GdR TACT

Tribologie : principe et méthodes analyses (vibrations induites), paramètres de surface

Francesco Massi

Dipartimento di Ingegneria Meccanica e Aerospaziale

E-mail: francesco.massi@uniroma1.it

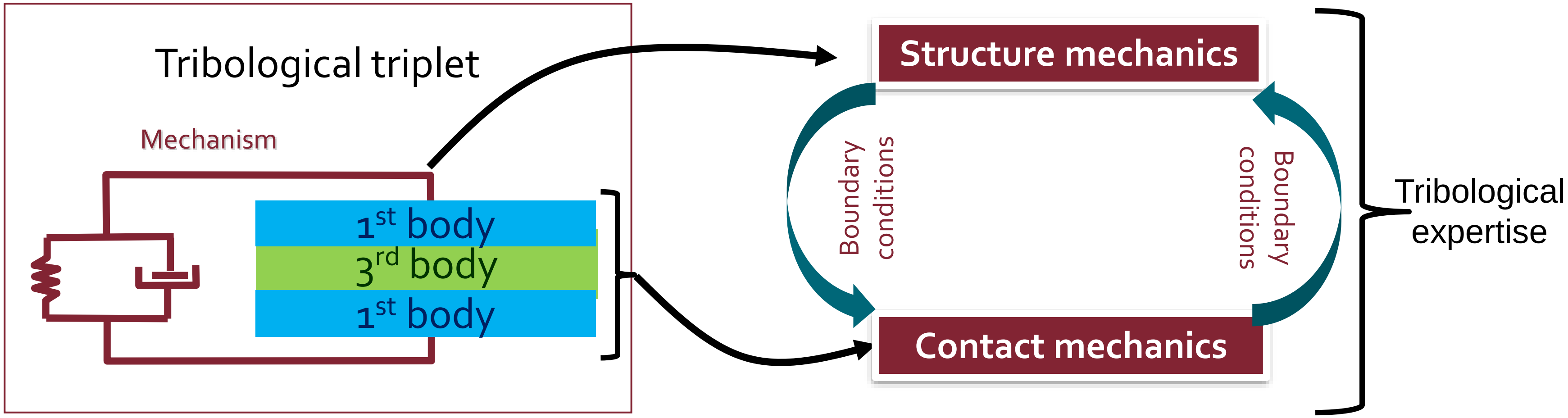
SAPIENZA UNIVERSITÀ DI ROMA

Few words on contacts in general

Tribological triplet

Definitions

Site of the coupling/dialog between bulk and surface, structure mechanics and contact mechanics.

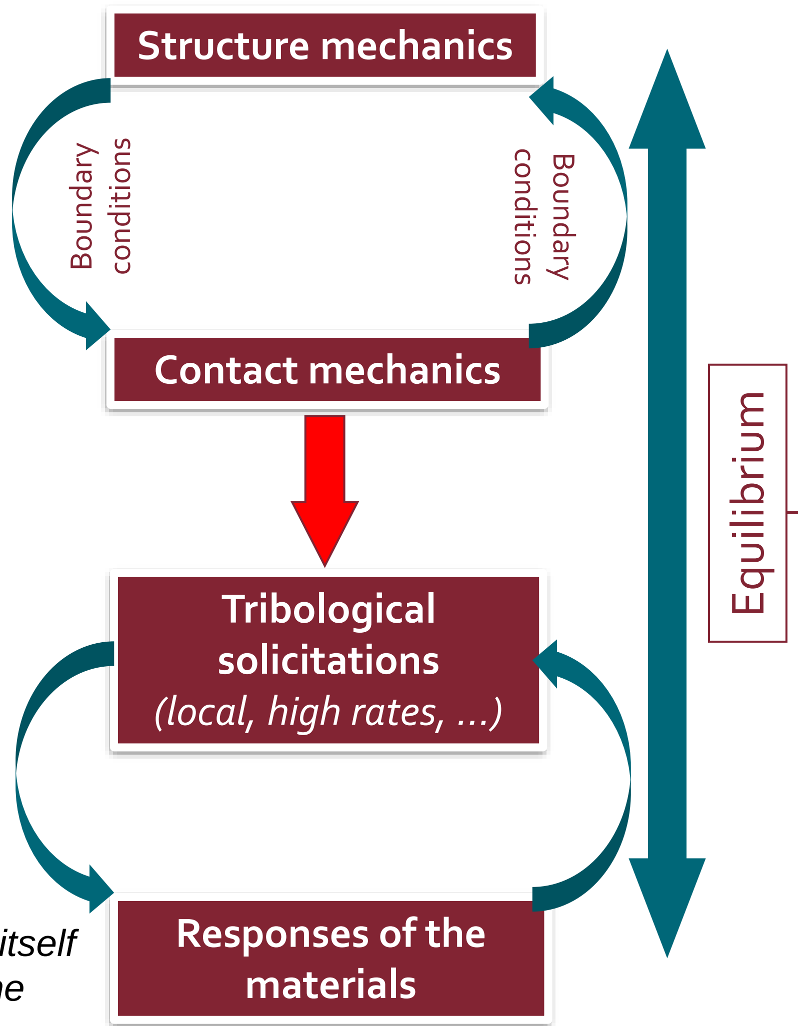


Mechanism (mechanical system)	- Impose the operating conditions - Impose the loads and the boundary conditions (velocities, stiffness, …)
1st bodies	- Receive the solicitations from the mechanism - Bulk deformation - Surface reactivity, tribological transformations of surfaces
3rd body	- Transmission of the load; - Separation of the solids in contact; - Flows in order to accommodate most of the velocity difference between the two solids (rheology of the contact)

Few words on contacts in general

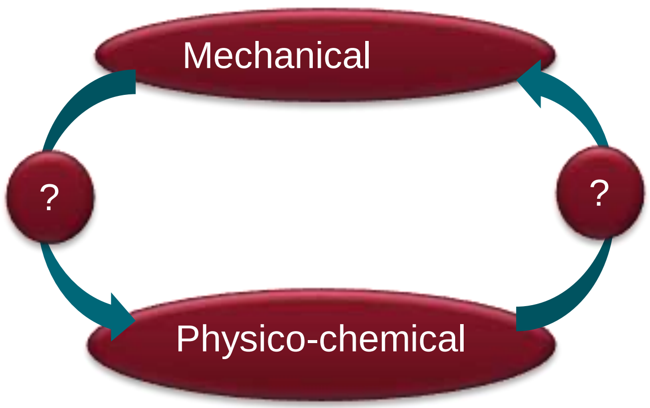
Tribological triplet

Definitions



The surface « sacrifices » itself for protecting the volume

Series and interaction of phenomena at different scales :



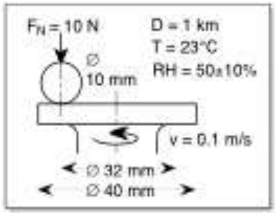
Critical analysis of classical models

Friction coefficient(s)

Basic concepts ? …or basic misconceptions?

Reproducibility and comparison of frictional tests performed by 31 laboratories in 7 different countries (Czichos 1987)

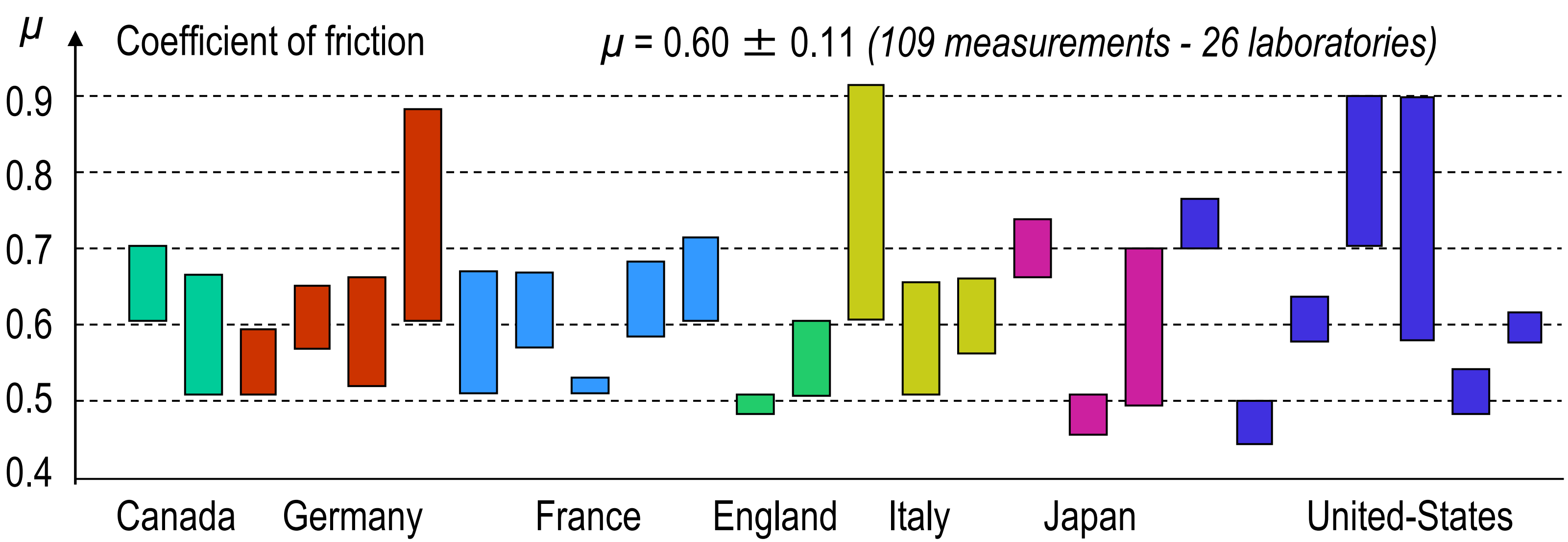
Contact steel-steel (AISI 52100) in dry ball-disc configuration in well defined boundary conditions



No specifications on the experimental set-up! *(…what about the effects of the system (mechanism)? rigidity, heating, etc…)*

Trying to define a data collection for friction coefficients… *NO WAY!*

VAMAS international scientific standardization campaign



Critical analysis of classical models

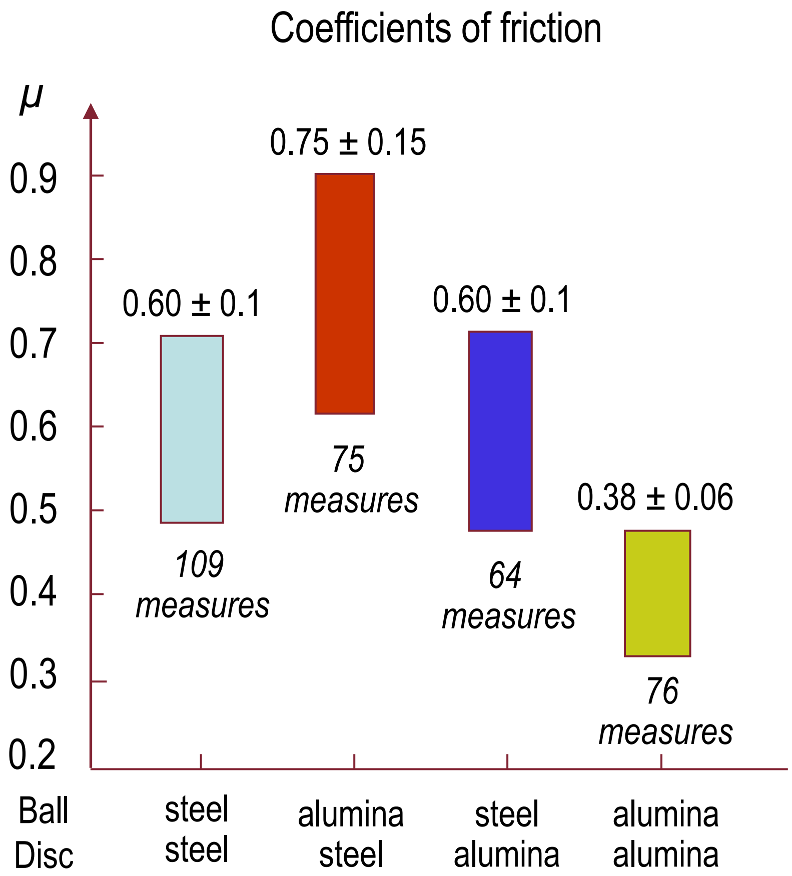
Friction coefficient(s)

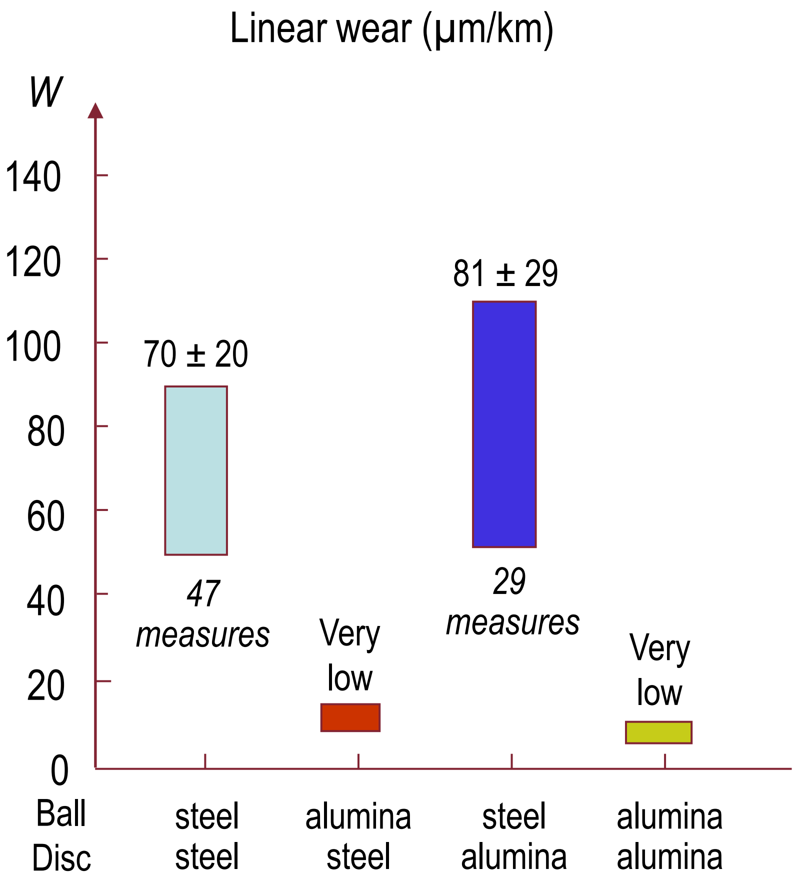
VAMAS (continuation) *(Czichos 1987, 1989)*

Basic concepts ? …or basic misconceptions?

Friction of different configurations steel (AISI 52100) and alumina (α-Al_2O_3)

F_N = 10 N; v = 0.1 m.s^{-1}; T = 23°C; D = 1 km





Repeatability *(same lab)*: coefficient of friction ± 13 % and wear ± 14 %

Repeatability *(different labs)*: coefficient of friction ± 14 % and wear ± 38 %

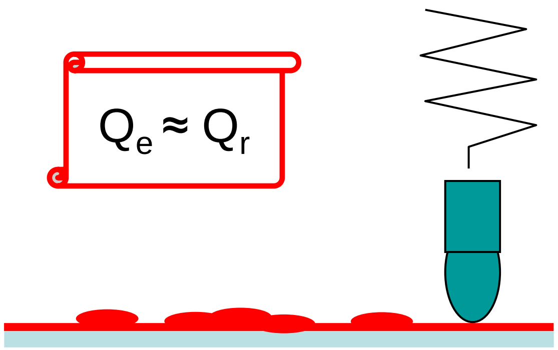
Source: - course of « Durability of Materials: introduction to tribology», J. Denape, ENI of Tarbes.

Critical analysis of classical models

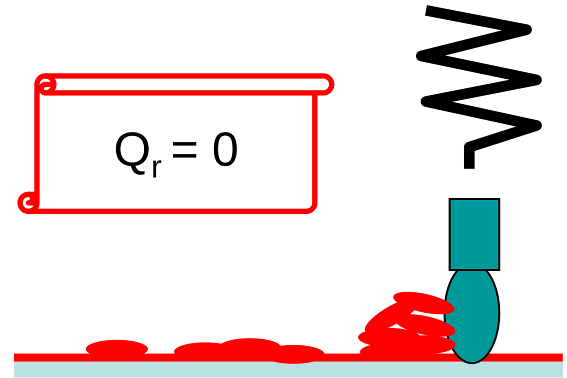
Wear

Wear and boundary conditions

Influence of the stiffness of the system (mechanism):



Low stiffness :
all the 3rd body passes by



High stiffness:
few of the 3rd body passes by

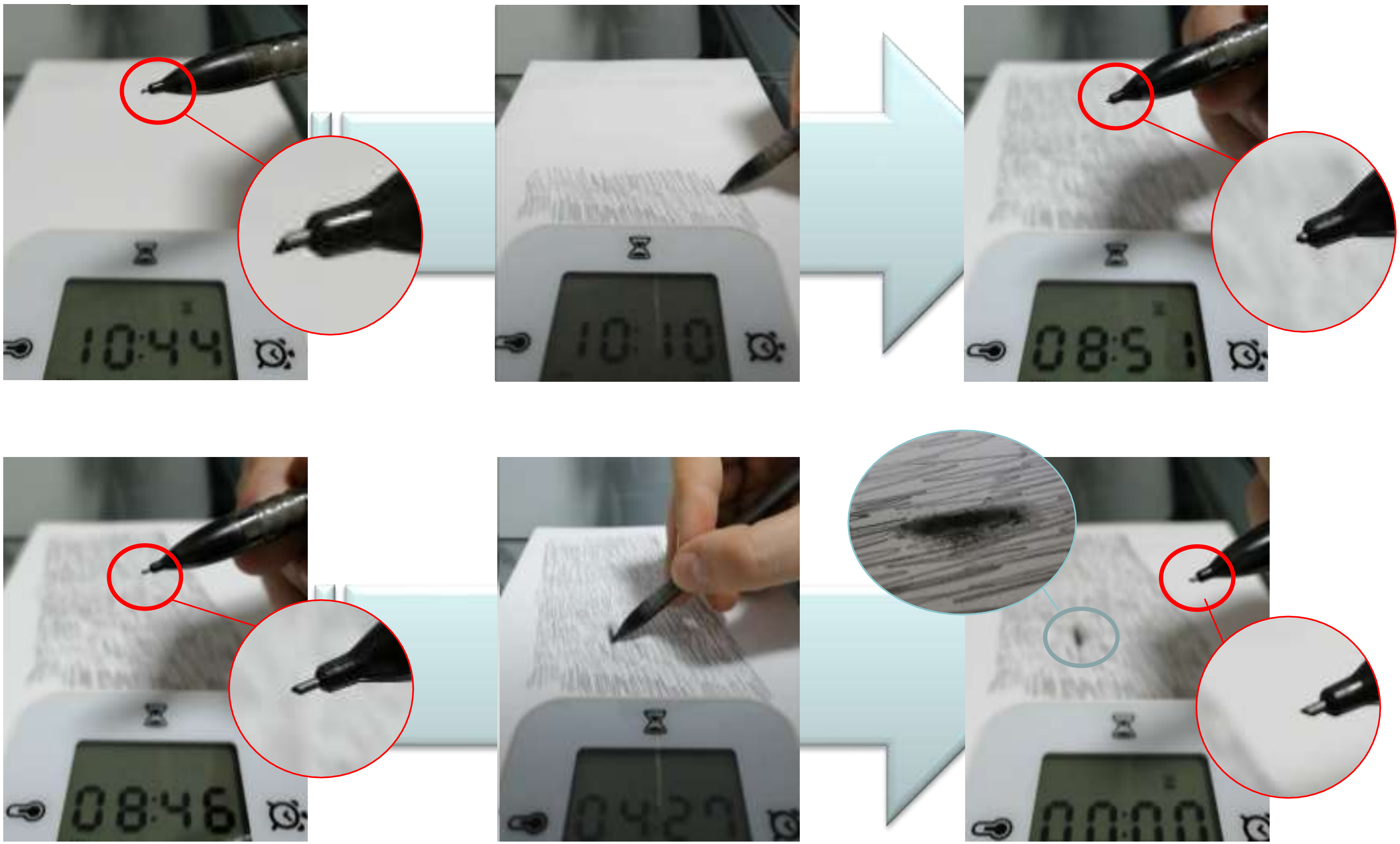
Trying to extrapolate from a contact configuration to another, need to know the stress actually viewed by contact!

Wear maps should be performed for a given mechanism!

