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June 2022

EMR'22 Summer School
"Energetic Macroscopic Representation"

«Human-in-the-Loop for tactile feedback devices»

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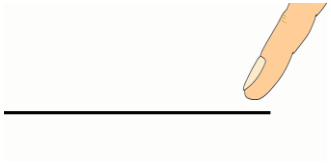
Surface « Haptic » Devices



Friction reduction: *'active lubrication'*

- Outline -

1. Design of a surface haptic interface and vibration control, using EMR: A brief summary
2. Human-machine interaction: biomechanics, perception and behaviour
3. Controller adaption to improve perception?
4. Human-in-the-loop for tactile interfaces: Next steps

Appendix: Graphical Rules of EMR

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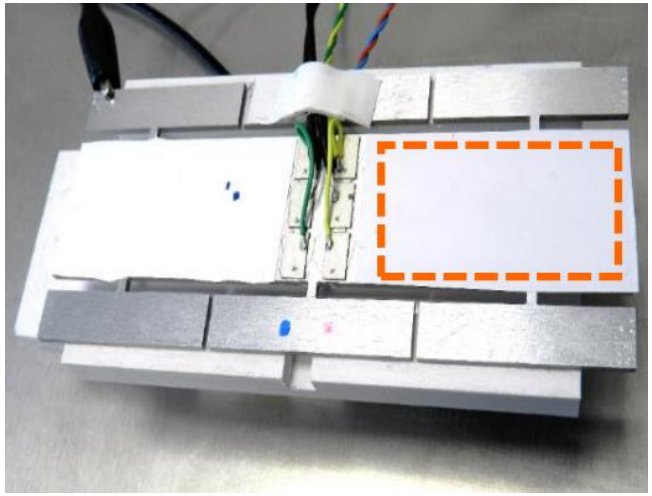
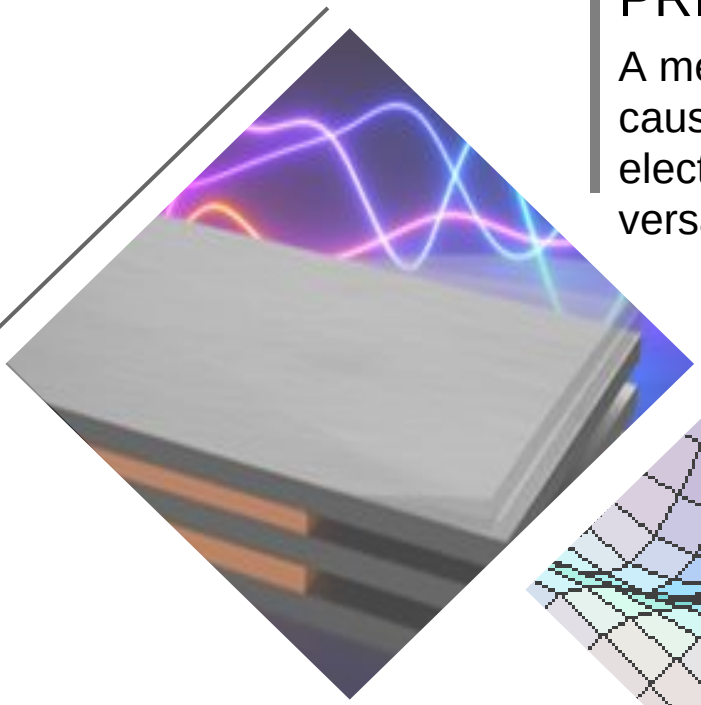
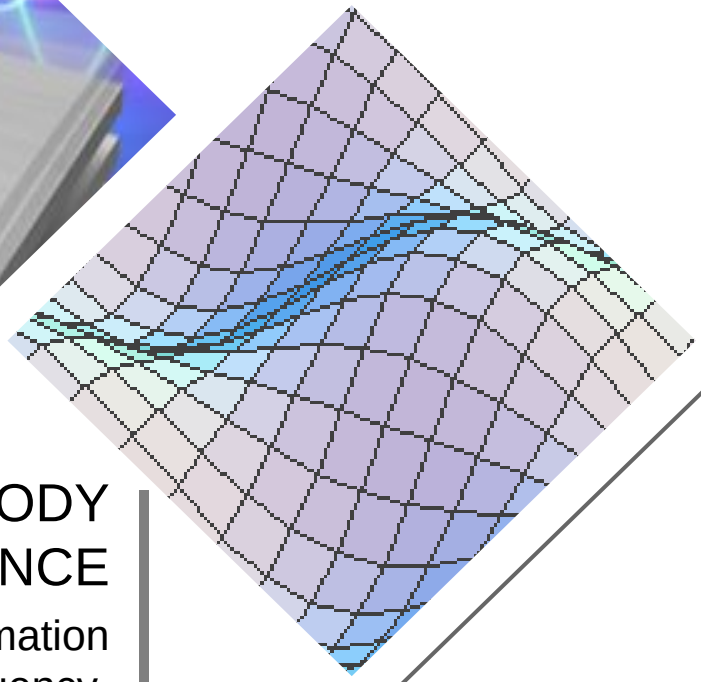


