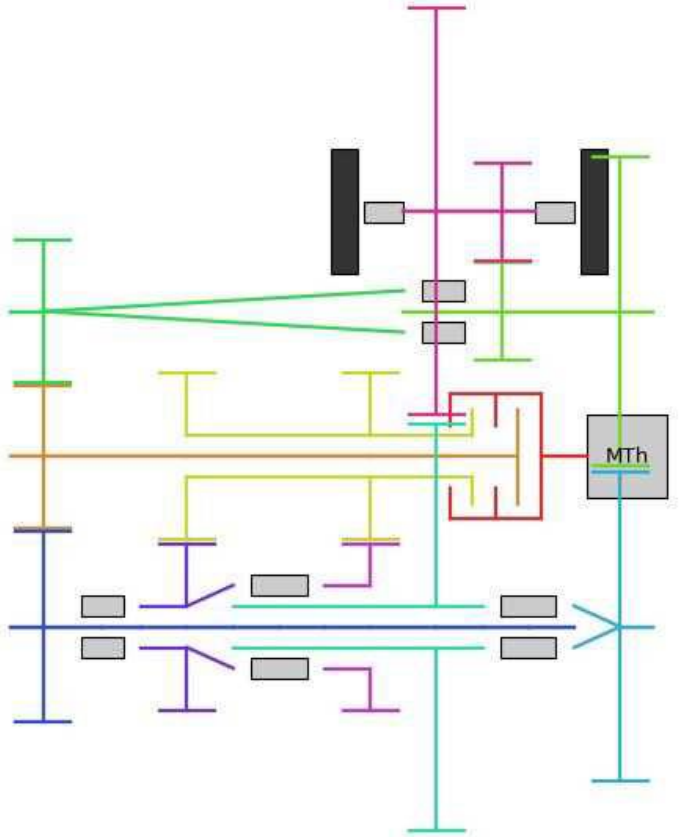
Bas Korsten, co-leader of the “Next Rembrandt” team

The gearbox engineer

Skecth of human or machine?



2D model of a six gearbox ratios of a manual transmission



2D model of a five gearbox ratios of a dual-clutch transmission

From S. Masfaraud (2016) - Méthodes numériques pour la recherche et la conception d'architectures optimales de boîtes de vitesses, Thèse ENS Paris-Saclay.

What does it take to sample and screen the space of gearbox architectures

- 992 architectural schemes scanned
- 1.5 x 10^9 architectures generated
- 1.5 x 10^8 architectures tested
- 1,390 viable architectures extracted
- 13,600 CPU-hours on Intel Xeon E5-1620v2
- Further screening based on price and mass constraints
- Expert assessment to evaluate plausibility regarding to volume optimization

2D model of a six gearbox ratios of a manual transmission

- 142 architectural schemes scanned
- 2.5 x 10^8 architectures generated
- 2.5 x 10^7 architectures tested
- 320 viable architectures extracted
- 13,600 CPU-hours on Intel Xeon E5-1620v2
- Further screening based on price and mass constraints
- Expert assessment to evaluate plausibility regarding to volume optimization

2D model of a five gearbox ratios of a dual-clutch transmission

From S. Masfaraud (2016) - Méthodes numériques pour la recherche et la conception d'architectures optimales de boîtes de vitesses, Thèse ENS Paris-Saclay.

What we learned from innovative gearbox design

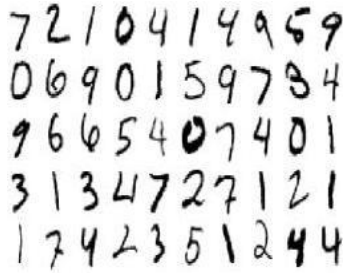
- There might be an Alpha-Go for gearbox design
  - Not clear what is is the complexity ceiling to extend it to engine design for instance
  - Requires the potential of HPC to sample and screen architectures in order to scale up
- Need to embark field expertise together with modeling ability:
  - Gearbox engineering, mechanical systems, optimization, graph sampling…
- Contribution of machine learning?
  - Not obvious at this stage, but…
  - … it may help to better select high level design parameters and save brute force exploration time
- How to embrace such a design process disruption?
  - Mindset of the organization
  - Mindset of field experts