Critical analysis of classical models

Wear and boundary conditions

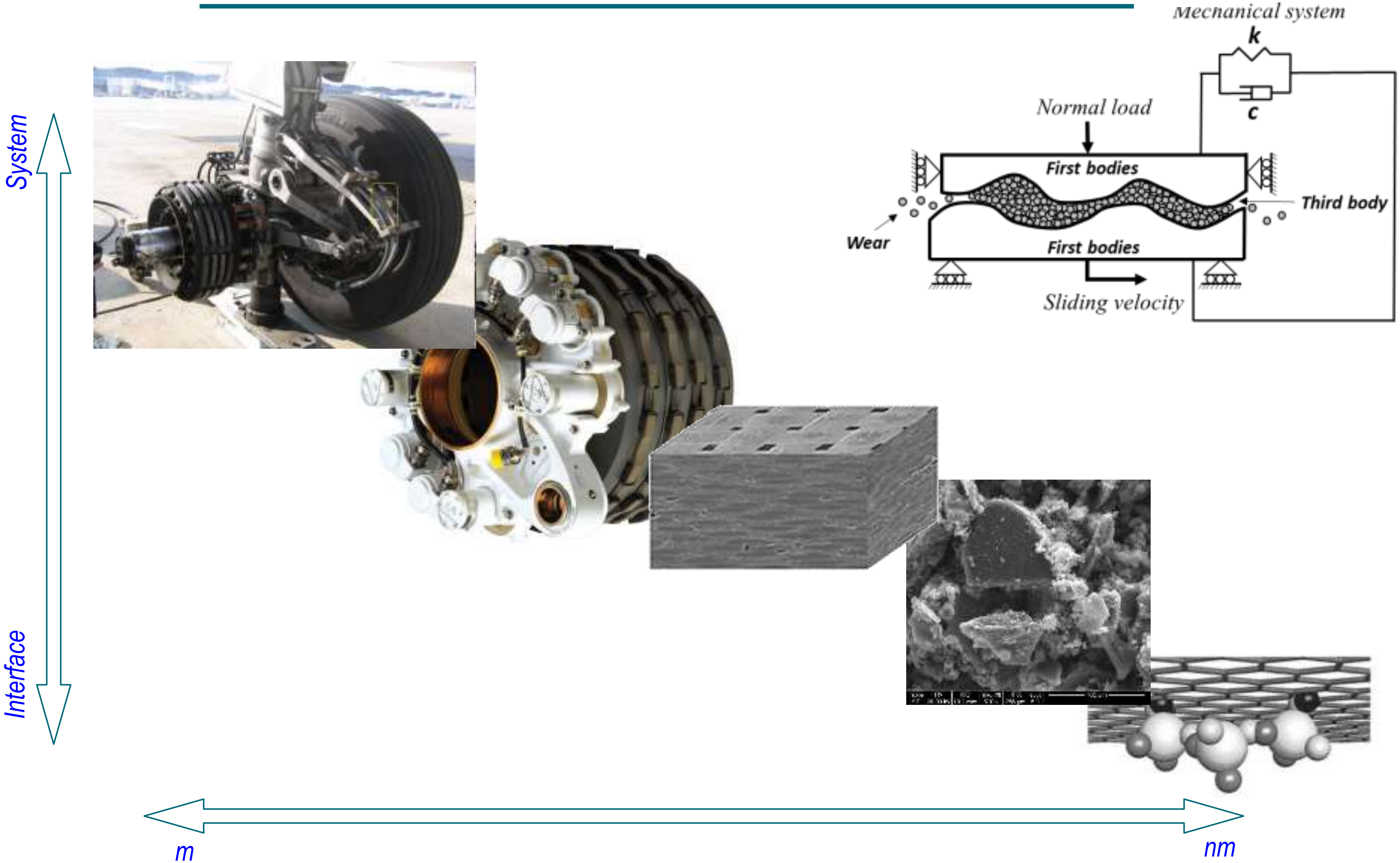
Example of protective 3° body: grafite.



Few words on contacts in general

Tribological triplet

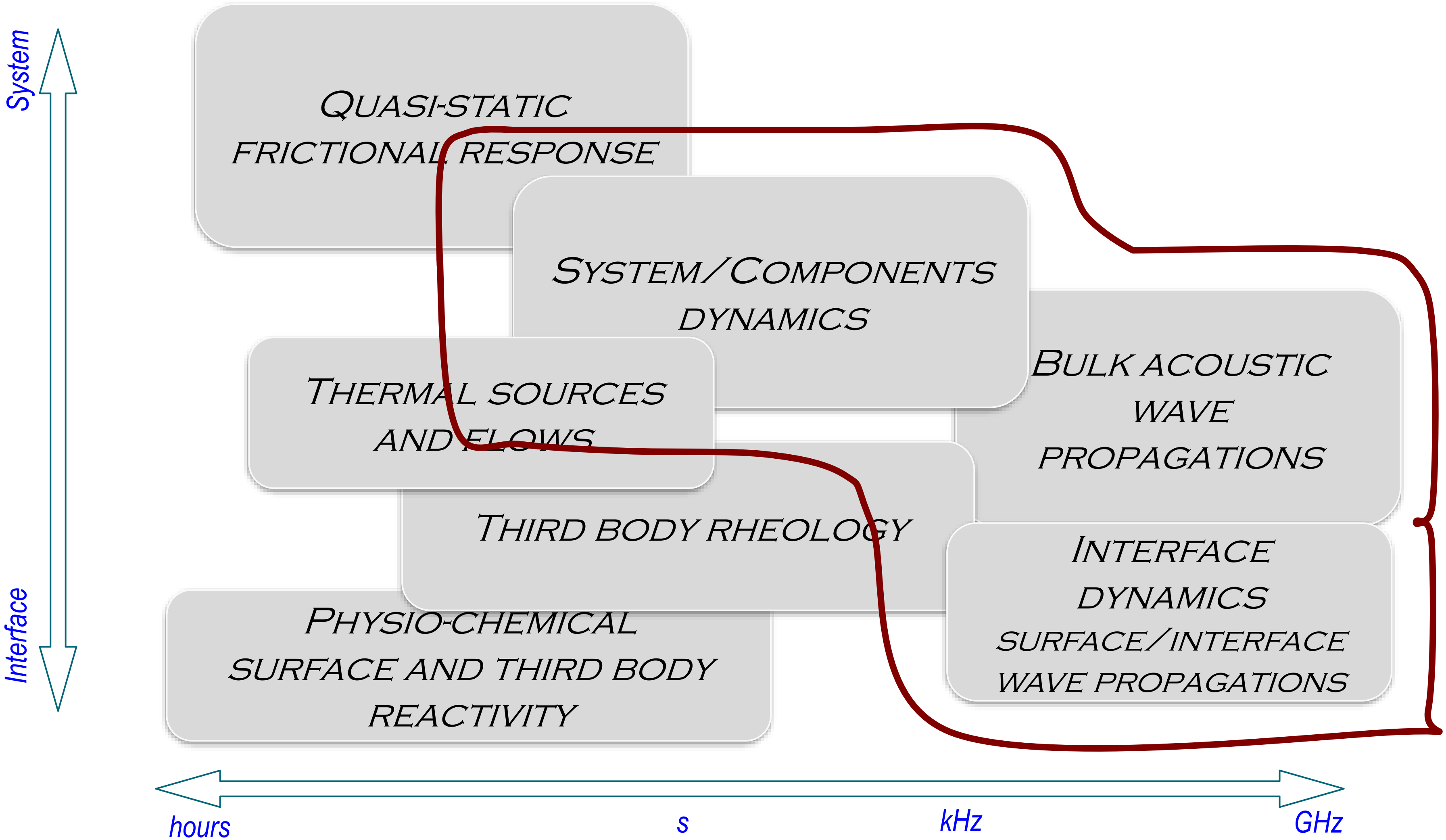
Space scales in a tribological issue



Few words on contacts in general

Tribological triplet

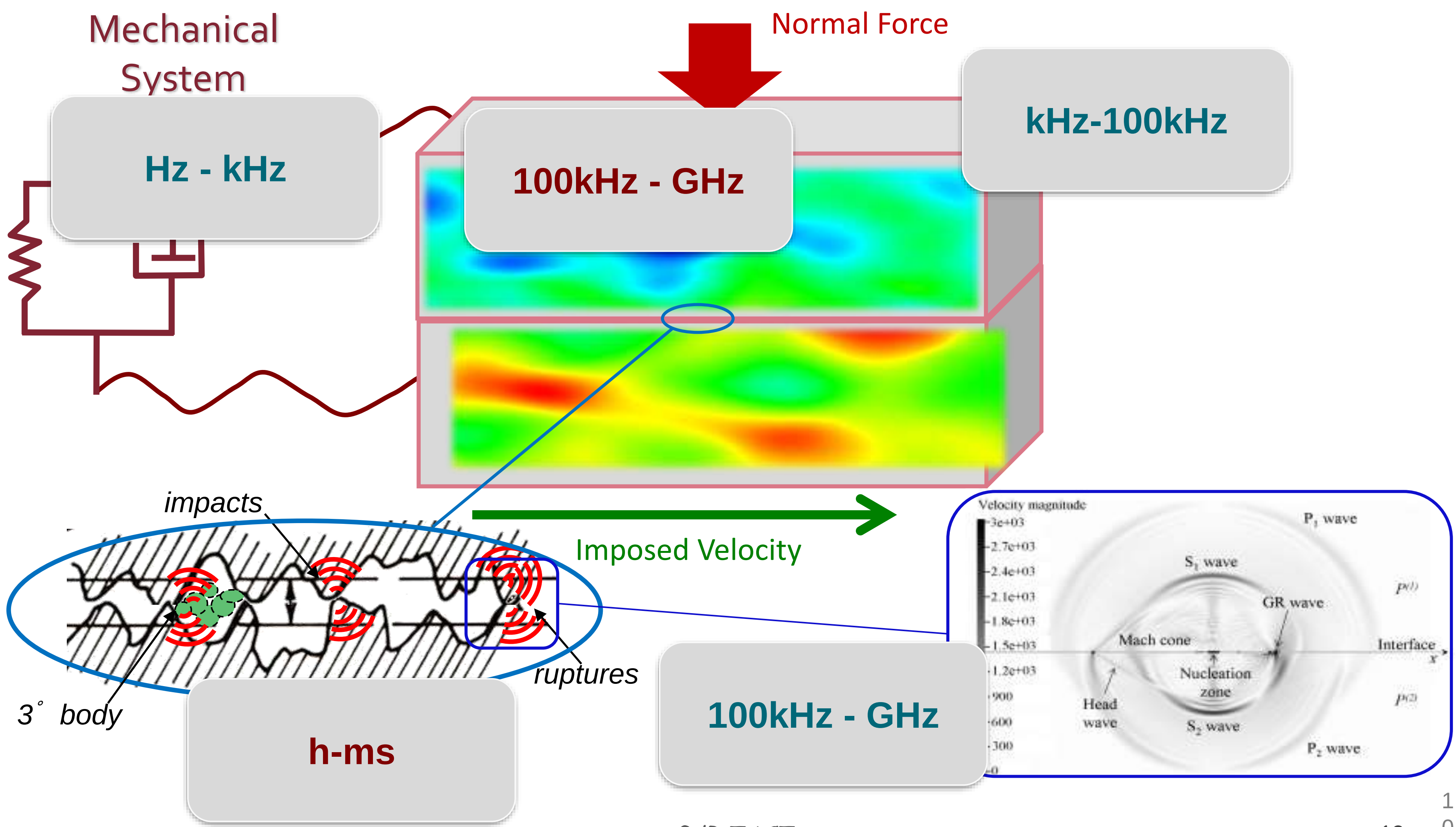
Time scales in a tribological issue



Few words on contacts in general

Contact Induced Vibrations

The several “dynamics” of a contact



Tactile perception and Friction-Induced Vibrations

Challenges in tactile perception

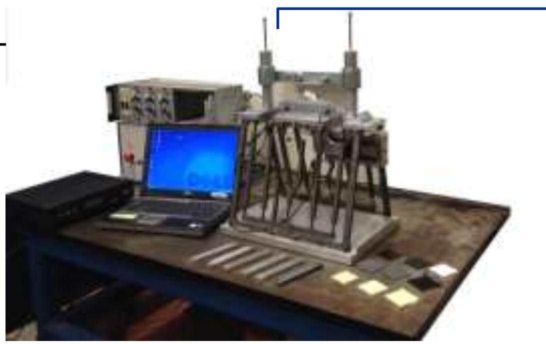
Mechanical and biomechanical challenges

Tribological results on tactile perception: FRICTION-INDUCED VIBRATIONS

Correlated of FIV features with physical surface feature.

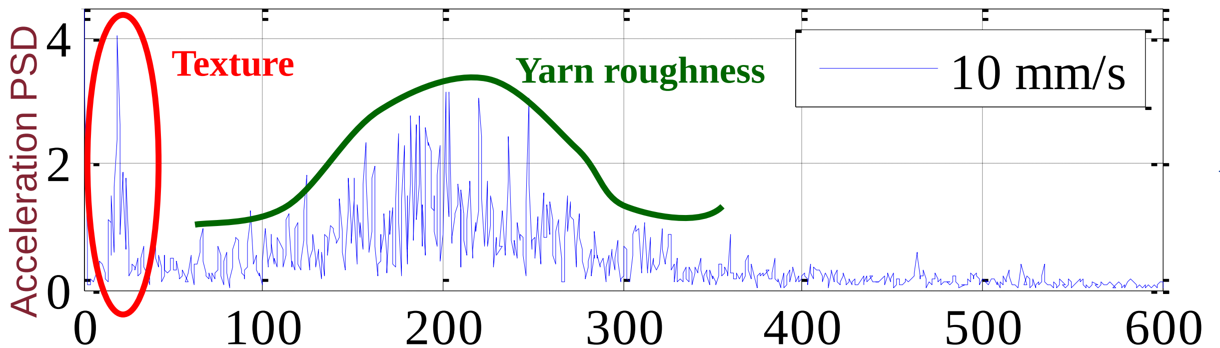
Example of induced vibration spectra when perceiving a textile with the finger

TRIBOTOUCH



Fabric with defined texture periodicity and medium yarn roughness

Acceleration spectra measured at the fingernail



- Friction induced vibrations in “stable conditions” are a “picture” of the contact interface.
- This is related to the fabric structure:
  - the frequency peaks are correlated to the fabric texture ;
  - the larger frequency distribution is linked to the yarn roughness.

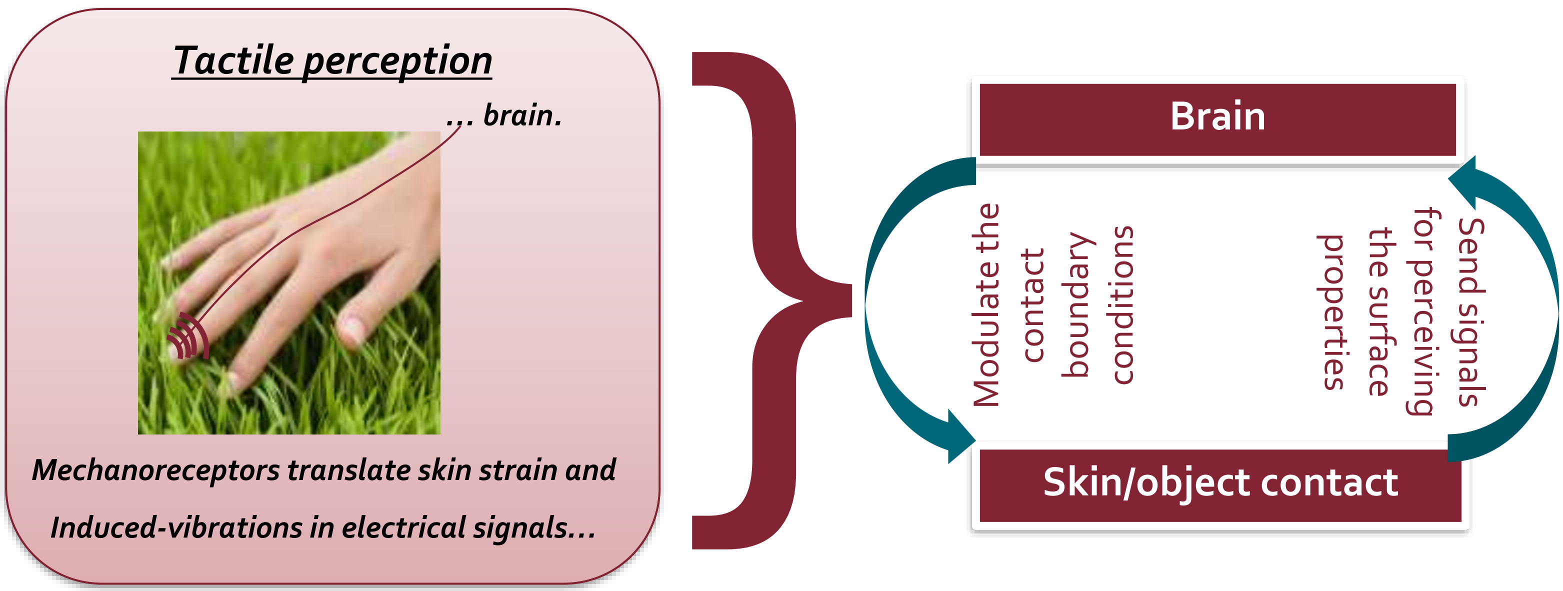
Tactile perceptionbyfrictioninducedvibrations, **TribologyInternational**, 44 (2011), 1100–1110

Tactile perception and Friction-Induced Vibrations

Tactile perception and tribology

Definitions

The **origin of tactile** sense is at the **“mechanical” TOUCH** between the skin and the perceived surface, where mechanical (and not only) stimuli are “captured” by receptors.



Touch is an active process in which brain receive impulses by the receptor on the skin, interpret the signals and control the touch parameters (velocity, force, …).

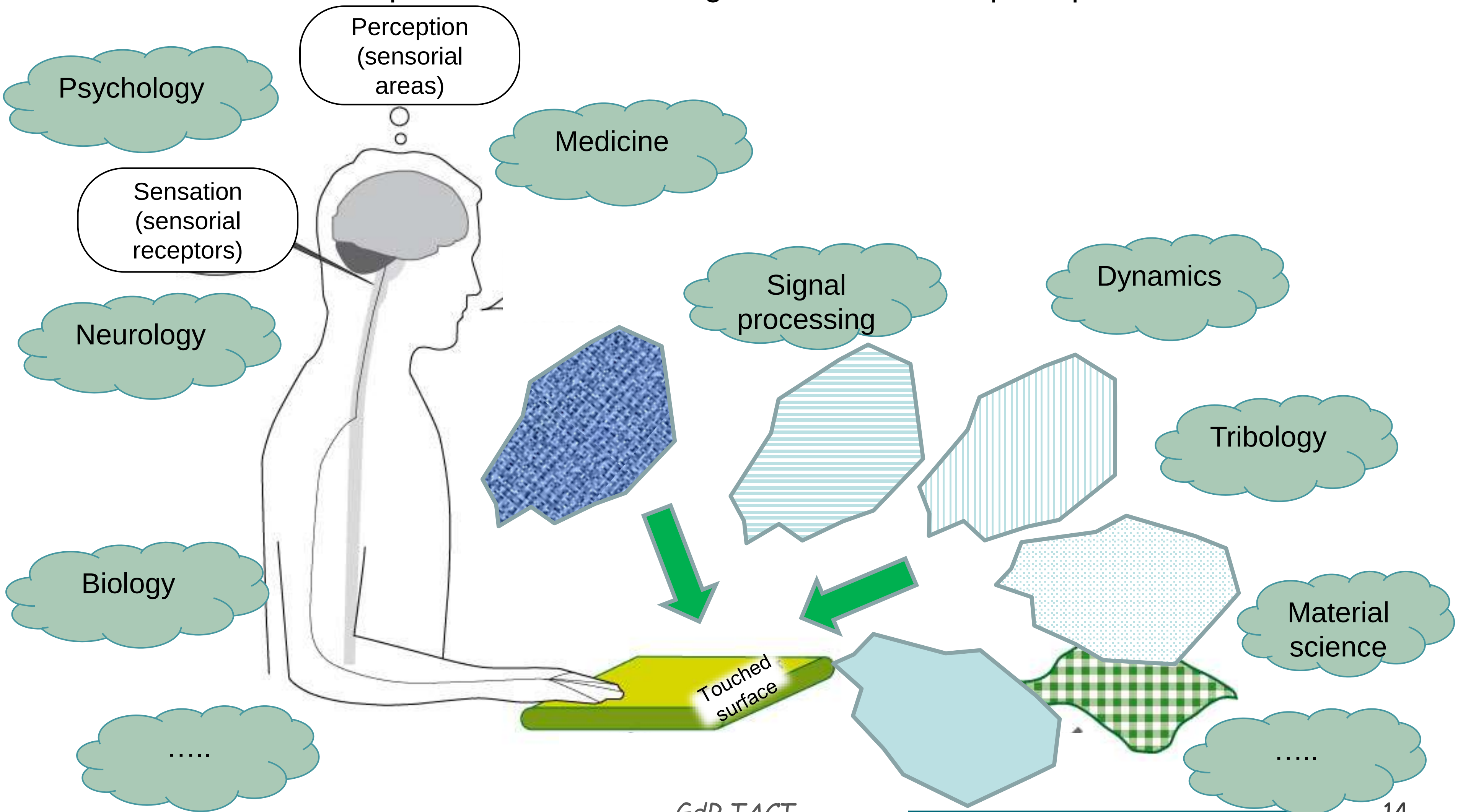
Tactile perception and Friction-Induced Vibrations

Challenges in tactile perception

Mechanical and biomechanical challenges

From the contact to the brain… multidisciplinary and multiphysical issue

Which are the disciplines and the challenges linked to tactile perception?



