Digitalisation d'examens cliniques : l'industrialisation nécessaire de la recherche en machine learning

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Executive summary (1)

Using Machine Learning algorithms tends to become routine

• Example: Python code for designing an AdaBoost classifier:
  • >>> data=load_data() # load the data from file
  • >>> ... # split into train and test data
  • >>> clf = ensemble.AdaBoostClassifier(n_estimators=1000) # call the algorithm
  • >>> clf.fit(X_train, Y_train) # calibrates on train data
  • >>> p_lab=clf.predict(X_test) # predicts on test data
  • >>> print(report(Y_test, p_lab) # display performance indicators

How field experts will interact with them to get insights is less clear

• Need ML experts to formalize the problem, the design of the decision system, the performance metrics, ...
• Need data intelligence
• Imagine the use: full automatization VS. visualization and help to decision making → a long way to go...

Crossing expertise within interdisciplinary cooperation seems to be the key...
Executive summary (2)

Overwhelming digitalization brings cultural change both in academia and industry

• Innovation cycles are shorter, from research to market
• Industry needs to be ‘academized’ and academic research needs to be industrialized
• Need for new ecosystems → Paris has talent!

Key questions

• Innovation through interdisciplinarity: transitional state or stationary regime?
• Impact of IoT in clinical research: what will be the future of medicine, healthcare, public health, ...
• Will ML replace the clinician?
• Value and power: Who will own the data?
This talk originates in...

Concerns:

• Spread of digital technologies for everyday uses VS their absence in clinical consultation
• Levels of fundraising for brain research at the neuronal level (cf. HBP with budget 1.2 billion €) VS the poor investments in studying human behavior

Questions:

• Can ML participate to the modernization of clinical research?
• Where are the data?
This talk describes...

A specific project

- Goal: prediction of the risk of fall
- SmartCheck: digitalization of a neurological test (Romberg)

The experience of interdisciplinarity

- Some findings
- The future of research?
The risk of fall: some facts from WHO report (October 2012)

Worldwide:

- Fall is the second cause of accidental deaths (WHO report, 2012)
- 37.3 millions of falls requiring medical care per year
- Each year an estimated 424,000 individuals die from falls globally

France:

- 84% of everyday life accidents are falls
- Cost for public institutions: about 1 billion €

Main victims:

- Adults older than 65 suffer the greatest number of fatal falls.
- a vicious circle \( \rightarrow \) cf. Figure

Today: Assessment and prevention are qualitative
What to measure?

State-of-the-art

- Posturography: two centuries old! Numerous studies!
- In the GPS era: Mobility is the key indicator
- Sensors: either very expensive (clinical use) or very cheap (mobile, video games)

Which data?

- Outdoor activity ➔ relevance for seniors?
- Indoor activity ➔ in progress
- During medical consultation ➔ SmartCheck
Posturography data – before SmartCheck
Romberg test and statokinesigrams

Romberg test
- Comparison of two curves: eyes open/eyes close
- Hardly reproducible

Traditional context for clinical research
- Only then curves are recorded and analyzed
- Cohorts of the order of 10-100 subjects

Summary of each curve with a few (5) features
- Sway area, Sway path, AP/ML amplitudes + frequency bands
- cf. Baratto et al. (Motor Control, 2002)

Statokinesigram = Trajectory of Center of Pressure over 30s
Posturography sensors
WiiBB vs. ATMI

• Cheap (80€)
• ‘Hackable’...
• But... irregular sampling

• Very expensive (10k€)
• Opaque signal preprocessing
Posturography sensors

WiiBB vs. ATMI

- Very expensive
- Opaque signal preprocessing
- Muscular frequency during postural stabilization about 12Hz and sway path of many cms

- Cheap (80€)
- ‘Hackable’...
- But... irregular sampling
SmartCheck: know-how of COGNAC G
SmartCheck: know-how of CMLA
SmartCheck: funding from SATT IDFINNOV
SmartCheck: main bricks