What it takes to make Machine Learning work

Big data? … Well, quite big… and labelled

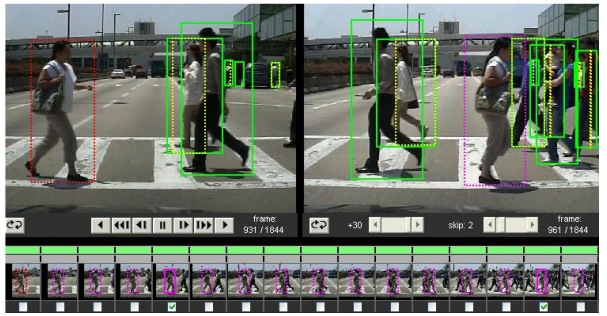
- **Supervised learning algorithms** outperform **human performance** in many pattern recognition tasks

  - LeCun et al. (1989): Handwritten zip code digit recognition
    → USPS database; about 10,000 digits
    → 10 categories; 7000 training data (16x16 gray level images)



  - Lu and Tang (2015): Face recognition
    → Life Faces in the Wild (LFW) data set
    → 5749 public figures; 13,233 uncontrolled face images
    → Training on 40,000 pairs of images (matched/mismatched)

  - Zhang et al. (2017): Pedestrian recognition
    →Caltech pedestrian data set
    → 10hours video at 30Hz;10^6 frames
    → 10% contain pedestrians; 2300 unique pedestrians
    → Some trouble with partial occlusions…



- But remember! Discriminant information is more important than massiveness of training data sets…