Tactile perception and Friction-Induced Vibrations

Tactile perception and tribology

Definitions

Skin-surface contact… what else?!?

“Servo-controlled” boundary conditions

Thermal flows between skin and object surface

Variation of load, velocity, direction, angles, …

Sebum ejection with temperature and strain

…

Transient stress-strain distributions (induced vibraions)

Nonlinear material properties of skin

Not trivial pressure distribution at the contact interface

Not trivial shear distribution at the contact interface

Not trivial surface profiles (skin vs object)

Quasi-static strain distribution (force and friction), transient strain variation (induced vibrations), heat flows (temperature), fluid interpolation (humidity), …

Tactile perception and Friction-Induced Vibrations

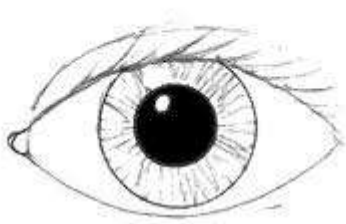
Tactile perception and tribology

Definitions

Tactile perception vs other senses

Reproducing the perception means understanding and reproducing the signals.

acoustic waves, frequency, A-level, tone, …



light, wavelength, colour, opacity, …

induced vibrations, spectral distribution, contact pressure, temperature…

Tactile perception and Friction-Induced Vibrations

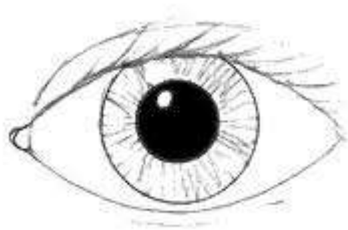
Tactile perception and tribology

Definitions

Tactile perception vs other senses

Solving tactile deficiency.

acoustic waves, frequency, A-level, tone, …



light, wavelength, colour, opacity, …

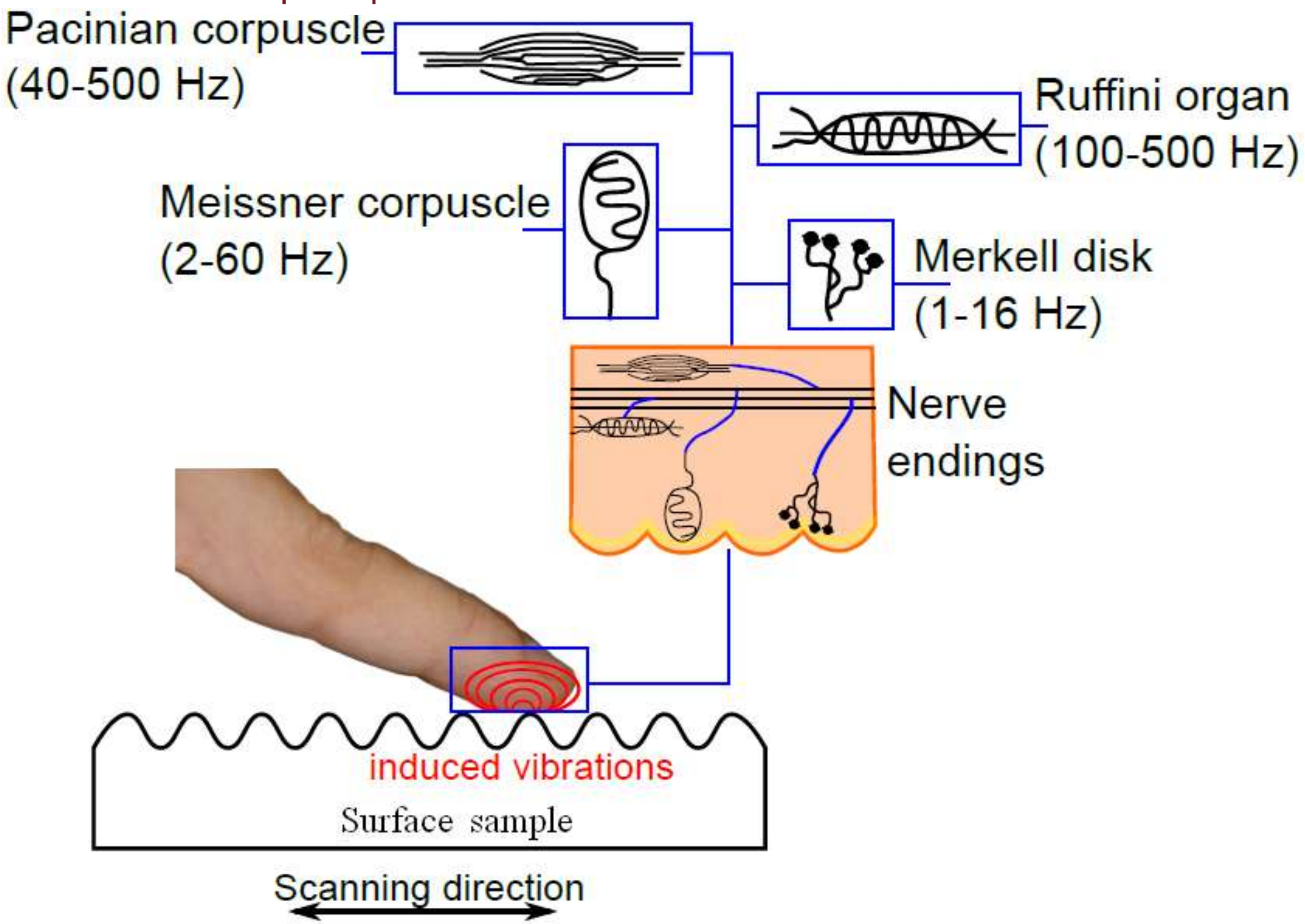
induced vibrations, spectral distribution, contact pressure, temperature…

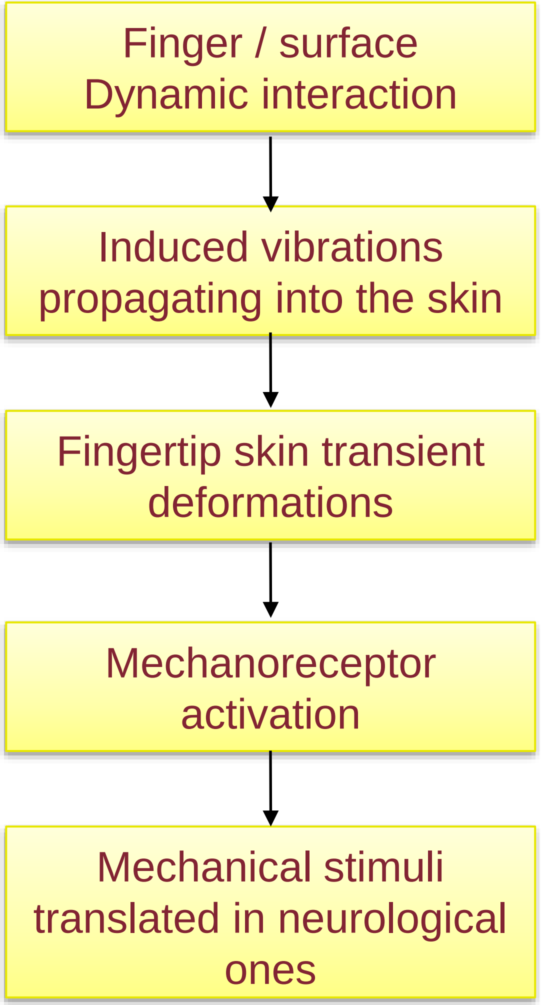
Tactile perception and Friction-Induced Vibrations

Tactile perception and tribology

Definitions

Tactile perception mechanism and friction induced vibrations





The tactile perception of textures is directly linked to the vibrations induced by the finger scanning.

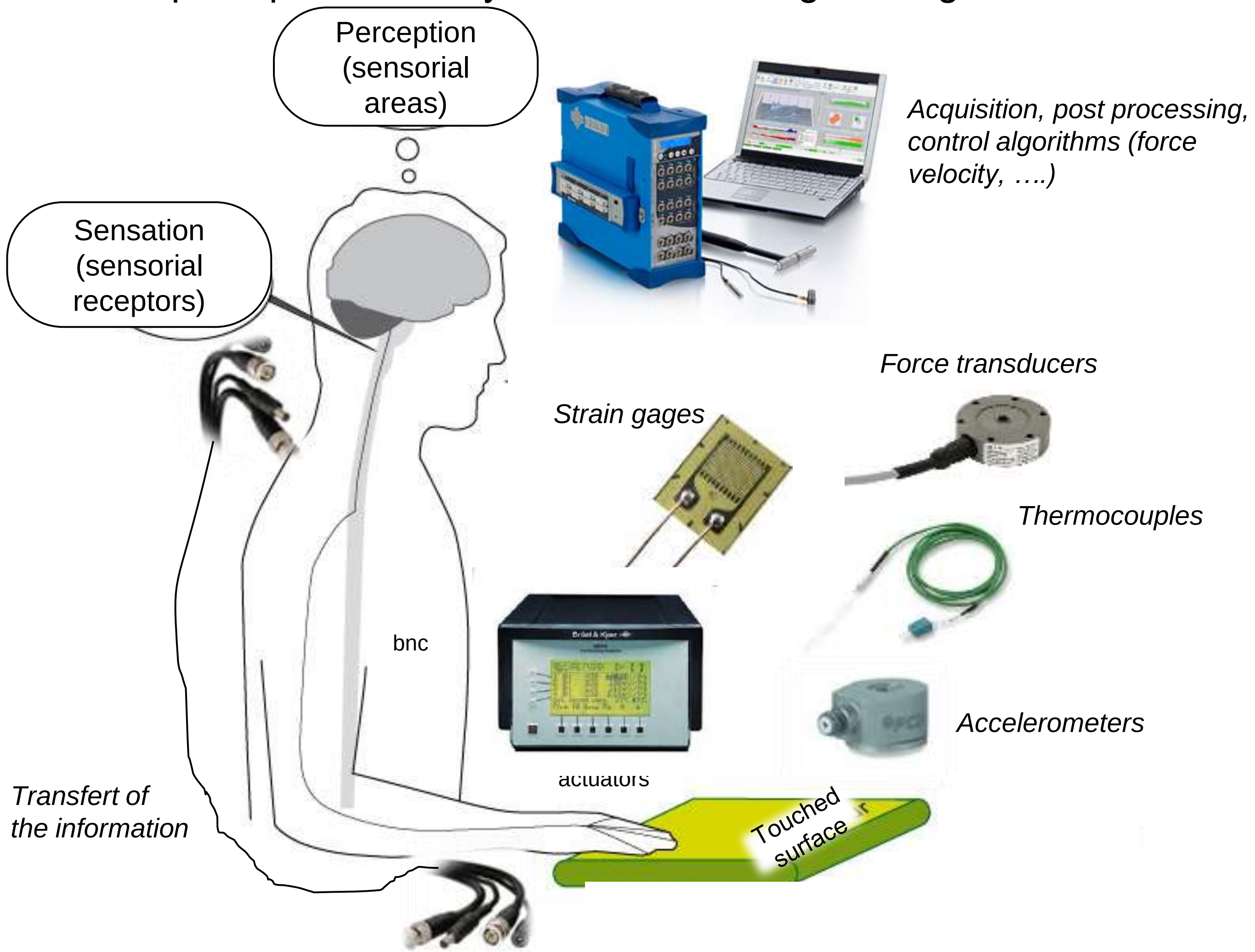
Tactile perception and Friction-Induced Vibrations

Challenges in tactile perception

Mechanical and biomechanical challenges

From the contact to the brain… multidisciplinary and multiphysical issue

Tactile perception seen by a mechanical engineering…



Tactile perception and Friction-Induced Vibrations

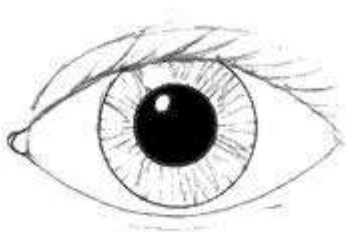
Challenges in tactile perception

Mechanical and biomechanical challenges

The role of tribologists in tactile perception

Which signals are at the origin of touch? Which parameter? Which levels?

acoustic waves, frequency, A-level, tone, …



light, wavelength, colour, opacity, …

induced vibrations, spectral distribution, contact pressure, temperature…

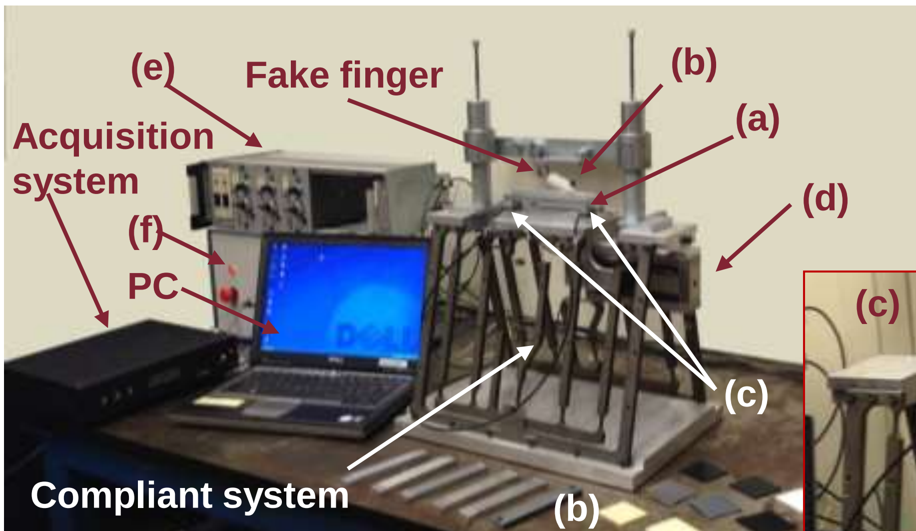
Tactile perception and Friction-Induced Vibrations

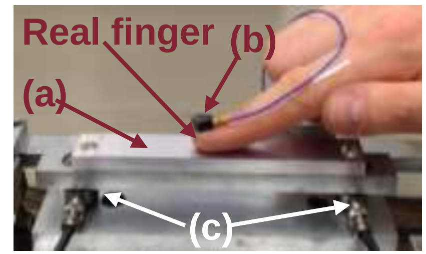
Challenges in tactile perception

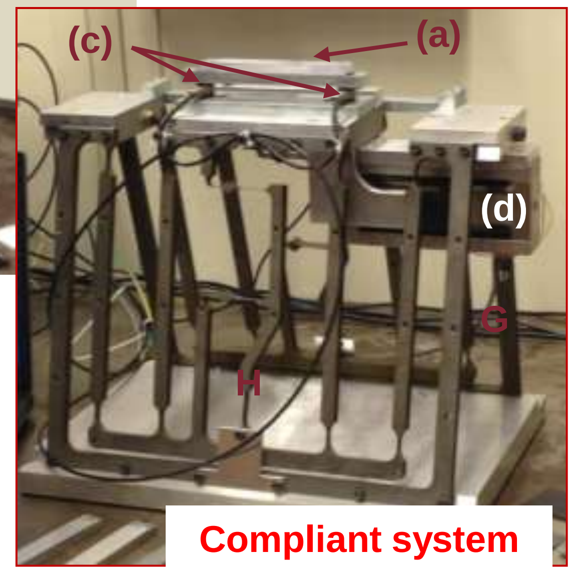
Mechanical and biomechanical challenges

Measuring low frictional force and extremely low vibrations with complex spectrum

Test bench designed to measure low amplitude friction-induced vibrations without introducing parasite noise







- (a) Surface samples
- (b) Accelerometer
- (c) Force transducers
- (d) Linear voice-coil
- (e) Charge amplifier
- (f) Digital servo drive

Tactile perception and Friction-Induced Vibrations

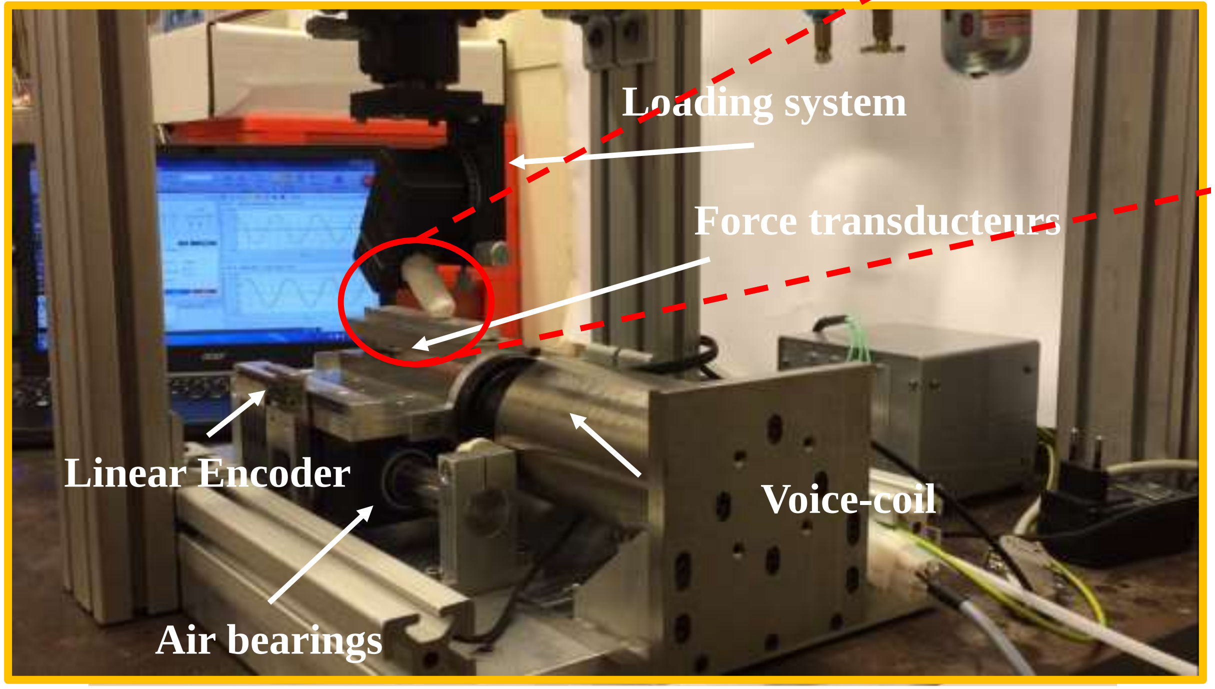
Challenges in tactile perception

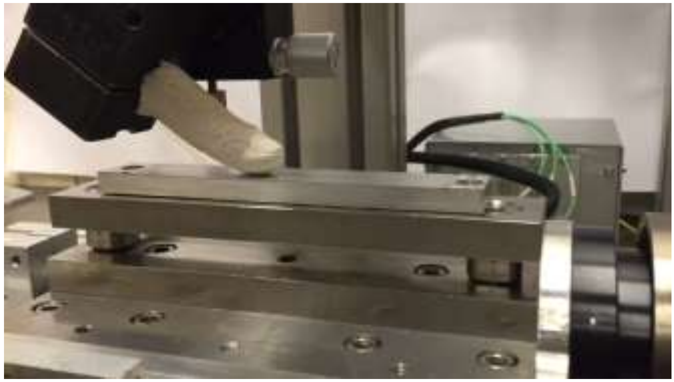
Mechanical and biomechanical challenges

Measuring low frictional force and extremely low vibrations with complex spectrum

Test bench designed to measure low amplitude friction-induced vibrations without introducing parasite noise

Objective: analysis of the Friction Induced Vibrations under controlled conditions





- Imposed external boundary conditions;
- Measure of induced vibration for well controlled boundary conditions

- Air bearing system allows for planar motion without introducing parasitic noise