= skills
= dialogue
SmartCheck team: a blend of expertise

**Coordinators**
- Pierre-Paul Vidal (COGNAC G)
- Nicolas Vayatis (CMLA)
- Robert Marino (IDF INNOV)

**Clinicians**
- Neurology
  - Damien Ricard (VdG)
- ENT
  - Catherine de Waele (Pitié)
- Rehabilitation
  - Alain Yelnik (F. Widal)

**Mathematicians**
- Machine learning
  - Julien Audiffren (ENS Cachan)
- Signal processing
  - Laurent Oudre (Paris 13)

**IT engineers**
- Android app development
  - Nikos Promponas (ENS Cachan)
Objectives of our research (1)
To characterize phenotype from low-level sensor measurements

**Descriptive**
- Quantification for instant and longitudinal assessment of the patient
- Positioning the patient in the cohort (norms)

**Predictive/Prescriptive**
- Evolution of a pathology
- Risk indexes, e.g. Risk of a fall within six months
- Prescription of therapeutic routes

**Assessment, scientific discovery and knowledge management**
- Fair comparisons of therapies, assessment along lifecycle of a therapy
- Explore and compare patterns over a large database
Objectives of our research (2)
Underlying mathematical innovations

**Representation learning for functional data:**
- signal processing, optimization, statistics, ...

**Dedicated Machine Learning methods:**
- Tasks: clustering/scoring/ranking/recommendation
- Variants: metric learning, multiview learning, transductive learning, structured-output prediction, privacy-preserving learning, ...
- Implementation: scalable versions (in sample size or signal size), multi-party collaboration

**Reproducible research**
- In what sense?
Scientific and technical challenges

Main goals for clinical research:
- Re-invent clinical assessment
- Identify low-level behavioral correlates of classical nosology
- Infer the origin of trouble (motor, muscular, vestibular, sensorial, ...)
- Assess the risk of future fall

Main modeling and algorithmic issues:
- Perform automatic feature selection in high dimensional setup
- Calibrate high dimensional predictive models
- Recover interpretable dimensions

Main technical steps:
- Collect data massively (thousands of statokinesigrams) → standardize protocols
- Secure ‘clean’ signals → Extract raw data and solve the ‘random sampling’ issue
- Digitalize clinical feedback through expert annotation → need software interface
Main technical and practical issues

Access to raw data (sensor level)

Comparable data (standard protocols)

Collect large samples

Record contextual information

Monitoring the whole process

‘Clean’ databases

Scalable protocols

Ergonomic constraints
Findings

WiiBB is at least as reliable as ATMI!

Novel key descriptors for posture (among more than 1000!)

Static posture assessment can be used as predictor for balance unstability

Statistical evidence for detection of source of unstability

Revelation of the fine dynamics of stabilization, evidence of micro-falls

Interesting directions for analysis per-pathology and correlation to clinical assessment and other evaluations (dynamic posture, ocular movements, ...)

![Graphs showing ROC curve and classification results.](Image)
### Present achievements

**Clinical trials:** ongoing (to be extended to nursing houses, agreed in June 2015)

**Clean database on posture today (with less than 10 sources):**
- More than 3000 recordings (statokinesigrams)
- About 1200 patients
- About 300 fall questionnaires

**Methodology for digital assessment of posture and prediction of risk of fall**

**Publication and communications:**
- 1 paper submitted, 3 in preparation, 1 poster, 3 communications
- Targets: clinical research, bioengineering, sensor assessment, machine learning and signal processing

**Patents:** 1 submitted, 2 in preparation

**Full-scale test:** in preparation (start in 2016, operated by Sécurité Sociale – La Réunion)

**Spin-off:** to be launched in 2016
## Ongoing joint projects

### Cognac G / CMLA

<table>
<thead>
<tr>
<th>Dynamic posture of neurological patients</th>
<th>Pathological ocular movements of babies</th>
<th>Emotion and sensori-motor loops during training through HMI</th>
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<tbody>
<tr>
<td>- analysis of walk signals (accelerometric and piezoelectric sensors)</td>
<td>- eye tracking signals</td>
<td>- multiple sensor signals</td>
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<table>
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<tr>
<th>Stress and body-machine interaction in the cockpit</th>
<th>Overall activity of patients in recovery in their habitat</th>
<th>And more...</th>
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<tbody>
<tr>
<td>- multiple sensor signals</td>
<td>- multiple sensor signals (motion, gestures, eye tracking, ...)</td>
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Main issues during the project and beyond...