«Design and velocity control of a surface haptic device»

PIEZOELECTRIC PRINCIPLE

A mechanical strain is caused by an applied electrical potential (and vice versa)





ELASTIC BODY RESONANCE

Defined by a deformation shape and frequency.
It amplifies the vibration

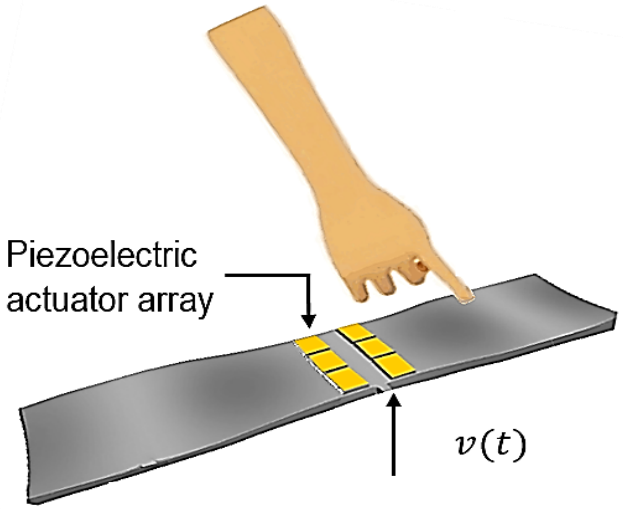
PARTS

- ✓ Actuators, piezoelectric
- ✓ Resonator (solid material)
- ✓ Sensor, piezoelectric
- ✓ Controller
- ✓ Support

METHODOLOGY

1. Define specifications
2. Pre-calculate dimensions (approximate model)
3. Refine dimensions FE simulation
4. Implementation
5. Control