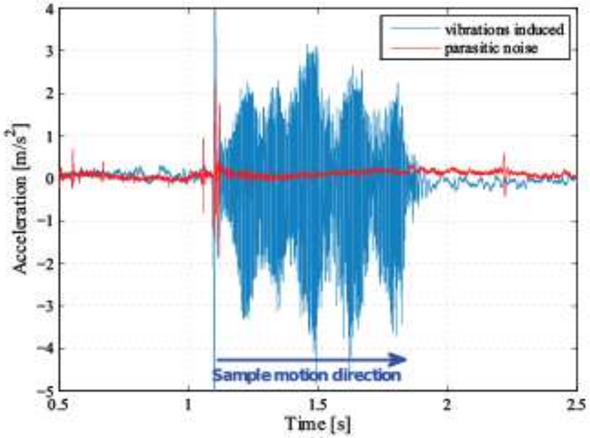
Tactile perception and Friction-Induced Vibrations

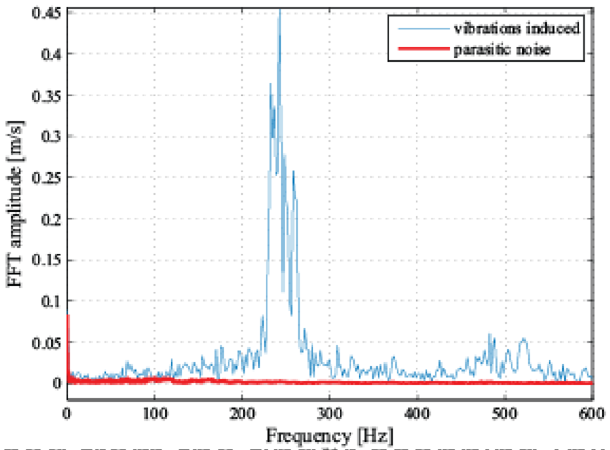
Challenges in tactile perception

Mechanical and biomechanical challenges

Measuring low frictional force and extremely low vibrations with complex spectrum

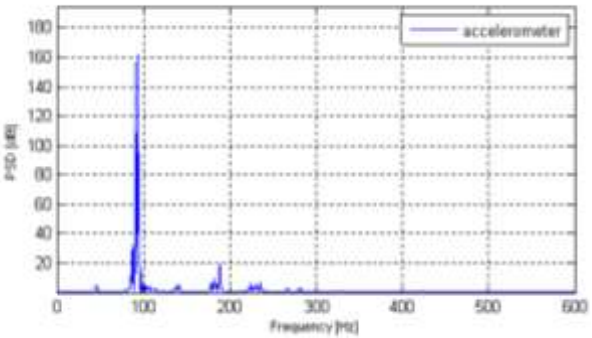
Low parasitic noise

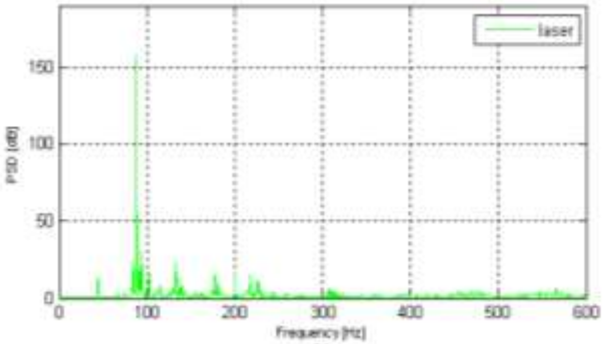




The comparison between the acceleration signals induced from the finger scanning (blue) and the parasitic noise (red) and their FFTs show that **the noise is negligible**.

Neglectable perturbation of the instrumentation





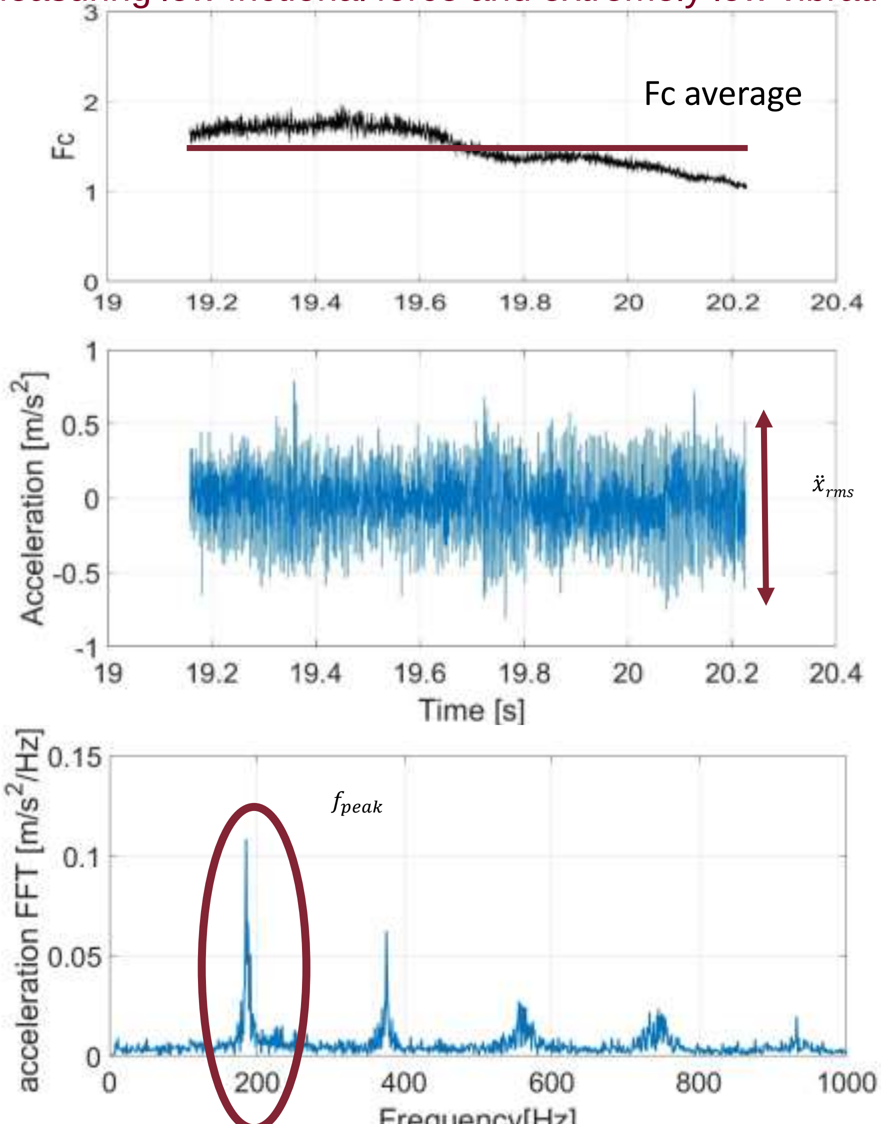
Comparison between the power spectral density of the signals obtained from the accelerometer (blue) and the laser vibrometer (green).

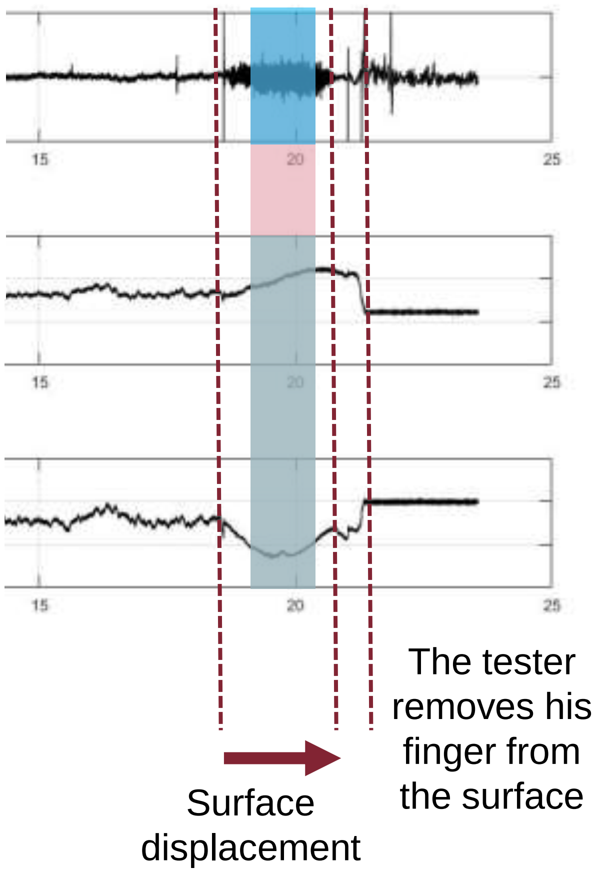
Tactile perception and Friction-Induced Vibrations

Challenges in tactile perception

Mechanical and biomechanical challenges

Measuring low frictional force and extremely low vibrations with complex spectrum





Tactile perception and Friction-Induced Vibrations

Challenges in tactile perception

Mechanical and biomechanical challenges

Choice of representative test parameters

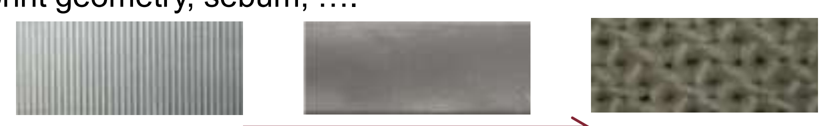
Definition of contact boundary conditions and parameter ranges for sensitive analysis.

Measurement configuration using real finger

Measurement configuration using fake finger

Surface samples:

1. Aluminium samples with **periodical roughness** obtained from milling with arithmetic roughness value **Ra varies between 0.64 and 5.2 µm** and the roughness **wavelength between 0.15 and 2.17 mm**
2. Steel samples with **isotropic roughness** obtained by sandblasting, with final mean **roughness between 0.4 and 5 µm**.
3. **Fabric samples**, in different materials and with **different texture and hairiness**.
4. Fingerprint geometry, sebum, ….



Scanning speed:

10 mm/s, 20 mm/s, 30 mm/s, 40 mm/s, 50 mm/s

Tactile perception and Friction-Induced Vibrations

Challenges in tactile perception

Mechanical and biomechanical challenges

Choice of representative surface descriptors

Need of a panel of surfaces with a quantitative variation of representative descriptors.

Blocking

Relief

Fibrous

Both the typology and the name of the descriptors have been recovered by cognitive psychological campaigns on a panel of subject (GdR TACT).

Tactile perception and Friction-Induced Vibrations

Challenges in tactile perception

Mechanical and biomechanical challenges

Decoupling effects of single parameters

Need to decouple the main parameters to investigate the effectiveness and role of each one into the signals perceived by the mechanoreceptors:

- Sliding velocity;
- Contact force;
- Angles between finger and surface;
- Hydration of the skin;
- …
- Topography of the fingerprints:

Moulding of a real fingerprint and artificial fingerprints from 3D printing

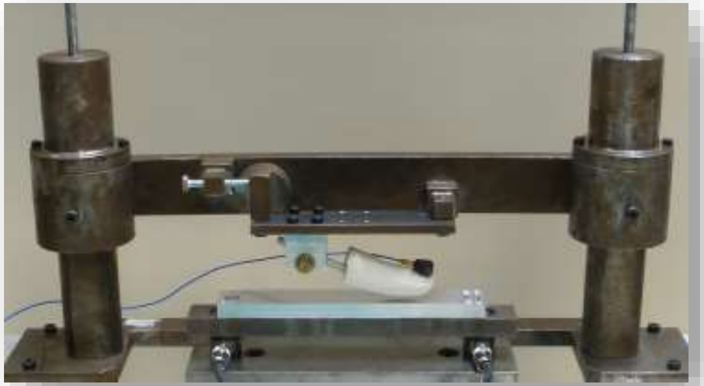
Tactile perception and Friction-Induced Vibrations

Challenges in tactile perception

Mechanical and biomechanical challenges

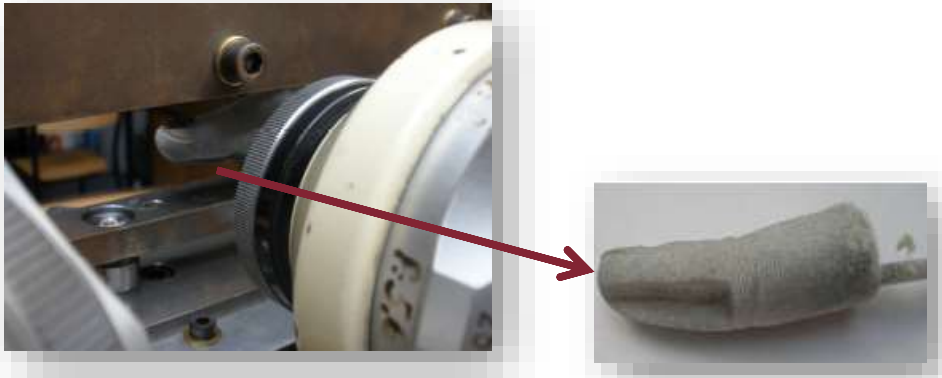
Understanding the reliability of the measured signals

Measurement of global and local dynamics on the fake finger



Measured vibrations:

- The acceleration is measured at the fingernail, far away from the contact;
- The contact forces are measured by tri-axial force transducers, far from the contact.



Local vibrations:

- Need to investigate if the spectra of the measured vibrations are the same of the local ones, where mechanoreceptors stay;
- Image cross correlation technique allows for calculating the local vibrations.

Tactile perception and Friction-Induced Vibrations

Challenges in tactile perception

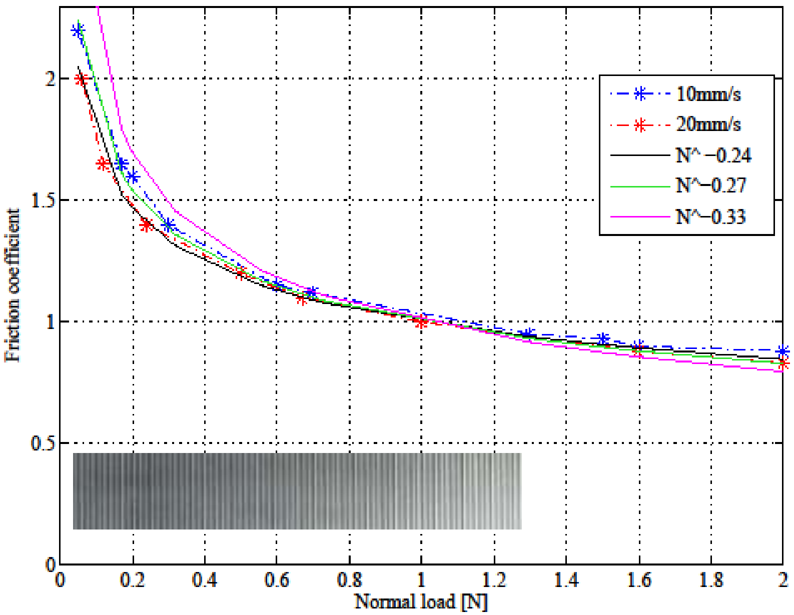
Mechanical and biomechanical challenges

Tribological results on tactile perception: FRICTION FORCE

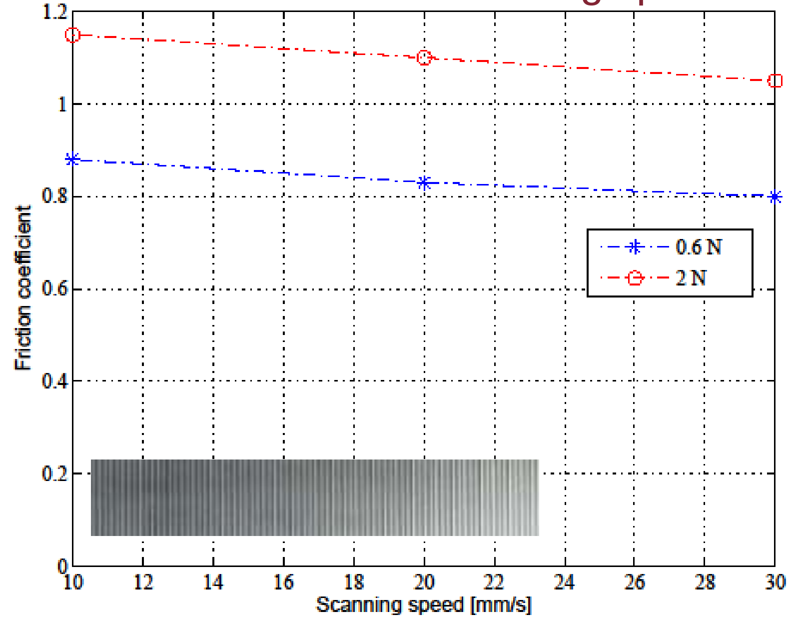
The first step is the characterization of the macroscopic friction force, its robustness and behavior with respect to the contact parameters.

Friction coefficient on rigid surfaces

Friction coef. *vs* Load



Friction coef. *vs* Scanning speed



- Friction coefficient decreases in a non-trivial trend with the increase of normal load.
- Friction coefficient decreases slightly with the scanning velocity.

Tactile perception and Friction-Induced Vibrations

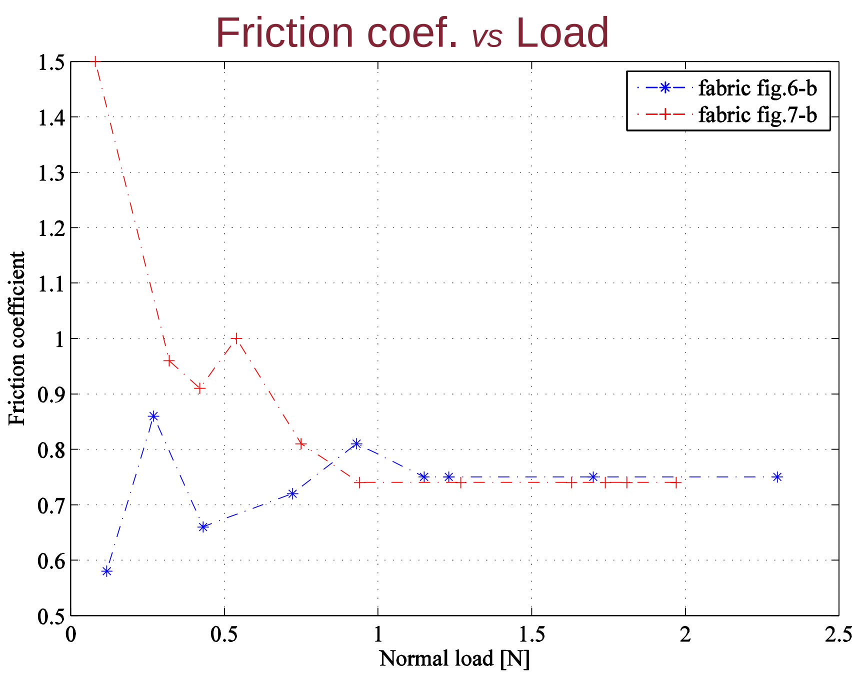
Challenges in tactile perception

Mechanical and biomechanical challenges

Tribological results on tactile perception: FRICTION FORCE

The first step is the characterization of the macroscopic friction force, its robustness and behavior with respect to the contact parameters.

Friction coefficient on textiles



- Fabrics with higher hairiness show a larger friction coefficient for lower loads.
- All the fabrics reach similar values at higher loads, due to the compression of the hairiness.

Tactile perception and Friction-Induced Vibrations

Challenges in tactile perception

Mechanical and biomechanical challenges

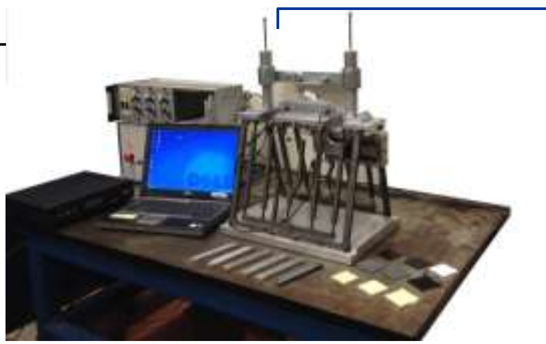
Tribological results on tactile perception: FRICTION-INDUCED VIBRATIONS

Correlated of FIV features with physical surface feature.