<table>
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<tr>
<th>Data</th>
<th>Standardization</th>
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<tr>
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<td>Quality assessment</td>
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<tr>
<td>Time constants</td>
<td>Different focus for neurophysiologists/clinicians, and mathematicians/computer scientists</td>
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<td></td>
<td>Perspectives for junior researchers involved?</td>
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<td>Administration and ethics</td>
<td>Consortium agreement (between public institutions!): heavy and incredibly long process</td>
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<td>Privacy: storage of individual data</td>
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<td>IT</td>
<td>Development cycle: cost for exploration!</td>
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<td>Maintenance issues: OS versions, communication protocols</td>
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Our vision for capitalizing and promote research a portal for physiological signal processing and learning

A multi-entry platform for behavior quantification

- Access: Open/restricted
- Contributors: Data/algorithms
- Focus: Clinical assessment/pathology/sensor
- Objective: Low-level/High-level

Expectations

- Reproducible clinical research
- Reliable data and methods
  - Robust
  - Peer-reviewed
- Connect scientific communities

<http://www.ipol.im>

A pioneer initiative for online numerical experimentation in the field of image processing
Main findings about interdisciplinarity

Interdisciplinarity is easy! As long as there is...

- Shared intellectual interest
- Mutual respect
- Time and space for interaction
- Location-location-location

Interdisciplinarity also presents risks and costs

- Doubtful short-term value for junior researchers in academic promotion
- Relies on new technologies and digital tools to share data and methods
- Investment on HR for software development, maintenance

Interdisciplinarity forces cultural change in organizations

- Revision of the evaluation system for labs and individuals
- Need for flexible funding (hardly compatible with rules of public accounting)
- Tension between centralized services/economy of scale and need for local resources/agility
- Invest on (and own!!) digital tools for interaction
- New practices: first industrialize, then do research!
L’historique du projet SmartCheck

**2012**
- Janvier 2012 : prise de contact par PP Vidal
- Avril-juin 2012 : stage de deux étudiants 2A ENSTA et étude de faisabilité

**2013**
- Janvier 2013 : évaluation AERES pour COGNAC G
- Juin 2013 : premier prototype SmartCheck au VdG
- Juillet 2013 : décision du CI de la SATT IDFINNOV pour le financement des essais cliniques
- Septembre 2013 : constitution de l’équipe (postdoc + ARC + dév Android)
- Décembre 2013 : perte d’une partie de l’équipe

**2014**
- Janvier 2014 : signature accord de valorisation CNRS/ENS Cachan
- Mars 2014 : nouvelle équipe
- Juillet 2014 : deuxième prototype (version Android)
- Septembre 2014 : arrivée d’un ingénieur de recherche mi-temps sur SmartAlgo (plate-forme)
- Décembre 2014 : Accord CPP
- Intégration des questionnaires ‘patient’

**2015**
- Janvier 2015 : Financement PEPS MI
- Mars 2015 : démarrage inclusions essai clinique
- Août 2015 : financement CDS
- Novembre 2015 : mockup SmartAlgo
- Fin 2015 : dépôt de deux brevets

**2016**
- Février 2016 : déploiement du dispositif à la Réunion par la Sécurité Sociale
- Mars 2016 : lancement d’une spin-off pour la valorisation du dispositif
- Avril 2016 : fin de l’essai clinique
- Premières publications
Merci !

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