Dynamic model and closed loop control implementation



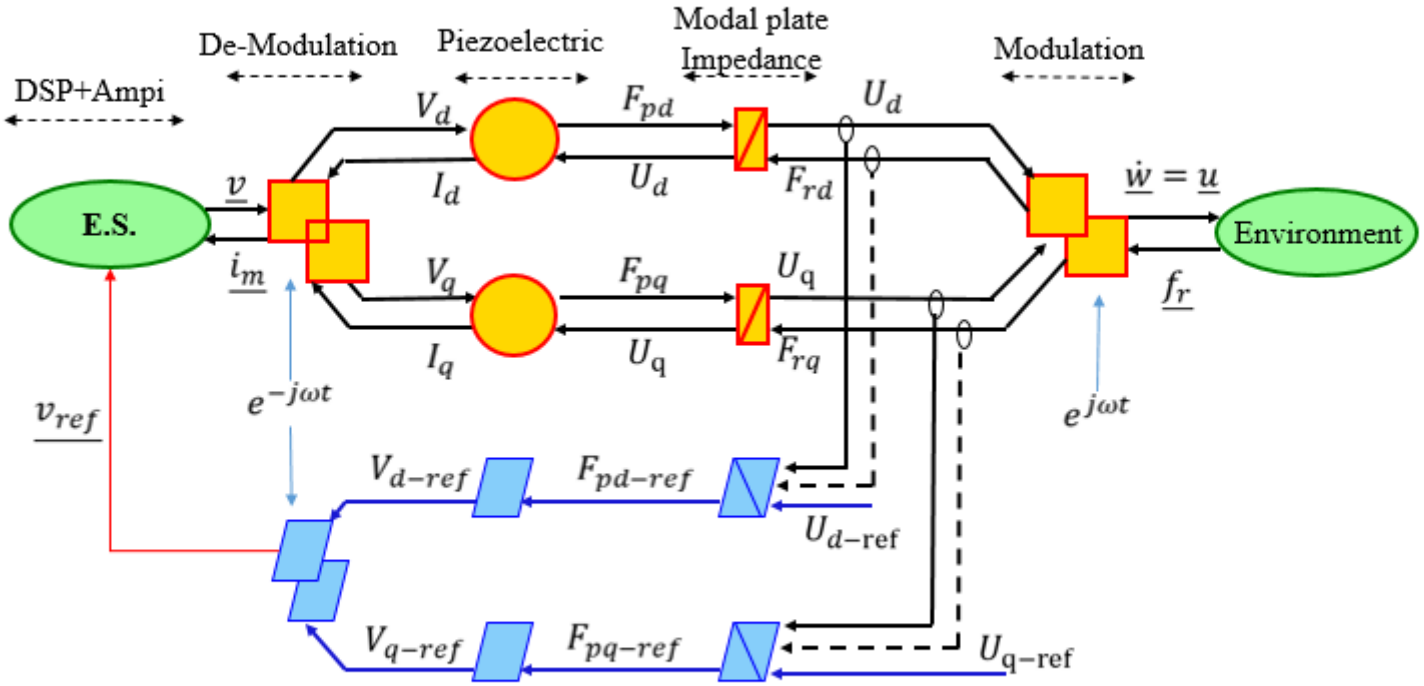
Assuming a single predominant mode

$$F_p(t) - F_r(t) = M_n \ddot{w}_n(t) + D_n \dot{w}_n(t) + K_n w_n(t)$$

[Giraud *et al.*, 19]

Decoupled system control EMR

$\delta\omega \approx 0$



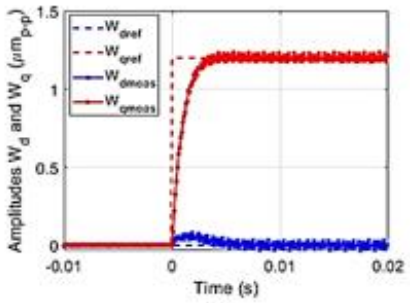
[Giraud *et al.*, 19]

Controlled amplitude in the dq frame

1 Dynamic response of the controlled modes

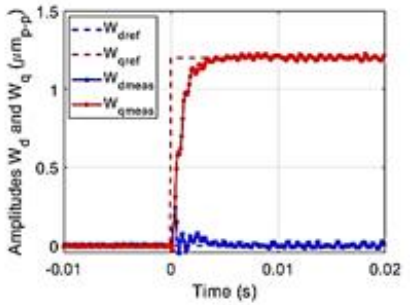
$\tau = 1.1$ ms , $\xi = 1$

Longitudinal mode



(b)

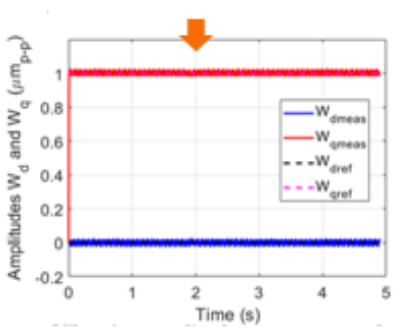
Transverse mode

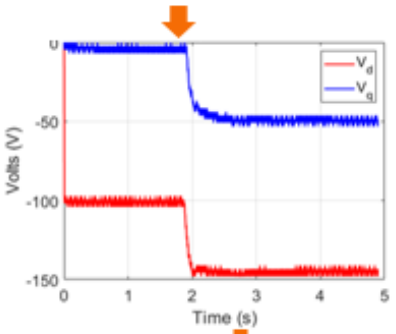


(a)