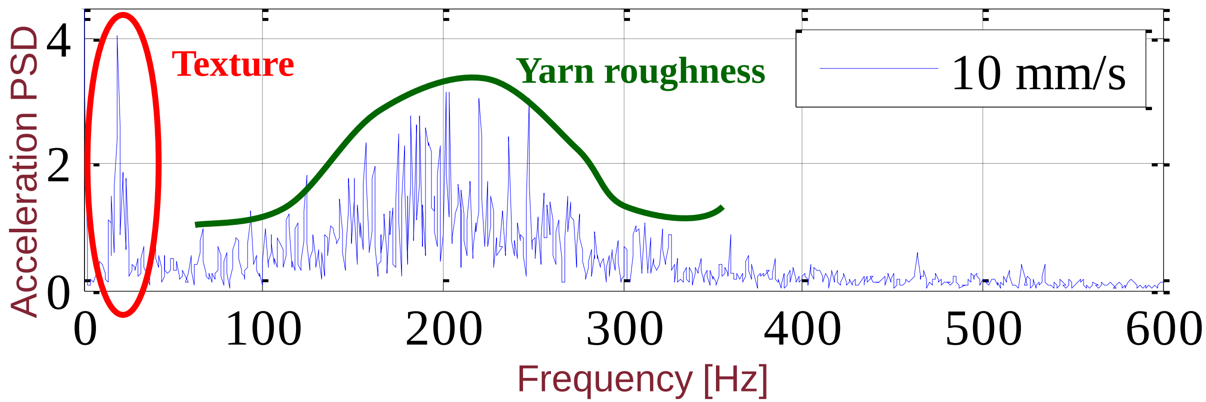
<u>Example of induced vibration spectra when perceiving a textile with the finger</u>

Fabric with defined texture periodicity and medium yarn roughness

TRIBOTOUCH



Acceleration spectra measured at the fingernail



- Friction induced vibrations in “stable conditions” are a “picture” of the contact interface.
- This is related to the fabric structure:
  - the frequency peaks are correlated to the fabric texture ;
  - the larger frequency distribution is linked to the yarn roughness.

Tactile perception and Friction-Induced Vibrations

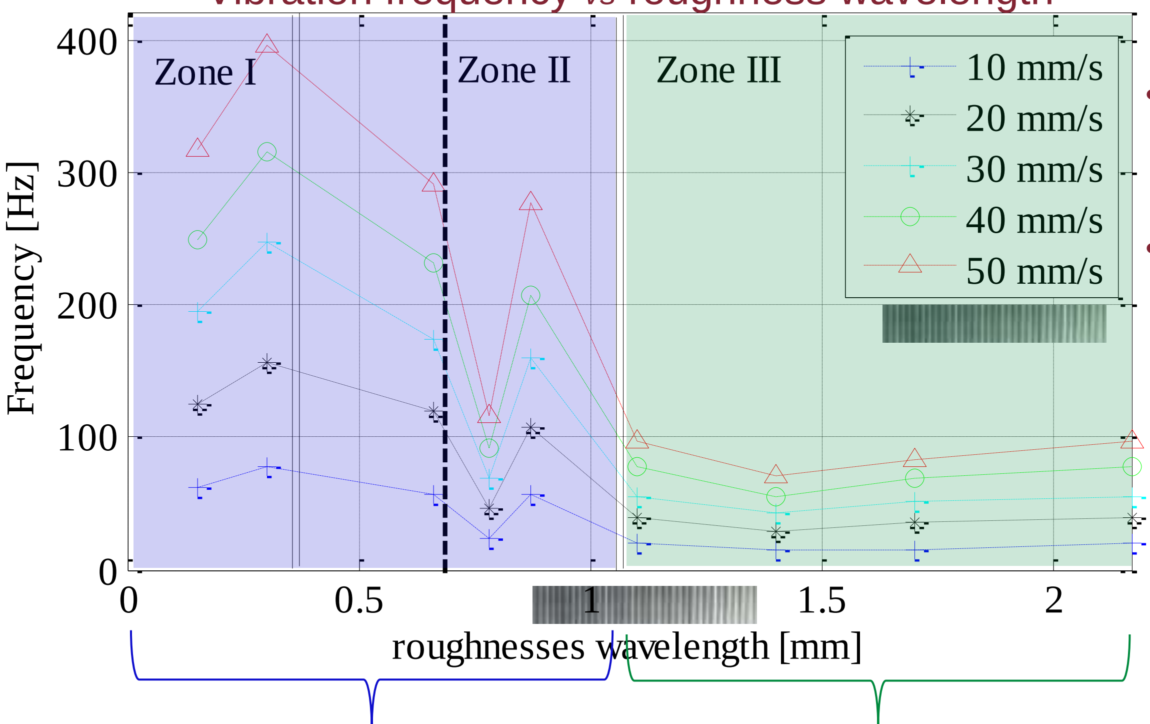
Challenges in tactile perception

Mechanical and biomechanical challenges

Tribological results on tactile perception: FRICTION-INDUCED VIBRATIONS

Then, friction-induced vibrations when scanning the surface with a finger are detected, analyzed and correlated with physiological and psychological literature.

Vibration frequency *vs* roughness wavelength



Dynamic perception

Static perception

- Non-linear dependence of the frequency peak with respect to the roughness wavelength of the sample;
- The induced vibration frequency is function of the combination of the fingertip and surface sample roughness:

○**Zone I and Zone II**: The frequency peak is function of the ratio between the sample and fingerprint wavelengths.

○**Zone III**: The frequency peak is function of the only fingerprint wavelength.

✓ These results agree with the ***"duplex perception model"*** from neurophysiologic analyses.

[Hollins M., Bensmaïa S., Risner R., Proceedings of fourteenth annual meeting of the international society for psychophysics , 115-120, 1998]

Tactile perception and Friction-Induced Vibrations

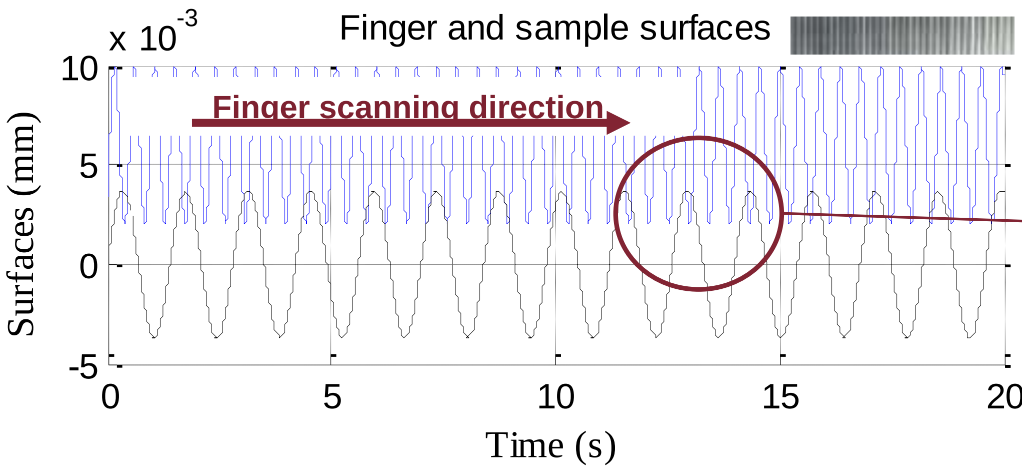
Challenges in tactile perception

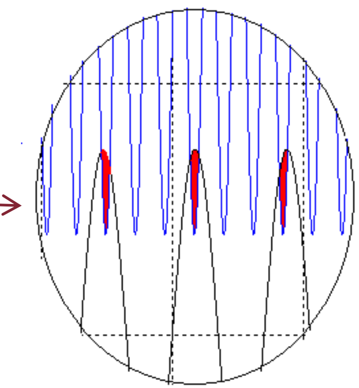
Mechanical and biomechanical challenges

Tribological results on tactile perception: FRICTION-INDUCED VIBRATIONS

Then, friction-induced vibrations when scanning the surface with a finger are detected, analyzed and correlated with physiological and psychological literature.

Frictio-induced vibrations frequency *vs* Roughness wavelength





- The reduced model accounts only for the fingerprints and surfaces topography, by decoupling the topography from other parameters such as skin and surface materials, frictional forces, etc…
- The compliance of the skin (respect to the steel) and its deformation (local vibration) is approximated by the intersection of the two sinusoids.

- The global vibration signal is calculated as the integration of the interpenetration areas between the two surfaces and the vibrationspectra are is entirely ascribed to the "adaptation" of the skin to the sample surface.

Tactile perception and Friction-Induced Vibrations

Challenges in tactile perception

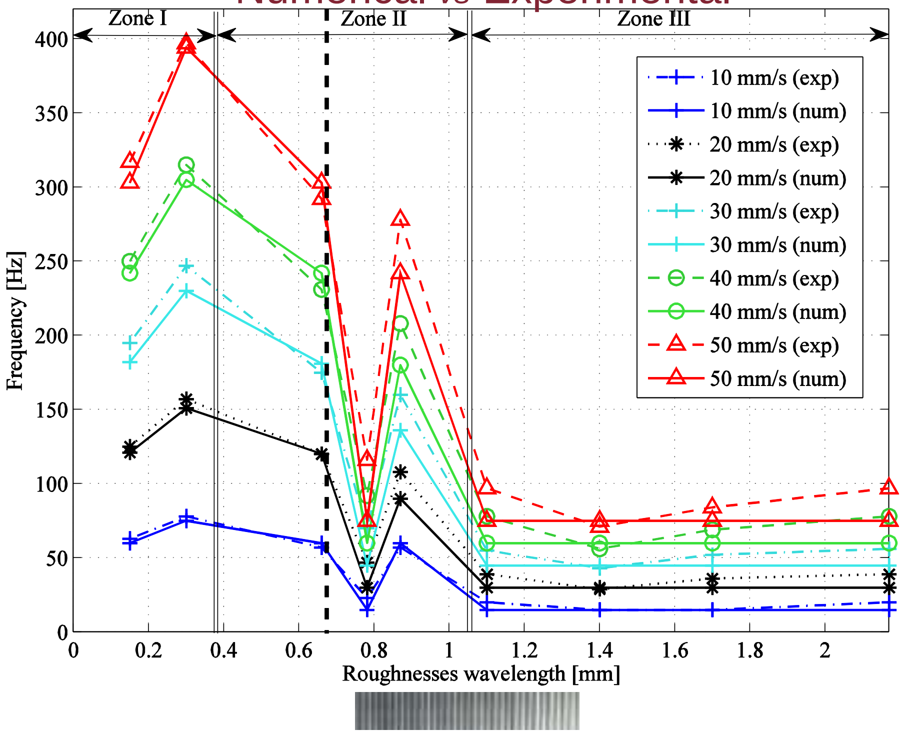
Mechanical and biomechanical challenges

Tribological results on tactile perception: FRICTION-INDUCED VIBRATIONS

Then, friction-induced vibrations when scanning the surface with a finger are detected, analyzed and correlated with physiological and psychological literature.

Frictio-induced vibrations frequency *vs* Roughness wavelength

Numerical *vs* Experimental



- The same frequencies of the induced vibrations are recovered by the numerical model;
- The trend of the frequency peaks as a function of roughness wavelength is the same for the numerical and experimental results;
- The amplitude of the spectra is not comparable because it is function of parameters not included into the model (materials, load, contact low, etc)

✓ These results allow for ascribing the ***"duplex perception model"*** to the filtering role of the fingerprints

Tactile perception and Friction-Induced Vibrations

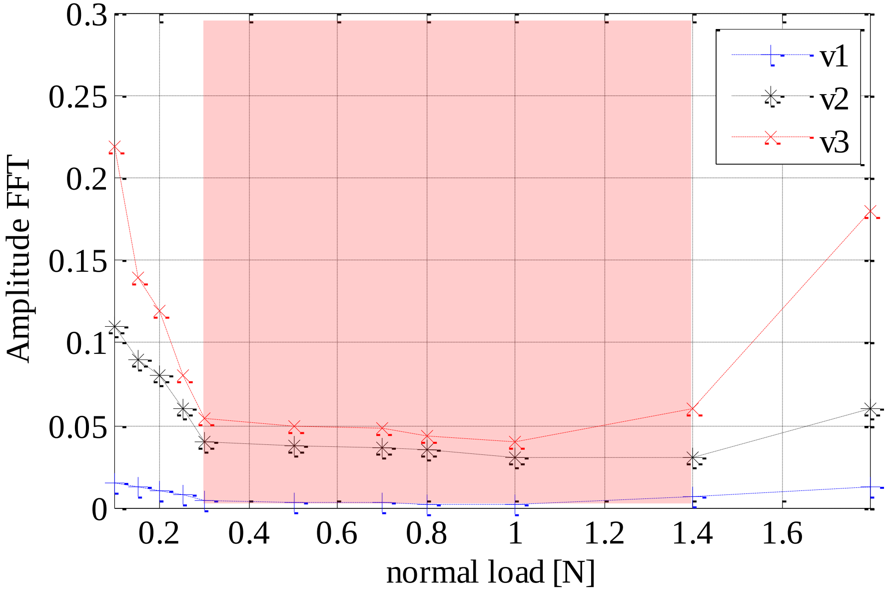
Challenges in tactile perception

Mechanical and biomechanical challenges

Tribological results on tactile perception: FRICTION-INDUCED VIBRATIONS

Then, friction-induced vibrations when scanning the surface with a finger are detected, analyzed and correlated with physiological and psychological literature.

Frictio-induced vibrations frequency *vs* Contact force



- For forces ranging among 0.3 and 1 N, the vibration amplitude is almost constant;
- The vibration amplitude rises for higher force values, affecting the roughness perception.

✓ These results agree with neurophysiologic and psychophysical studies asserting that human tactile pattern recognition is independent of contact forces ranging from 0.2 to 1 N, while for higher forces, the perceived roughness increases with the load.

[Johnson K. O., Yoshioka T., Vega-Bermudez F.: Tactile functions of mechanoreceptive afferents innervating the hand, Journal of Clinical Neurophysiology, 17, 539-558, 2000.
Lederman S.J., Taylor M.M., 1972, Fingertip force, surface geometry, and Perception of roughness by active touch, Perception & Psychophysics, 12 (5), 401-408.]

Tactile perception and Friction-Induced Vibrations

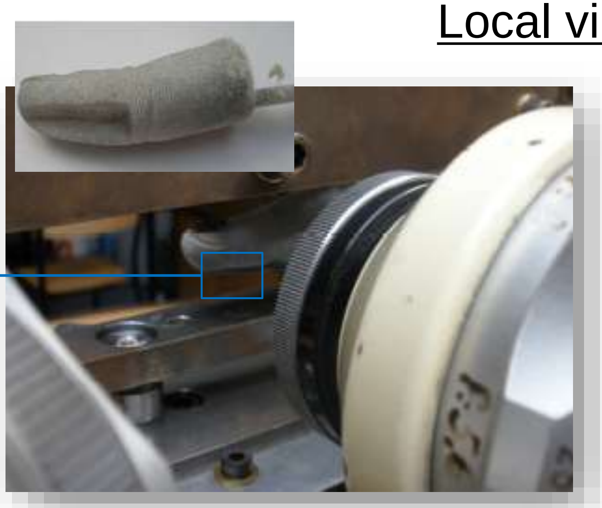
Challenges in tactile perception

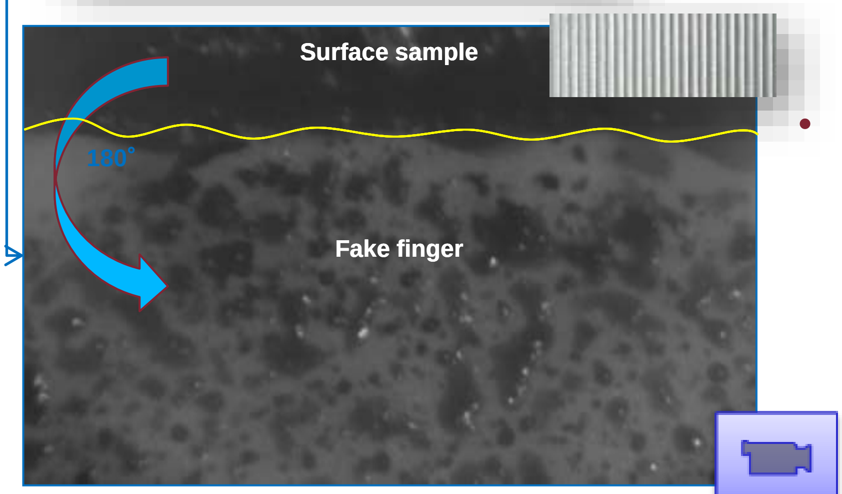
Mechanical and biomechanical challenges

Tribological results on tactile perception: FRICTION-INDUCED VIBRATIONS

Correlation between measured spectra and local vibrations at the mechanoreceptor locations.

<u>Local vibration recording on the fake finger</u>





- The analysis of the local vibrations provides important data to:
  - analyze the link between the local and measured vibrations;
  - develop and validate numerical models.
- A fast camera records the contact between the finger and the surface sample.
- Throughout image cross correlation technique, the displacement of the reference points chosen on the speckle image is recovered.

Tactile perception and Friction-Induced Vibrations

Challenges in tactile perception

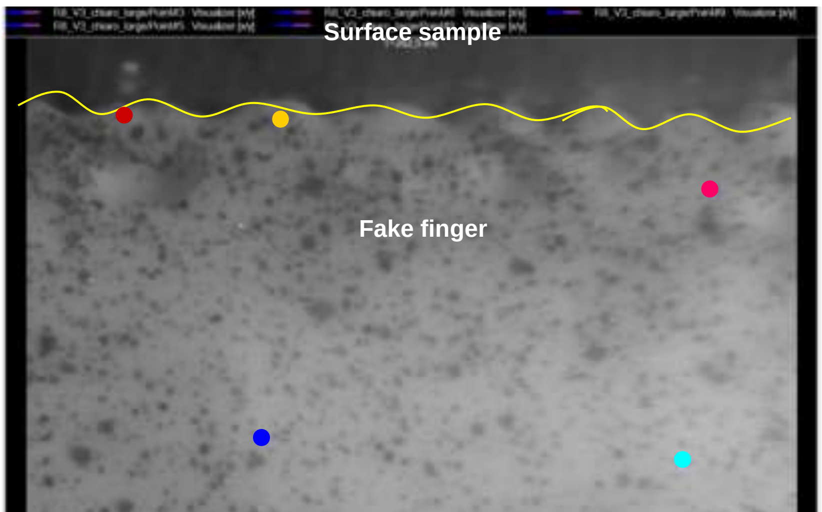
Mechanical and biomechanical challenges

Tribological results on tactile perception: FRICTION-INDUCED VIBRATIONS

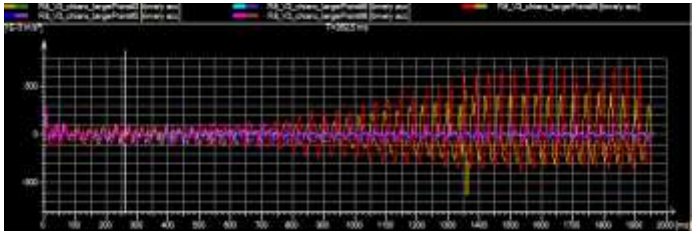
Correlation between measured spectra and local vibrations at the mechanoreceptor locations.

Local vibration recording on the fake finger

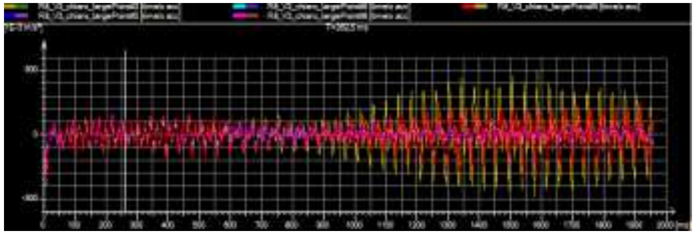
Point tracking



X- acceleration



Y- acceleration



- A comparison between local dynamics at the contact (fingerprints, mechanoreceptor position) and the global vibrations measured by the accelerometer (fingernail) can be performed.

- Tangential and normal components of the skin deformation (acceleration) at the mechanoreceptor location can be distinguished.

Challenges in tactile perception

Linking tribological signals with cognitive response

At the bridge between tribology and cognitive psychology

Do the topographic and tribological parameters allow to discriminate textures in a way similar to subjective tactile perception?