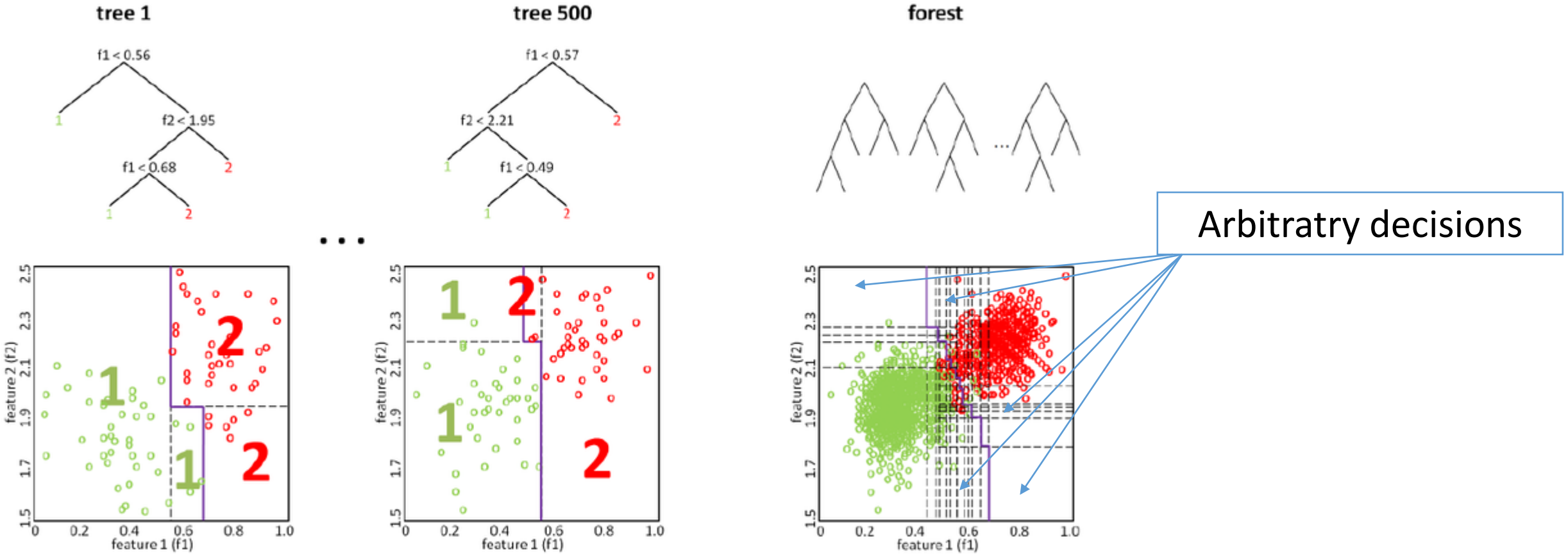
… but need to cover the input domain

TRAIN → TEST

This will probably not work with plain supervised learning (deep or shallow)…

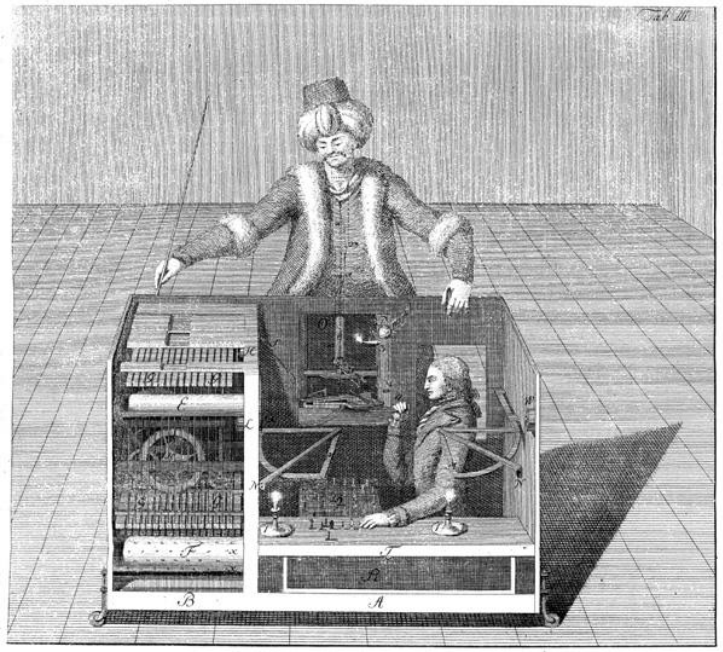
Artefacts in decision rules based on supervised learning