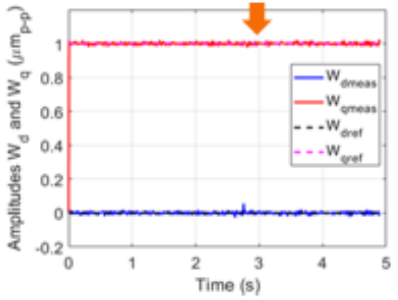
2 A finger is placed on the plate at t = 2-3 s

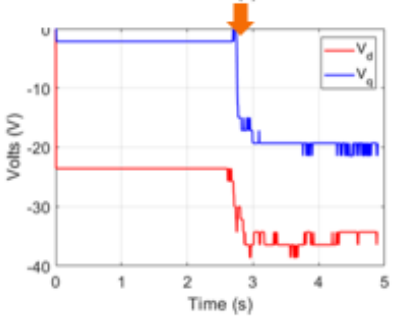
Longitudinal mode





Transverse mode





Controlled amplitude

Control voltage

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«Human-machine interaction: Biomechanics, perception and behaviour »


How does a human interact
with tactile technology?

How does a human interact with technology?

- The human performs an action on the interface
- The action elicits a physycal input in the device
- The device responds accordingly with a stimulus designed to transmit an information
- The stimulus is perceived
- If the information is understood, the human modifies their behaviour accordingly

In surface haptics: the objective is to emulate a real texture

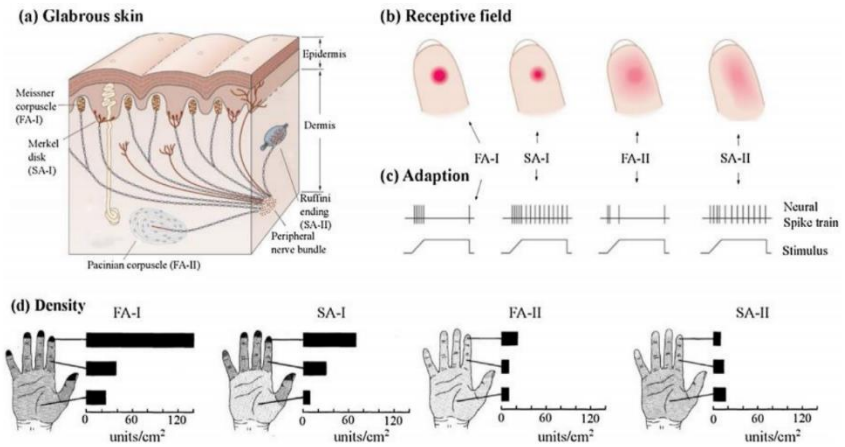
-The human performs an action on the interface – *Push, slide, rub, tap*

-The action elicits a physycal input on the device – *Force, position, velocity, trajectory*

-The device responds with a stimulus designed to transmit an information – *Vibration*

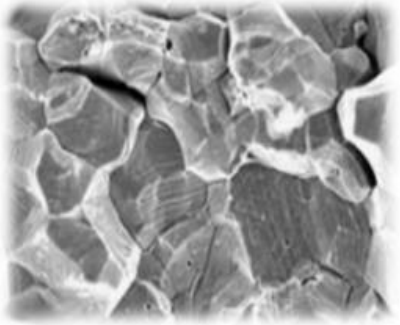
-The stimulus is perceived – *Thanks to skin and motor mechanoreceptors*

-If the information is understood, the human modifies their behaviour – *Embodyment?*