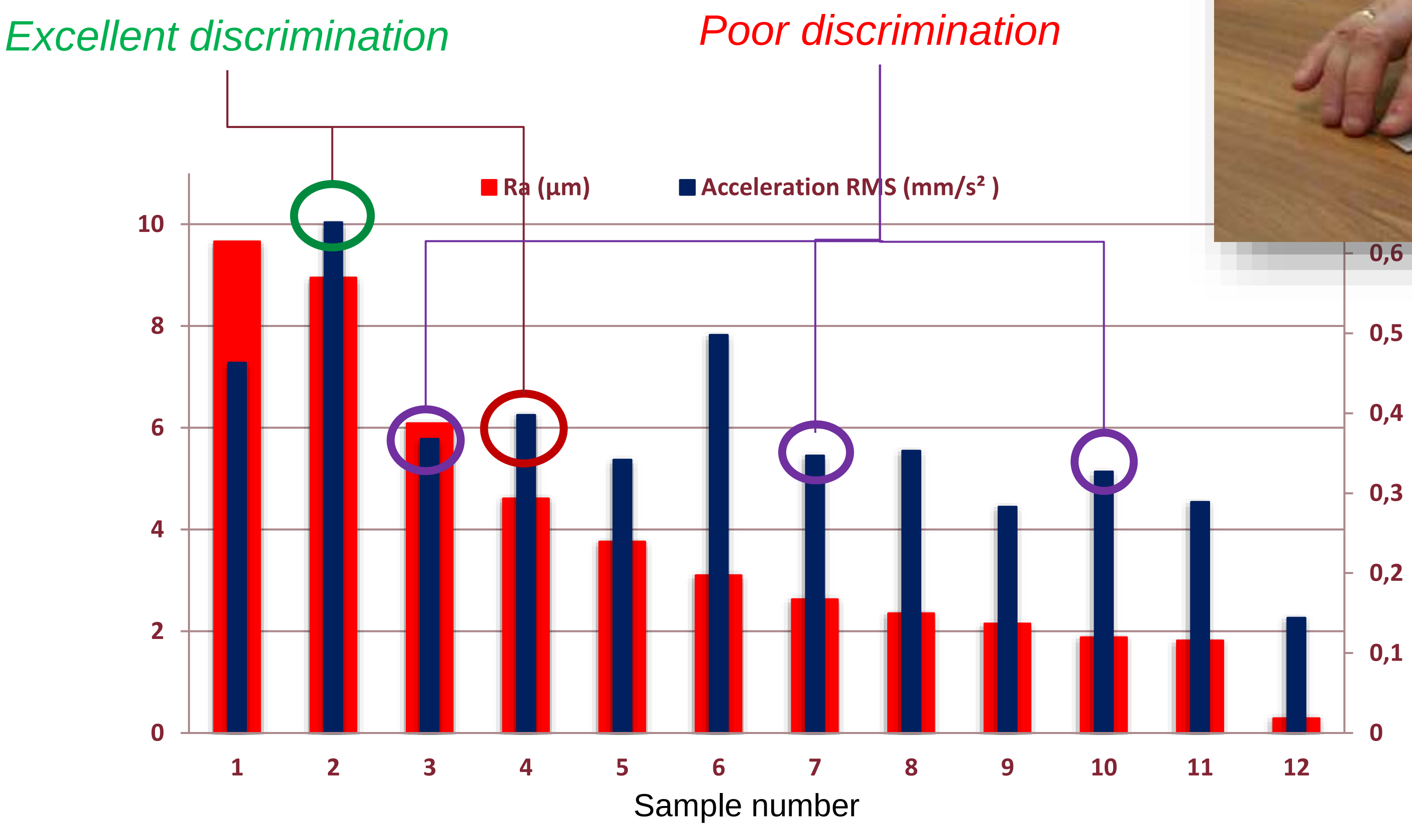
How to establish links between these different measured parameters (objective indexes) and subjective sense?

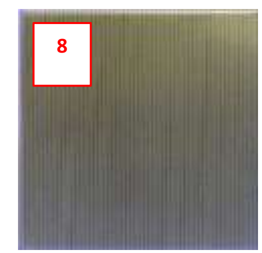
Tactile perception and Friction-Induced Vibrations

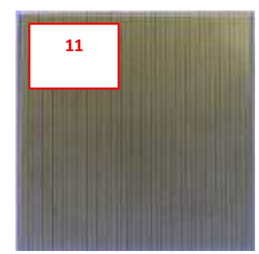
Challenges in tactile perception

Linking tribological signals with cognitive response

FIV vs surface discrimination: some examples







The tactile discrimination of textures is related to the acceleration RMS (Root Mean Square), more than to the effective surface topography.

Correlation between friction-induced vibrations and tactile perception during exploration tasks of isotropic and periodic textures, **Trib. Int.**, 2018

Tactile perception and Friction-Induced Vibrations

Challenges in tactile perception

Linking tribological signals with cognitive response

FIV vs surface discrimination: some examples

Two examples of campaigns to link tribological objective data to subjective perception of surfaces: Campaign on similarly patterned surface

Wooden controtype samples (WC)

- Samples «**Wood Countertype**» constituted by blades of floor covering imitation wood
- Samples with similar pattern and tactile pattern coherent with visual pattern

Wooden controtype samples

Replica samples (R)

- Samples « **Replica** » obtained as a countertype of the samples of the first set using PU resin
- Samples characterized by the same patterns of WC samples, but with different material

Stamp

Replica PU

Tactile perception and Friction-induced Vibrations: Discrimination of similarly patterned wood-like surfaces, **IEEE TRANSACTIONS ON HAPTICS**, 2016

Tactile perception and Friction-Induced Vibrations

Challenges in tactile perception

Linking tribological signals with cognitive response

FIV vs surface discrimination: some examples

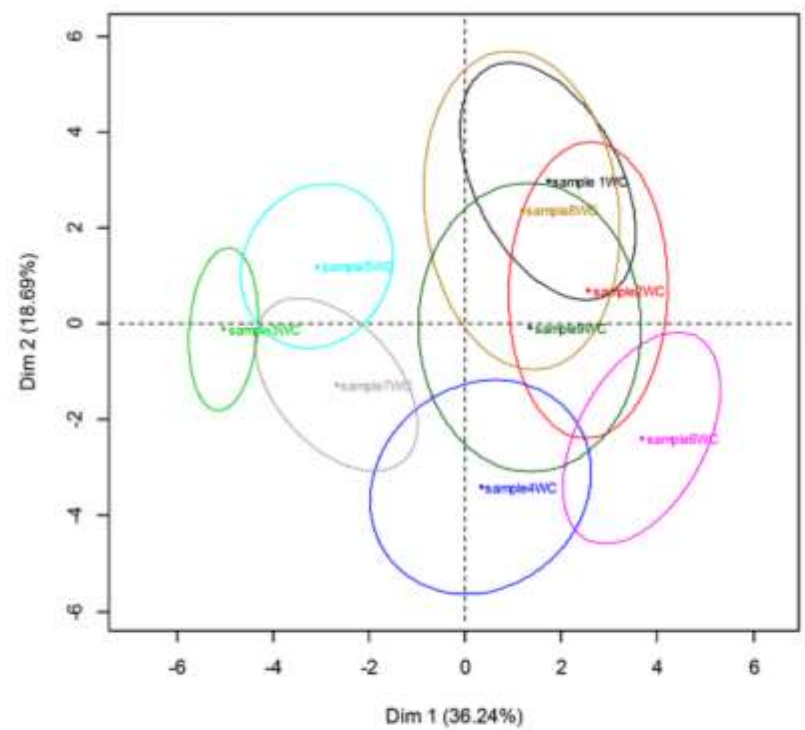
Two examples of campaigns to link tribological objective data to subjective perception of surfaces: Campaign on similarly patterned surface

Perception results

Wood Countertype

The **magnitude** of a single ellipse is an indication of the dispersion of the position attributed at the same sample, the **level of overlap** among the ellipses shows the similitude among the different samples

- The samples are divided in **two main groups** along the horizontal axe
- Samples are distributed along the vertical axe with different levels of overlapping



24

Tactile perception and Friction-induced Vibrations: Discrimination of similarly patterned wood-like surfaces, **IEEE TRANSACTIONS ON HAPTICS**, 2016

Challenges in tactile perception

Linking tribological signals with cognitive response

FIV vs surface discrimination: some examples

Two examples of campaigns to link tribological objective data to subjective perception of surfaces: <u>Campaign on similarly patterned surface</u>

<u>Tactile evaluation by Friction-Induced Vibrations</u>

- Speed: 20 mm/s
- Normal force: about 0,5 N
- Stroke: 60 mm
- Finger inclination angle: 20°

Sample 1WC | Sample 2WC | Sample 3WC | Sample 4WC | Sample 5WC | Sample 6WC | Sample 7WC | Sample 8WC | Sample 9WC

Tactile perception and Friction-induced Vibrations: Discrimination of similarly patterned wood-like surfaces, **IEEE TRANSACTIONS ON HAPTICS**, 2016

Tactile perception and Friction-Induced Vibrations

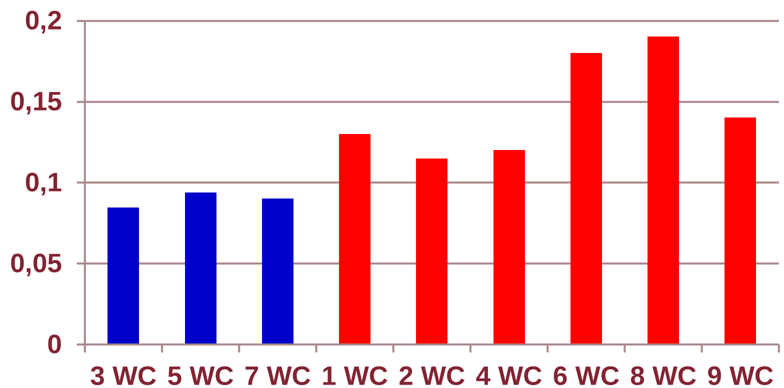
Challenges in tactile perception

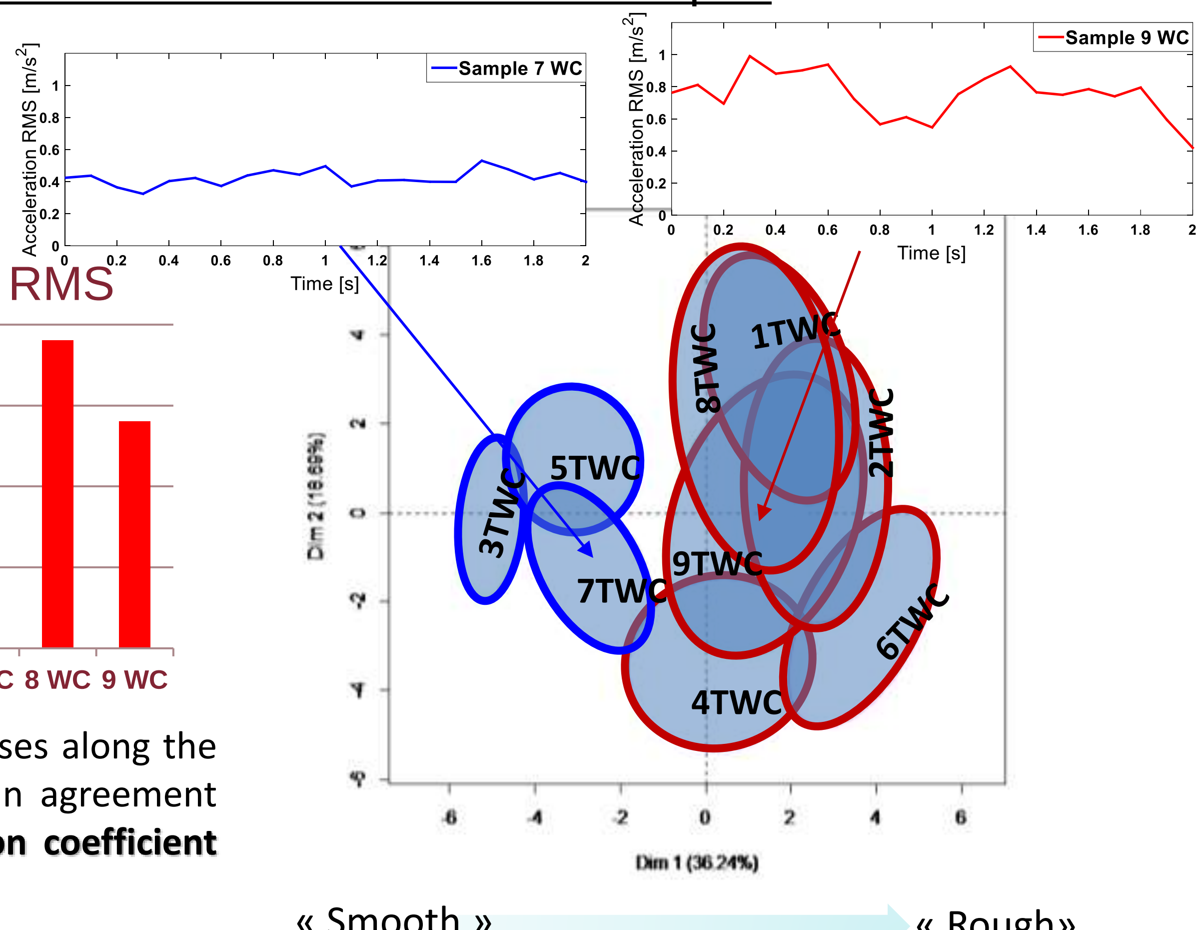
Linking tribological signals with cognitive response

FIV vs surface discrimination: some examples

Two examples of campaigns to link tribological objective data to subjective perception of surfaces: <u>Campaign on similarly patterned surface</u>

<u>Acceleration RMS STD vs "Smoother" descriptor</u>





The distribution of the sample ellipses along the **Y axis** of the perception panel is in agreement with the trend of the **mean friction coefficient** measured with the TriboTouch

Tactile perception and Friction-induced Vibrations: Discrimination of similarly patterned wood-like surfaces, **IEEE TRANSACTIONS ON HAPTICS**, 2016

Tactile perception and Friction-Induced Vibrations

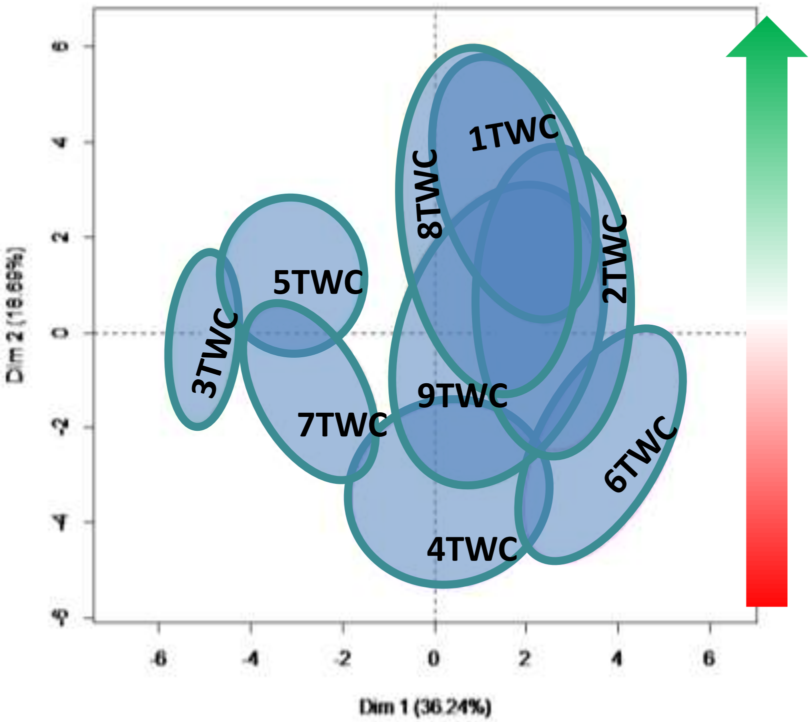
Challenges in tactile perception

Linking tribological signals with cognitive response

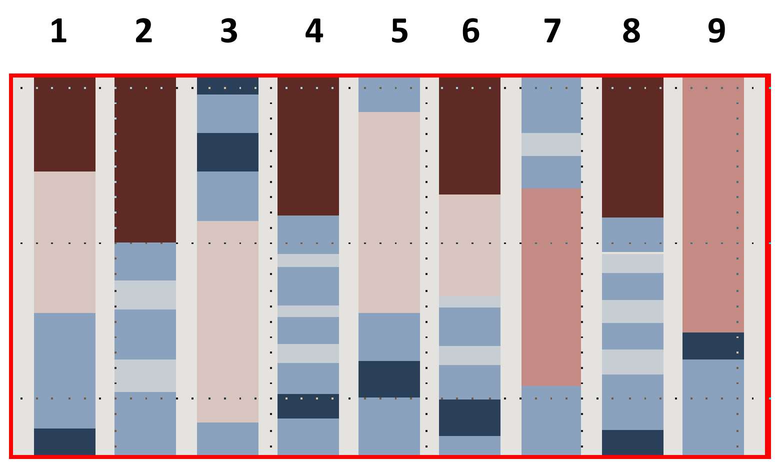
FIV vs surface discrimination: some examples

Two examples of campaigns to link tribological objective data to subjective perception of surfaces: Campaign on similarly patterned surface

Friction coefficient vs “Blocking” descriptor



Echantillons	Coefficient de friction
Sample 1WC	0.954
Sample 8WC	0.829
Sample 2 WC	0.943
Sample 9 WC	0.939
Sample 6WC	0.934
Sample 4WC	0.745



The distribution of the sample ellipses along the **Y axis** of the perception panel is in agreement with the trend of the **mean friction coefficient** measured with the TriboTouch

Tactile perception and Friction-induced Vibrations: Discrimination of similarly patterned wood-like surfaces, **IEEE TRANSACTIONS ON HAPTICS**, 2016

Tactile perception and Friction-Induced Vibrations

Challenges in tactile perception

Linking tribological signals with cognitive response

FIV vs surface discrimination: some examples

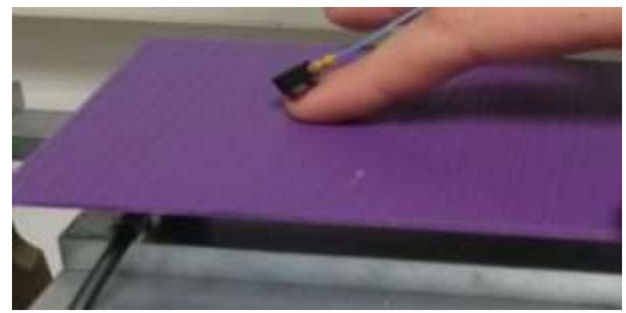
Two examples of campaigns to link tribological objective data to subjective perception of surfaces: Campaign on similarly patterned surface

Tactile perception of Replica samples

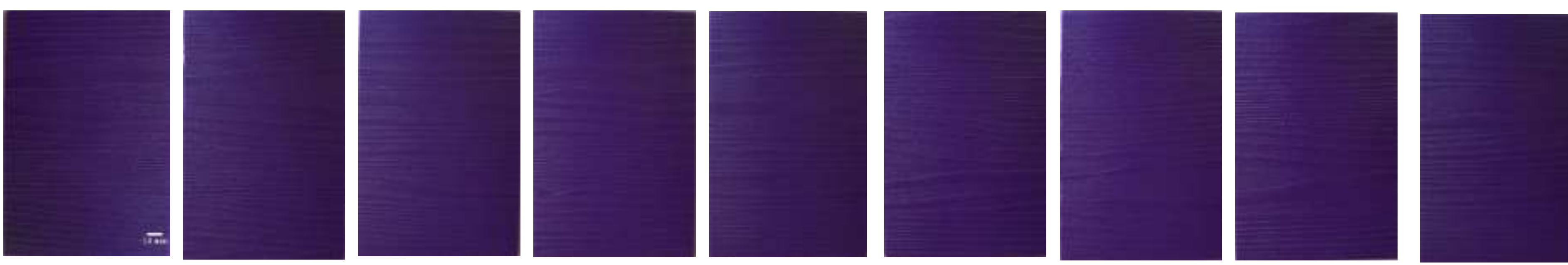
Campaign Replica

The test protocol and the Input data are the same:

- Speed: 20 mm/s
- Normal force: about 0,5 N
- Stroke: 60 mm
- Finger inclination angle: 20°



Sample1R **Sample2R** **Sample3R** **Sample4R** **Sample5R** **Sample6R** **Sample7R** **Sample8R** **Sample9R**



Tactile perception and Friction-induced Vibrations: Discrimination of similarly patterned wood-like surfaces, **IEEE TRANSACTIONS ON HAPTICS**, 2016

Tactile perception and Friction-Induced Vibrations

Challenges in tactile perception

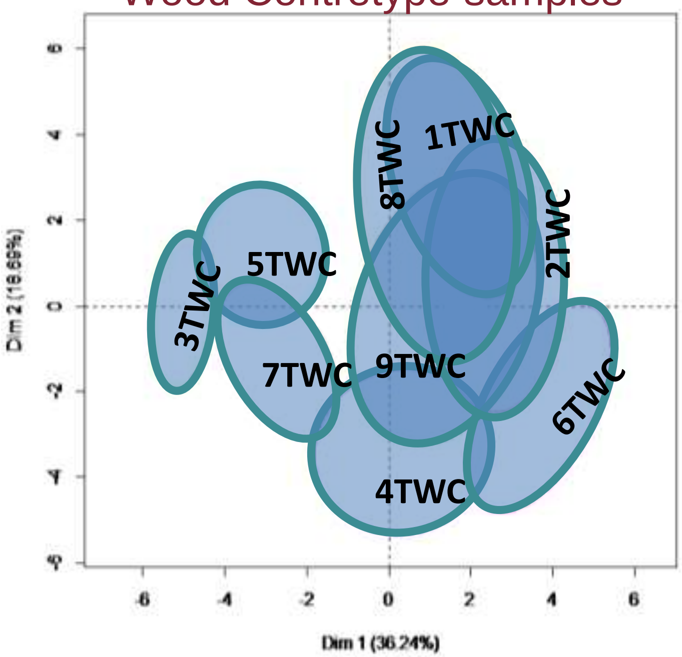
Linking tribological signals with cognitive response