Random Forest example



→ Need to learn with a reject option (see work by Marten Wegkamp, 2005-2008- 2011)

… and also needs human supervision



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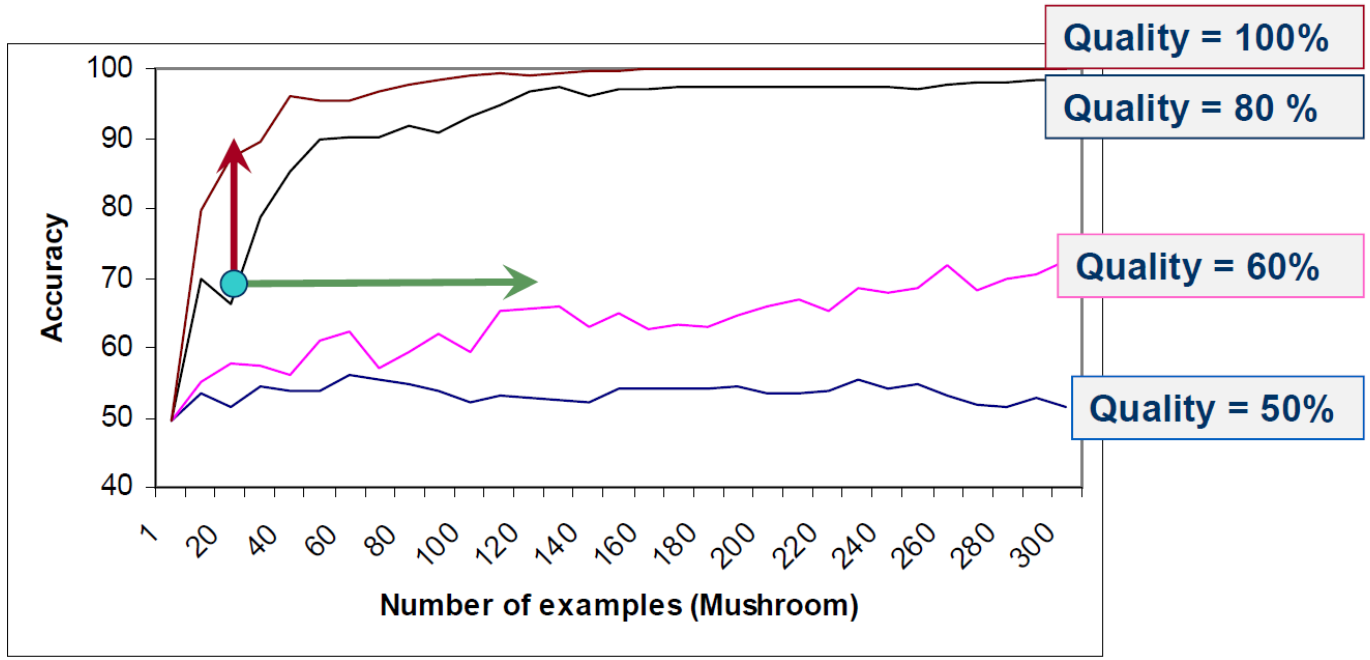
Quality labels better than big data