FIV vs surface discrimination: some examples

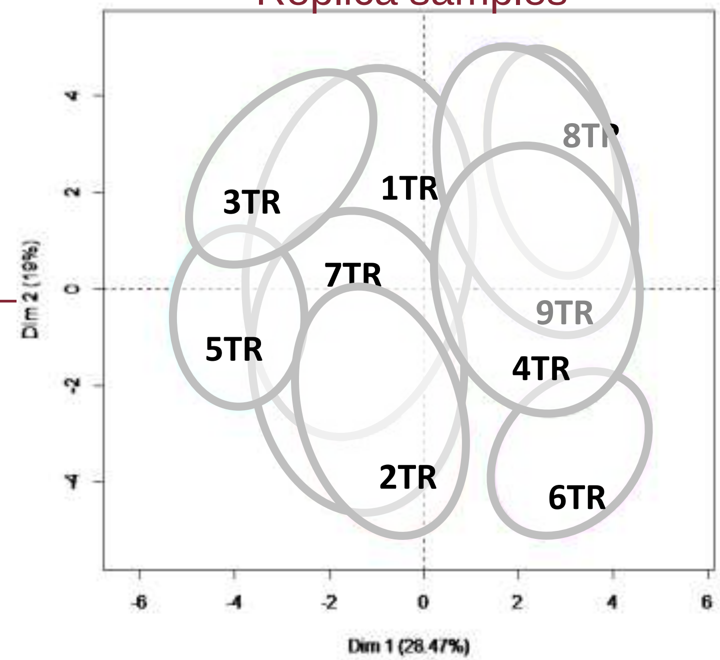
Two examples of campaigns to link tribological objective data to subjective perception of surfaces: Campaign on similarly patterned surface

Tactile perception of Replica samples

Wood Contretype samples



Replica samples



The level of overlapping and the size of ellipses suggest a lack of performance in the differentiation of samples compared to the Wood Countertype

Lower ability to discriminate Raplica samples

Tactile perception and Friction-induced Vibrations: Discrimination of similarly patterned wood-like surfaces, **IEEE TRANSACTIONS ON HAPTICS**, 2016

Tactile perception and Friction-Induced Vibrations

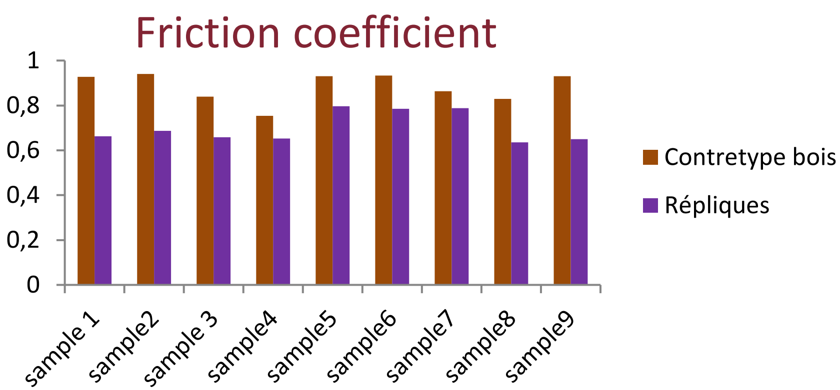
Challenges in tactile perception

Linking tribological signals with cognitive response

FIV vs surface discrimination: some examples

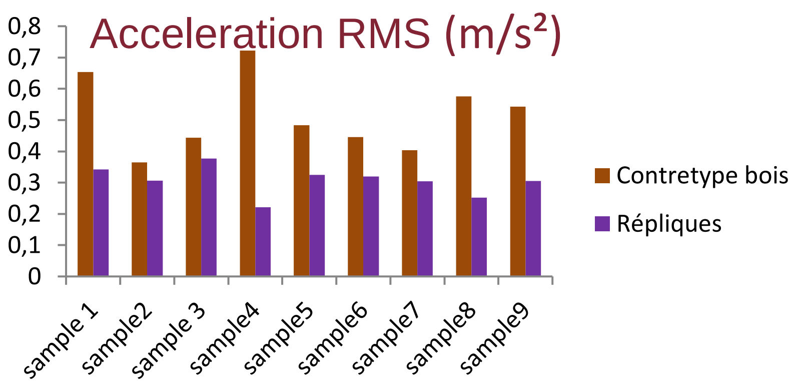
Two examples of campaigns to link tribological objective data to subjective perception of surfaces: <u>Campaign on similarly patterned surface</u>

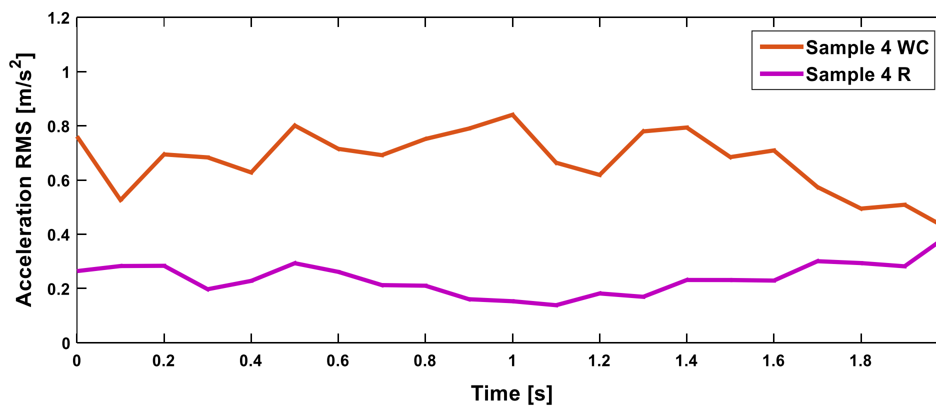
<u>Tactile perception of Replica samples</u>



WC samples

R samples





- The difference in material means difference in friction coefficient (adhesion component);
- Lower tangential forces means lower amplitude of induced vibrations (lower power).

Tactile perception and Friction-induced Vibrations: Discrimination of similarly patterned wood-like surfaces, **IEEE TRANSACTIONS ON HAPTICS**, 2016

Tactile perception and Friction-Induced Vibrations

Challenges in tactile perception

Mechanical and biomechanical challenges

FIV vs surface discrimination: some examples

…what's needed more? NOT AT ALL, like almost always in TRIBOLOGY!

Figura 1: fibreux1

Figura 2: fibreux2

Figura 3: fibreux3

Figura 4: fibreux5

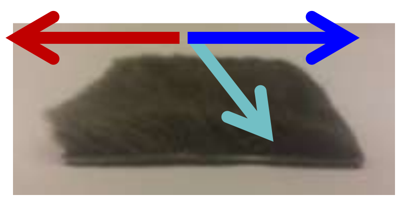


Figura 5: fibreux10

- Fibreux1: fiber length = 1 mm;
- Fibreux2: fiber length = 2 mm;
- Fibreux3: fiber length = 3 mm;
- Fibreux5: fiber length = 5 mm;
- Fibreux10:fiber length = 10 mm.

Test parameters:

- Scanning speed = 20 mm/s (imposed);
- Contact force = 0,5N (monitored).

Scanning direction:

- **Concorde** = fiber direction (α = 0°);
- **Transverse** = perpendicular to fiber direction (α = 90°).
- **Discorde** = opposite to fiber direction (α = 180°);

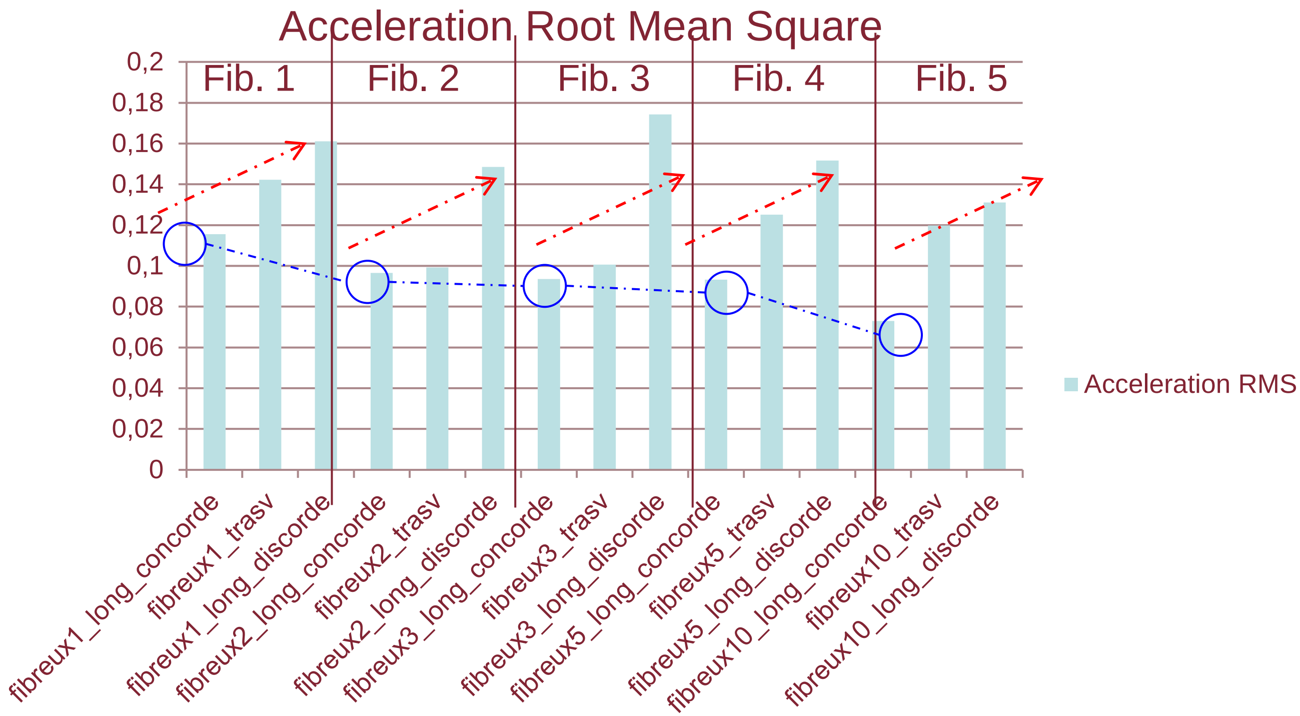
Tactile perception and Friction-Induced Vibrations

Challenges in tactile perception

Mechanical and biomechanical challenges

FIV vs surface discrimination: some examples

…what's needed more?   NOT AT ALL, like almost always in TRIBOLOGY!



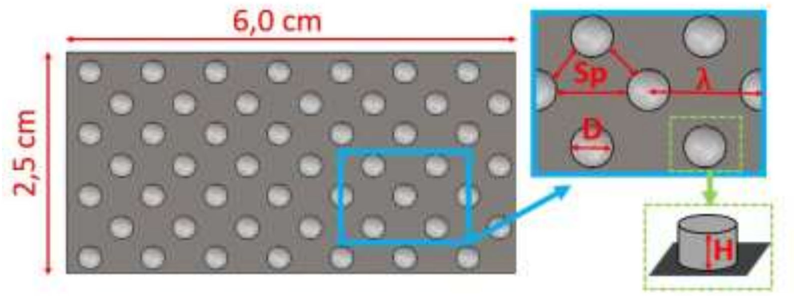
- Acceleration RMS increases passing by concorde (0°), transverse (90°) and discorde (180°) direction of the scanning. *The increase of the acceleration RMS can allow for perceiving the scanning direction…*
- Along the concorde direction (0°), the acceleration RMS is higher for short fibers. *The acceleration RMS can allow for perceiving the different between short and long fibers…*

Tactile perception and Friction-Induced Vibrations

FIV vs texture perception

Role of mechanical stimuli on perception of surface textures

From the surface to the perception of the surface



Dot diameter D 12 → 796 µm
Inter-dots distance Sp: 13 → 610 µm
Dot height H: 14 → 38 µm

Sensory Analyses

- Topographic perception:

*Test performed by a panel of **20 person** (13 male e 7 female ranging from 24 to 28 years old).*

- Hedonistic perception:

*Test performed by a panel of **43 person** (30 male e 13 female ranging from 10 to 29 years old).*

Samples	Topography perception	Hedonistic perception	
S01	Smooth	I like a lot	Uniform assessment (votes > 50% for one hedonistic categorization)
S39	Smooth	I like a lot	
S42	Smooth	I like a lot	
S33	Textured	I like	
S61	Textured	I like	
S45	Textured	I do not like	
S56	Textured	I do not like	
S07	Rough	I do not like at all	
S23	Rough		Non-Uniform assessment
S15	Adhesive		
S18	Adhesive		
S32	Textured		

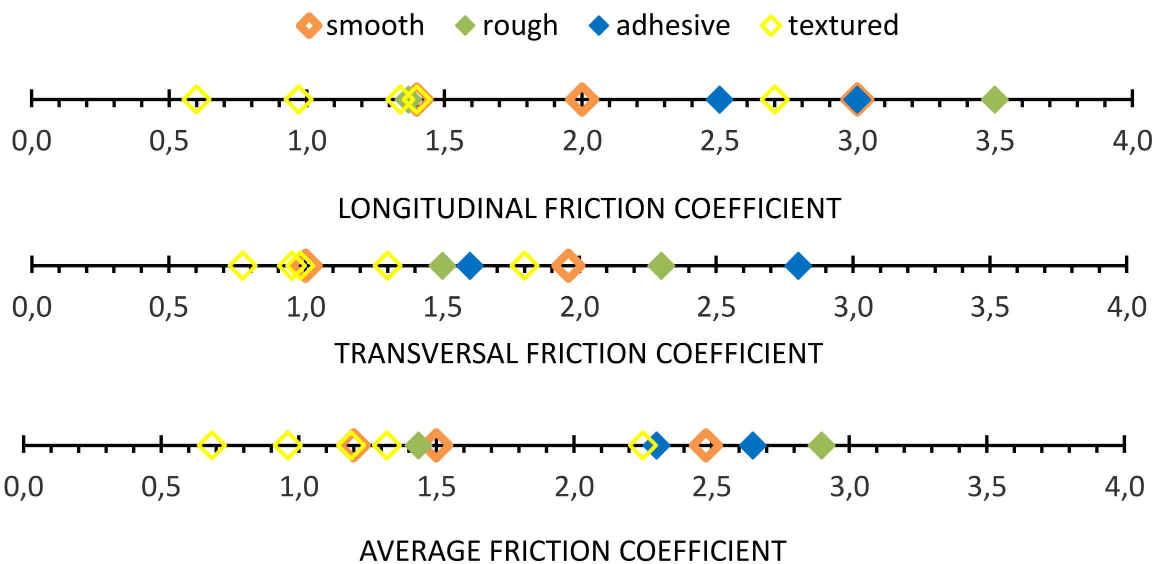
Tactile perception and Friction-Induced Vibrations

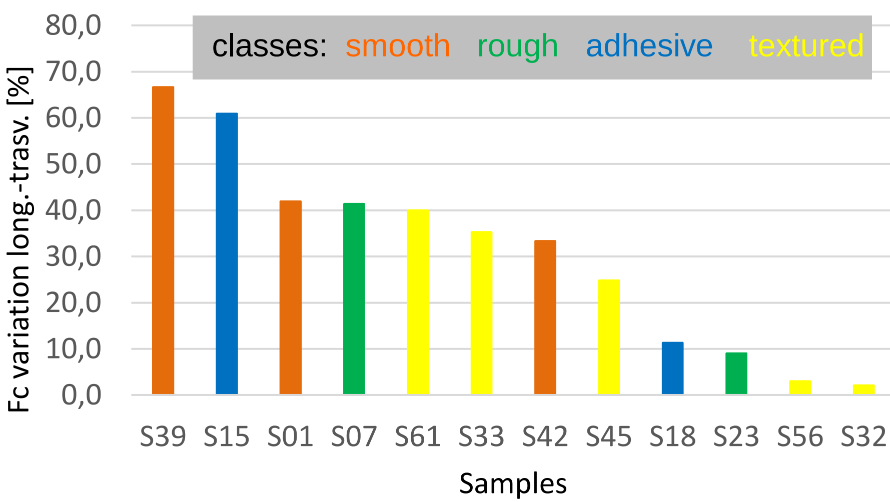
FIV vs texture perception

Role of mechanical stimuli on perception of surface textures

From the surface to the perception of the surface

- No correlations are found considering, separately, both the scanning directions.
- No correlation are found considering the Fc average values between the 2 scanning directions





- No-correlations are found considering the Fc variation between the 2 scanning directions.

The friction coefficient seems to not affect the topographic perception.

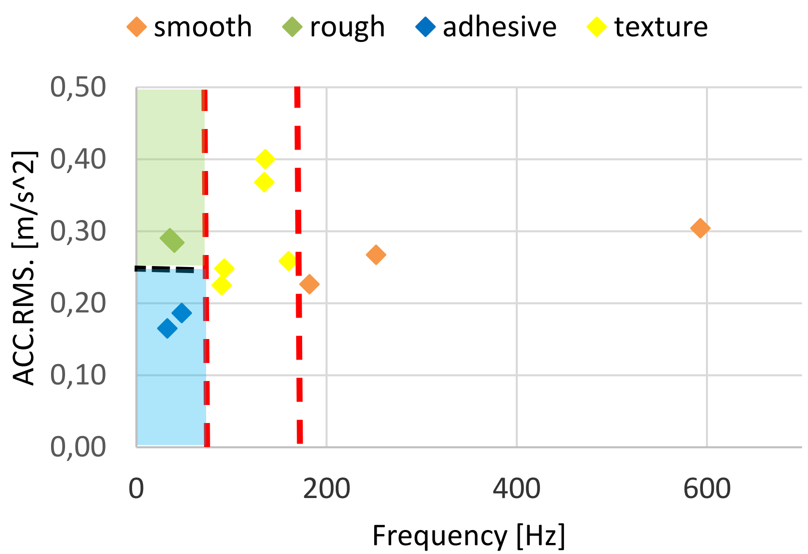
The role of mechanical stimuli on hedonistic and topographical discrimination of textures, **Tribology International** 143 (2020) 106082

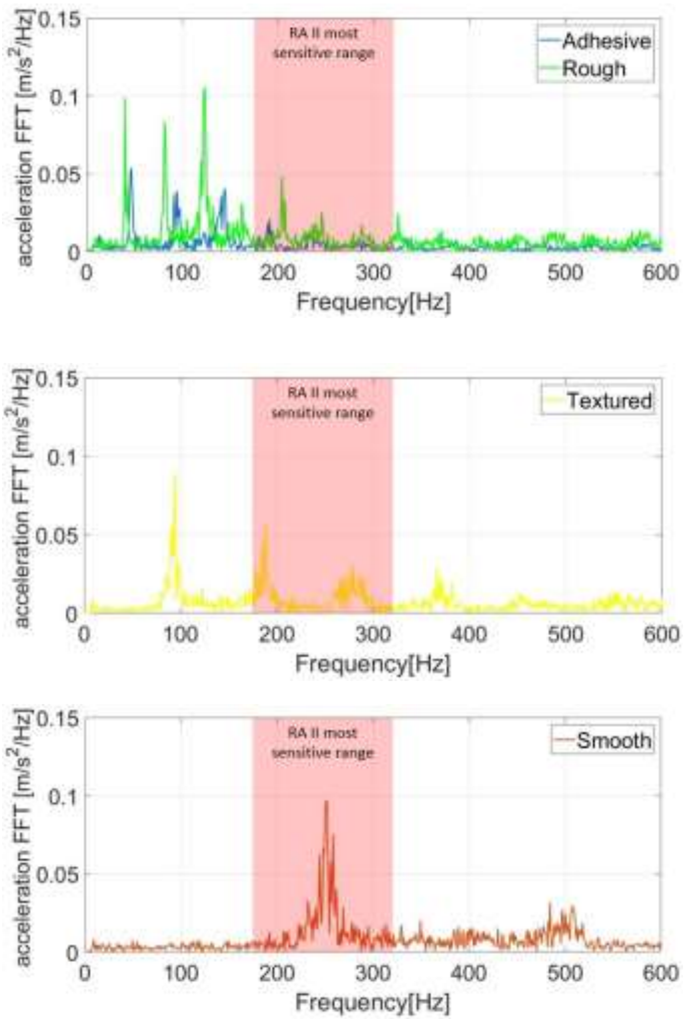
Tactile perception and Friction-Induced Vibrations