- Get more examples → Improve classification
- Get more labels → Improve label quality → Improve classification



Source: Get Another Label? Improving Data Quality and Data Mining Using Multiple, Noisy Labelers. By V. S. Sheng, F. Provost, P. G. Ipeirotis. Proceedings of KDD, 2008

See also: Quality management on Amazon Mechanical Turk. By P. Ipeirotis, F. Provost, J. Wang. Proceedings of the ACM SIGKDD, 2010.

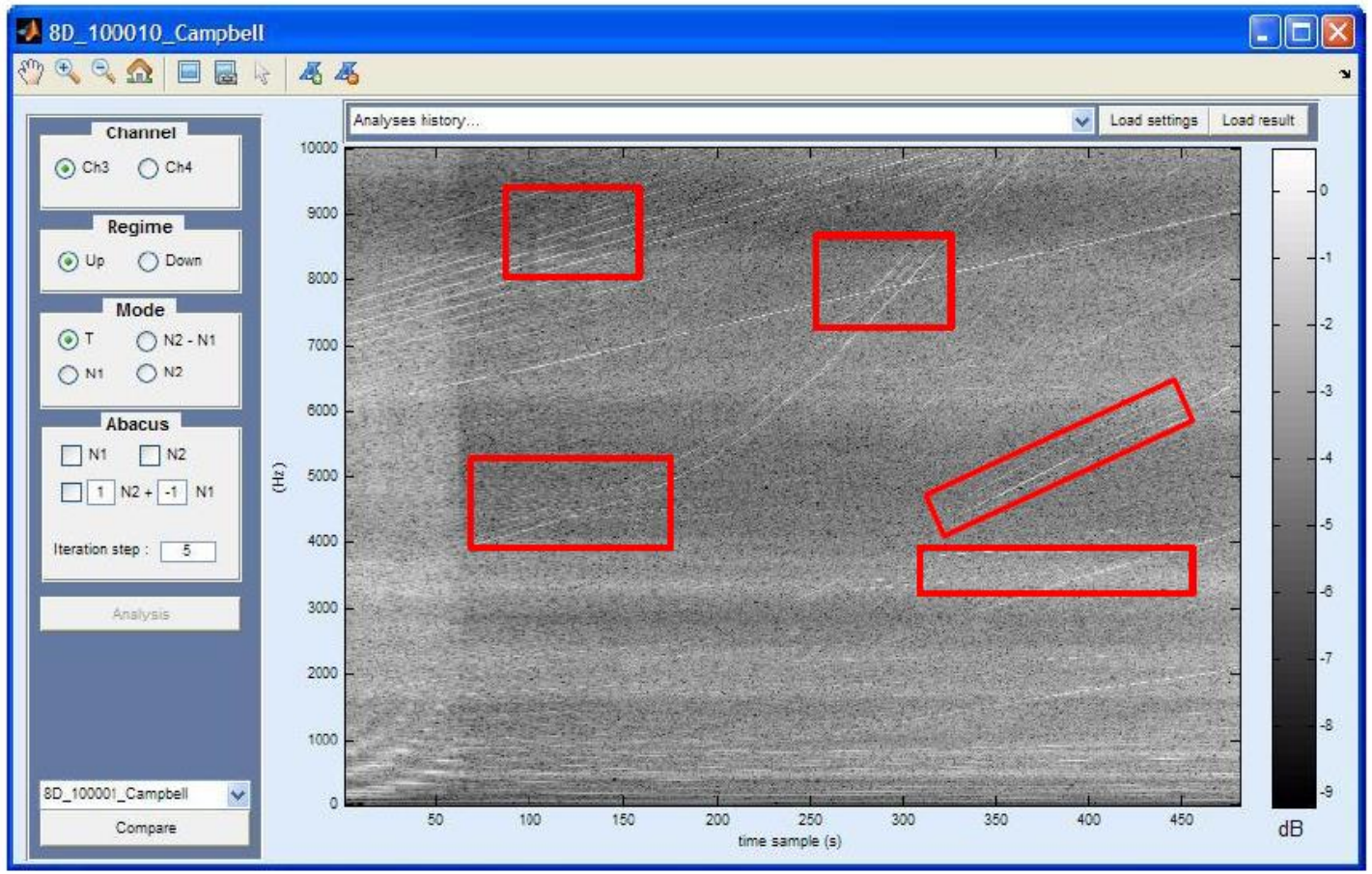
Why Machine Learning works so well in pattern recognition applications?