FIV vs texture perception

Role of mechanical stimuli on perception of surface textures

From the surface to the perception of the surface





- Smooth and textured perception completely clustered by the FIVs frequency content.
- Adhesive and rough perception are:
  - discriminated from the others by the FIVs frequency content
  - discriminated between them by the vibration amplitude

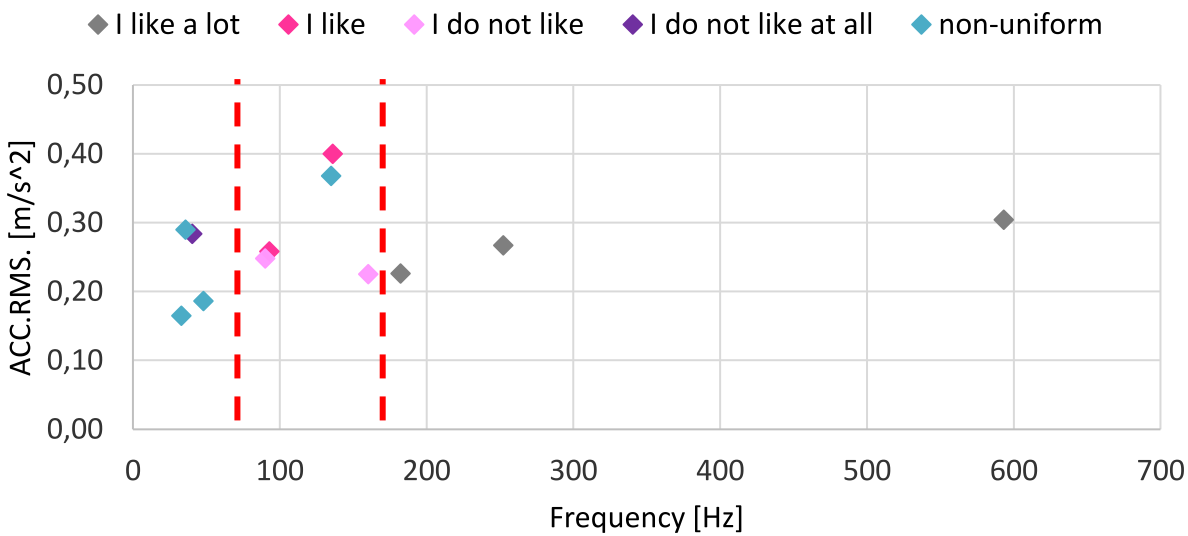
The role of mechanical stimuli on hedonistic and topographical discrimination of textures, **Tribology International** 143 (2020) 106082

Tactile perception and Friction-Induced Vibrations

FIV vs texture perception

Role of mechanical stimuli on perception of surface textures

From the surface to the perception of the surface



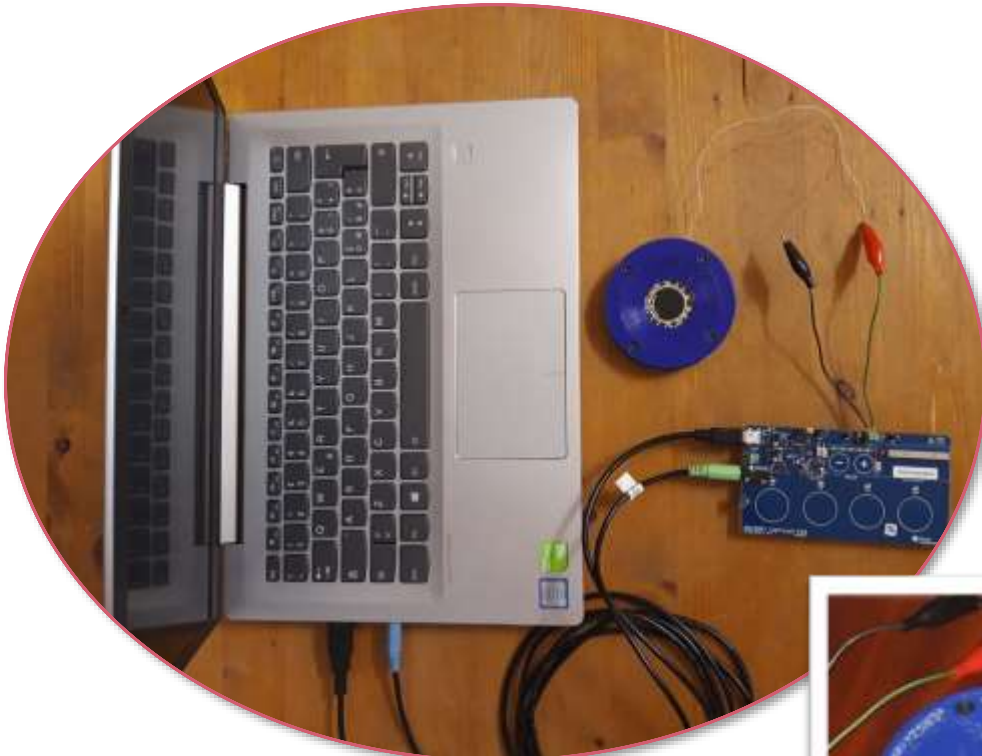
- The frequency content allows a clustering of the perception levels.
- Two main trends are recognize:
  - The perception transit from pleasant to unpleasant as long as the frequency content of the vibrations decreases.
  - The judgment becomes less uniform as long as the frequency content of the vibrations decreases.

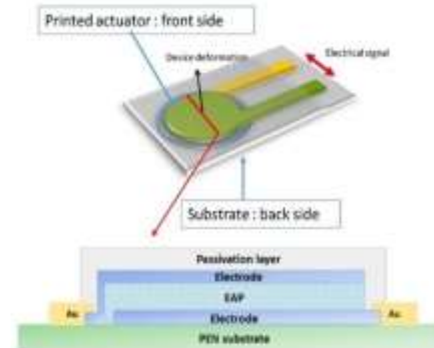
The role of mechanical stimuli on hedonistic and topographical discrimination of textures, **Tribology International** 143 (2020) 106082

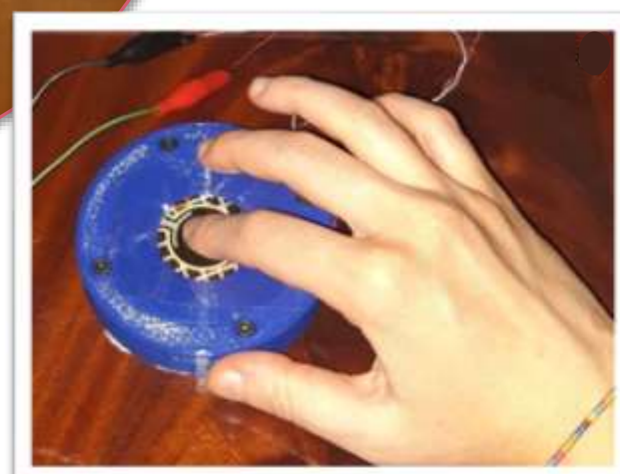
Tactile perception and Friction-Induced Vibrations

Rendering texture perception by FIV

Reproduction of mechanical stimuli for perception simulation (virtual surfaces)







Tactile rendering of textures by an Electro-Active Polymer piezoelectric device: mimicking Friction-Induced Vibrations, **Trib. Int.**, 2022

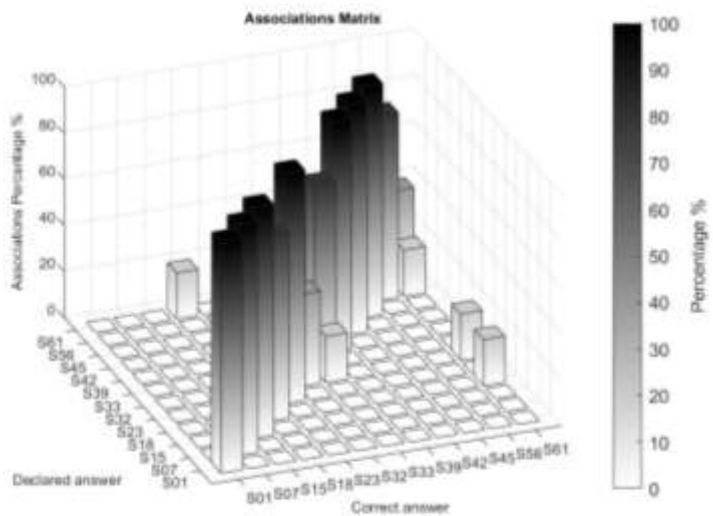
Tactile perception and Friction-Induced Vibrations

Rendering texture perception by FIV

Reproduction of mechanical stimuli for perception simulation (virtual surfaces)

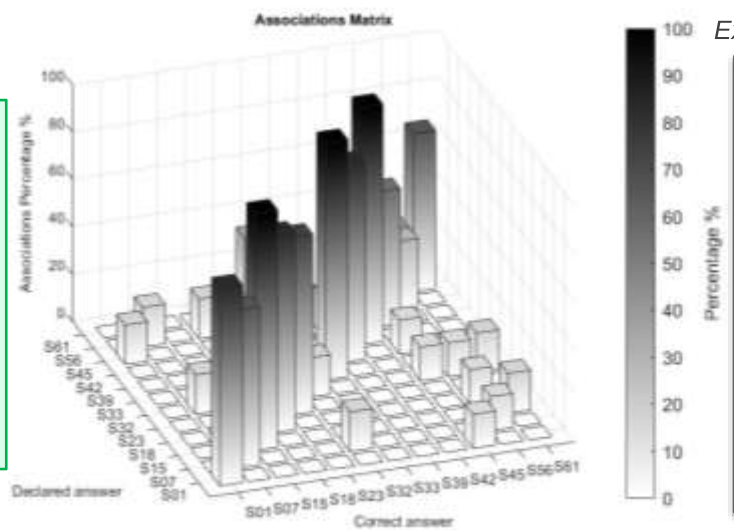
Discrimination task correlation matrices for real/simulated surfaces

Discrimination of real surface samples



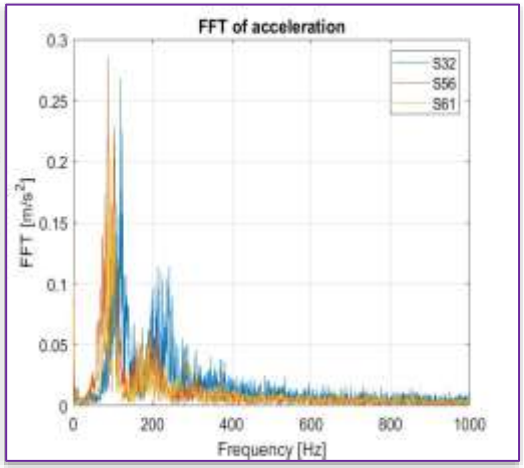
- Good performances in both the discrimination tasks, with high percentages of association on the principal diagonal of the matrices
- Agreement between the results of the discrimination of real samples and the discrimination of the simulated surfaces
- In both the discrimination tasks, errors or difficulties in the discrimination may be often explained through the FFT spectra of FIVs

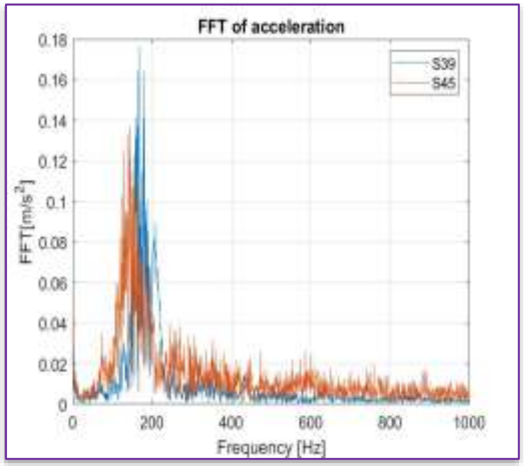
Discrimination of simulated surfaces



Examples

Interpretation of the results by means of the FIVs





Tactile rendering of textures by an Electro-Active Polymer piezoelectric device: mimicking Friction-Induced Vibrations, **Trib. Int.**, 2022

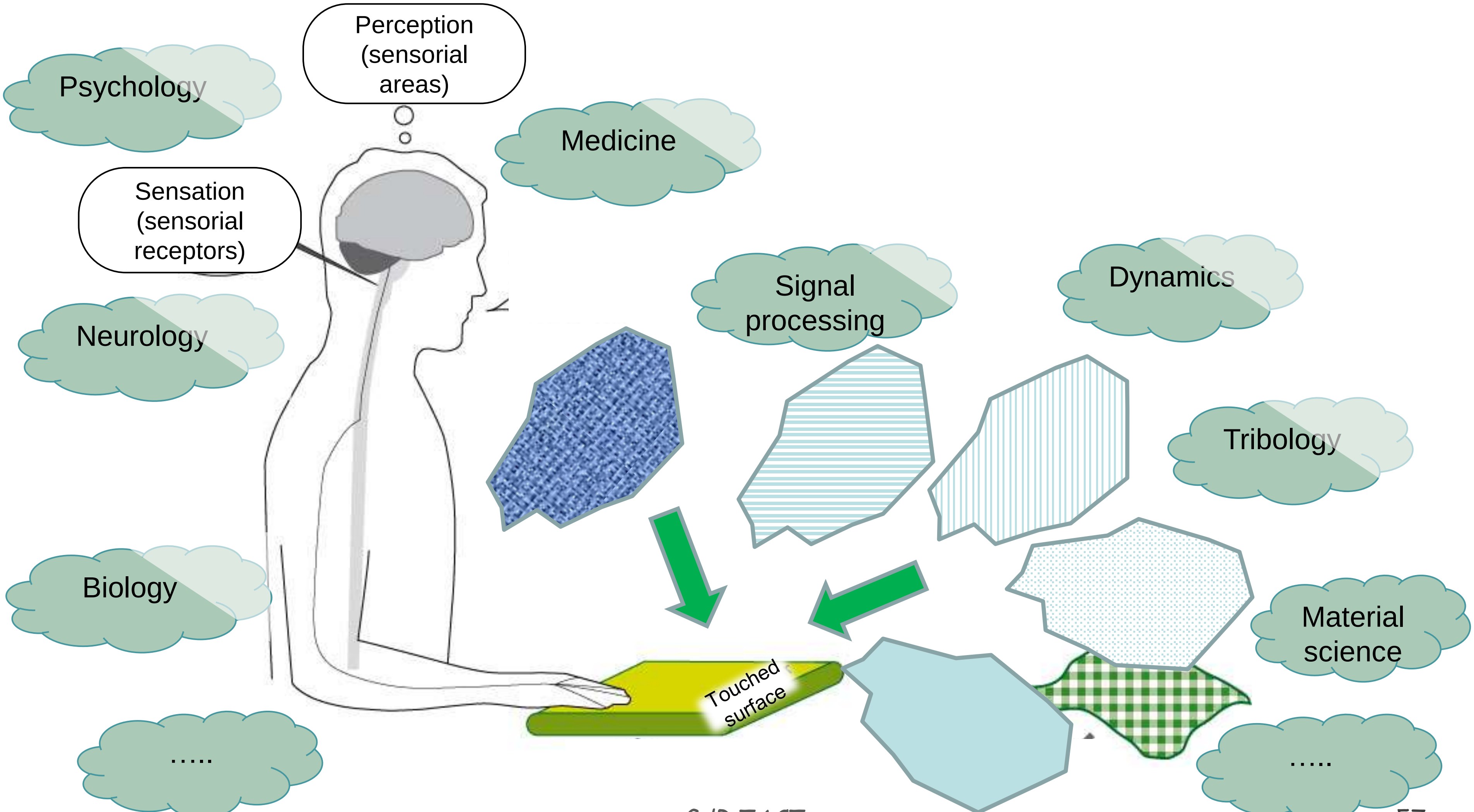
Tactile perception and Friction-Induced Vibrations

Challenges in tactile perception

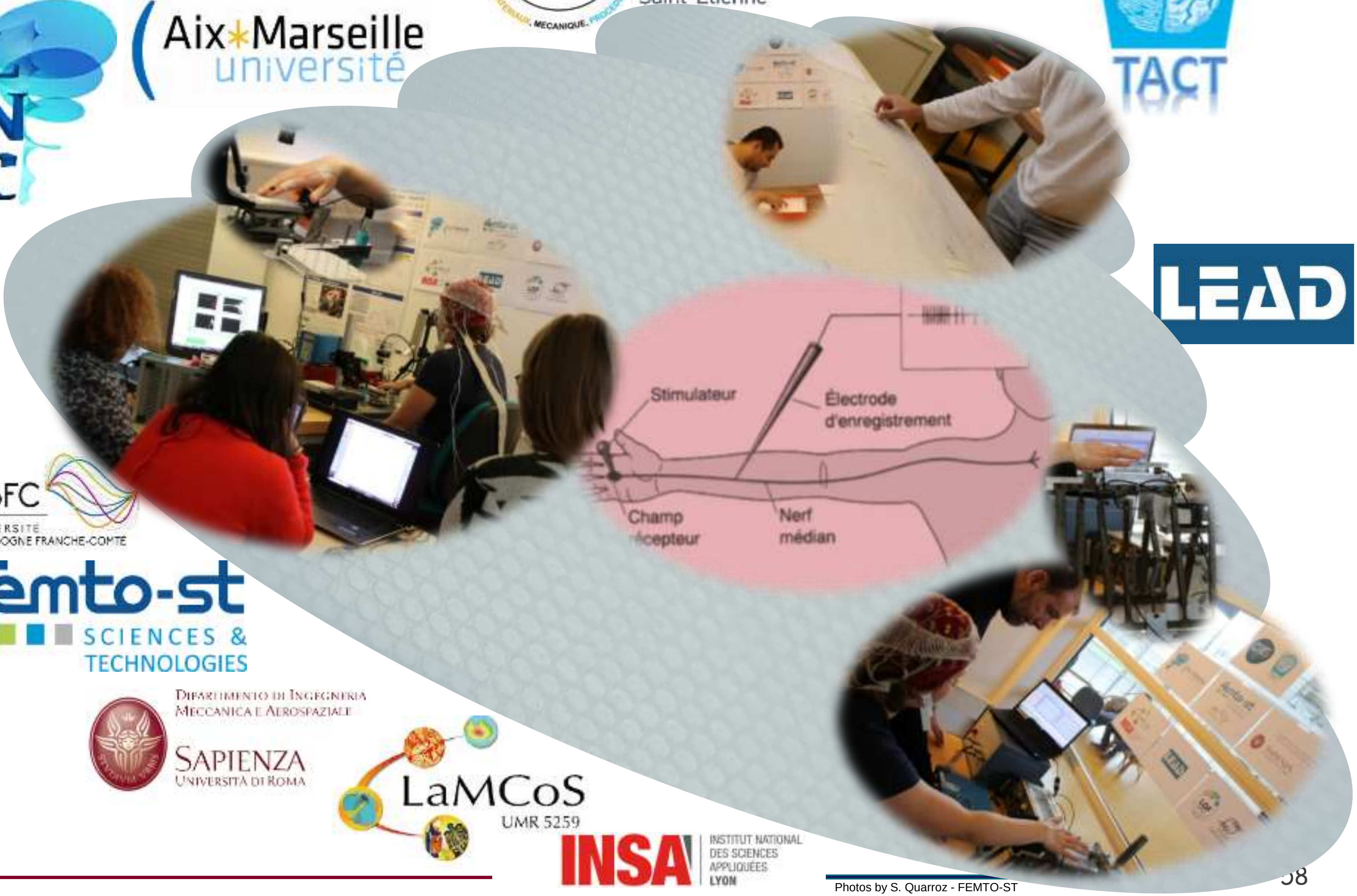
Mechanical and biomechanical challenges

From the contact to the brain… multidisciplinary and multiphysical issue

…what's needed more to understand tactile perception? A LOT MORE!!!



LGF UMR 5307
MINES Saint-Étienne
cnrs
GDR 2033 TACT
LNC
Aix*Marseille université



LEAD
UBFC UNIVERSITÉ BOURGOGNE FRANCHE-COMTÉ
femto-st SCIENCES & TECHNOLOGIES
DIPARTIMENTO DI INGEGNERIA MECCANICA E AEROSPAZIALE
SAPIENZA UNIVERSITÀ DI ROMA
LaMCoS UMR 5259
INSA INSTITUT NATIONAL DES SCIENCES APPLIQUÉES LYON

Photos by S. Quarroz - FEMTO-ST