- Pattern recognition is a standard problem
- Image data have standard formats
- Image databases on www applications are massive
- Performance heavily relies on humans tagging images ‘manually’
- Deep Learning is so fancy, mysterious and cool…

Not clear this line of thought will lead to a safe journey in the real world…

From marketing to industry: getting the job done…

An example of anomaly detection objective
Benchmark assessment of aircraft engine



Source: Confidential report (2012) - Mathilde Mougeot, NV

- What we see?

Time-frequency representation of vibration signals (Campbell diagram) wrt to speed during acceleration and decelaration regimes.

- Nature of anomalies

Tiny details in those images. Require a lot of expertise to tag.

- Databases are small

Only a few hundreds engines have been recorded with a very limited number of anomalies reported.

- But image structure helps!

Anomaly detectors can be built using adapted representations of such signals and basic nearest neighbors in feature space.

B2C vs. B2B

- Standardized data
- Large data sets
- Cheap supervision
- Standard problems
- End user IS NOT an expert
- Performance is not critical

Search engines
Recommender systems
Targeting
Image tagging, …

- Not always standardized data
- Small data sets
- Supervision ? Say again?
- Usually not standard problems
- End user IS an expert
- Performance is often critical

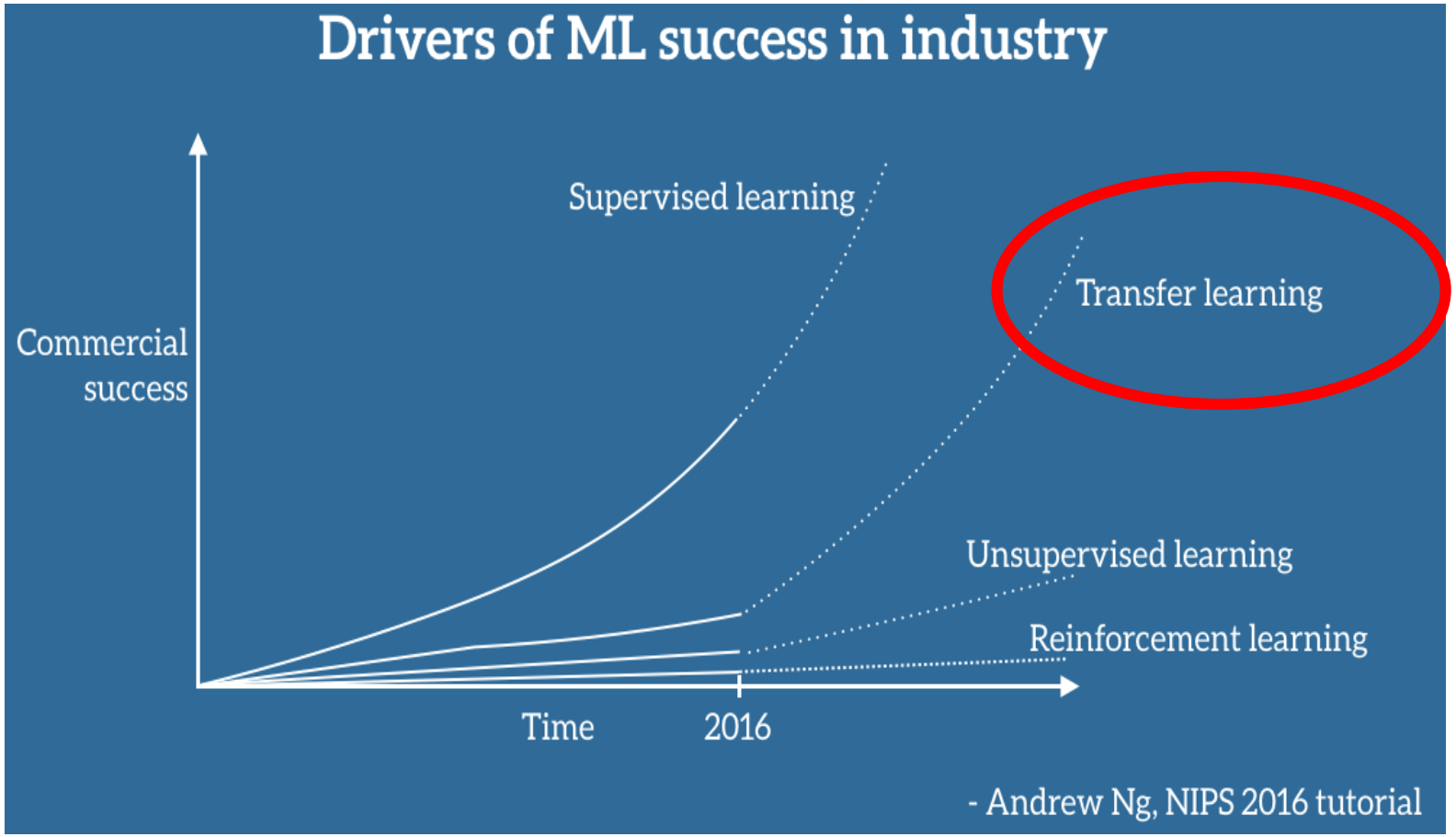
System design
Fraud detection
Predictive maintenance
Clinical decisions…

Challenges in the B2B industry

- Re-learn with small cost
  - **Domain adaptation**
  - **Zero-shot learning**
- Machine Learning pipelines have to face process improvement and novelty
  - Machine Learning algorithms require Lifecycle Management: **Continuous learning**
  - A possible asset: **Learning from simulations and combine with field data**
- Take into acount the human factor at the design stage
  - **Most important! an AI project is a software project!**
  - Annotation requires **commitment** of field experts
  - **Acceptability** relies on **robust** and **explainable** decision rules
  - Implementation of AI technologies may/will lead to revisiting business processes
  - Interfacing experts with ‘intelligent’ software is THE challenge

Conclusion

Expected impact of computational IA in the industry



NB: Andrew Ng is VP & Chief Scientist of Baidu, Co-Chairman and Co-Founder of Coursera, and an Adjunct Professor at Stanford University.

Main messages

- The third AI wave is computationaland relies on the advances of Machine Learning
  - Data-driven, similar to regression modeling with many variants
  - Heavily relies on mathematics to model complex data and formulate the task-related optimization problem
  - May/Will lead to industrial disasters (think of HAL)
  - The main risk: to be driven by a method and not by the problem to be solved in *its* context
  - Secondary risk: believe too much in training data

- Computational AI achieves nonlinear interpolation in high dimensional spaces
  - AI-based technologies may then outperform humans in certain *well-defined* tasks: detection, recognition, planning, etc.
  - Strong AI not for tomorrow…

- AI for B2B is very different from AI for B2C
  - Energy, healthcare, banking, defense… will not benefit of Computational AI ‘as-is’
  - Scaling up and industrialization of AI modules in B2B raises scientific challenges
  - Main issue: conduct a cultural change
    - train AI-enhanced experts, bring social sciences in industrial design, render accessible scientific SOA to engineers…

Research: http://nvayatis.perso.math.cnrs.fr/
http://www.cmla.ens-cachan.fr/

Training / M2 Master MVA: http://www.math.ens-cachan.fr/version-francaise/formations/master-mva/

French AI strategy:

- **FranceIA** https://www.economie.gouv.fr/France-IA-intelligence-artificielle
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