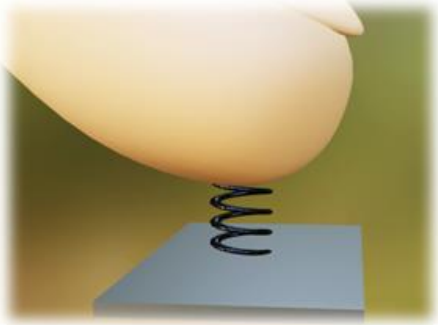


Systemic view of real texture interaction

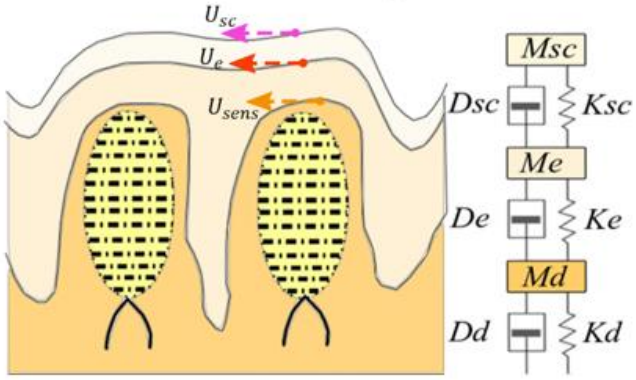
'Texture' sub-system



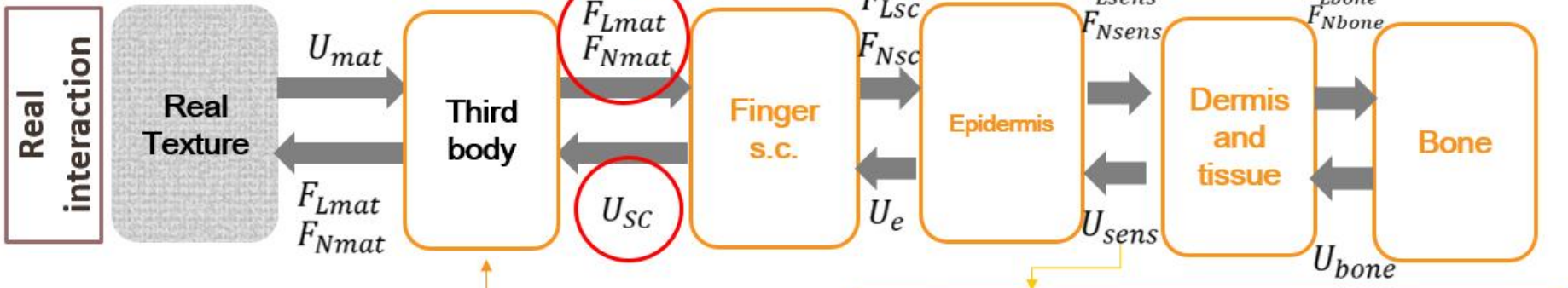
« third body »



'Human' sub-system



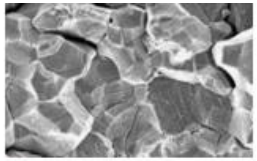
Creation of boundary conditions for perception



Consequence of the interaction of the two sub-systems

Information is recovered by the human on this level

Texture simulation with ultrasonic surface haptic device



Real interaction

Real Texture

U_{mat}

F_{Lmat}
F_{Nmat}

Third body

F_{Lmat}
F_{Nmat}

U_{SC}

Finger s.c.

F_{Lsc}
F_{Nsc}

U_e

Epidermis

F_{Lsens}
F_{Nsens}

U_{sens}

Dermis and tissue

F_{Lbone}
F_{Nbone}

U_{bone}

Bone

Not equal

hopefully perceived equal

Simulated interaction

Texture Model $W(x,y)$

U_{p_ref}

$Pos(x,y)$

Interface

U_p

F_{rL}
F_{rN}

Third body

F_{rL}
F_{rN}

U_{SC}

Finger s.c.

F_{Lsc}
F_{Nsc}

U_e

Epider-mis

F_{Lsens}
F_{Nsens}

U_{sens}

Dermis and tissue

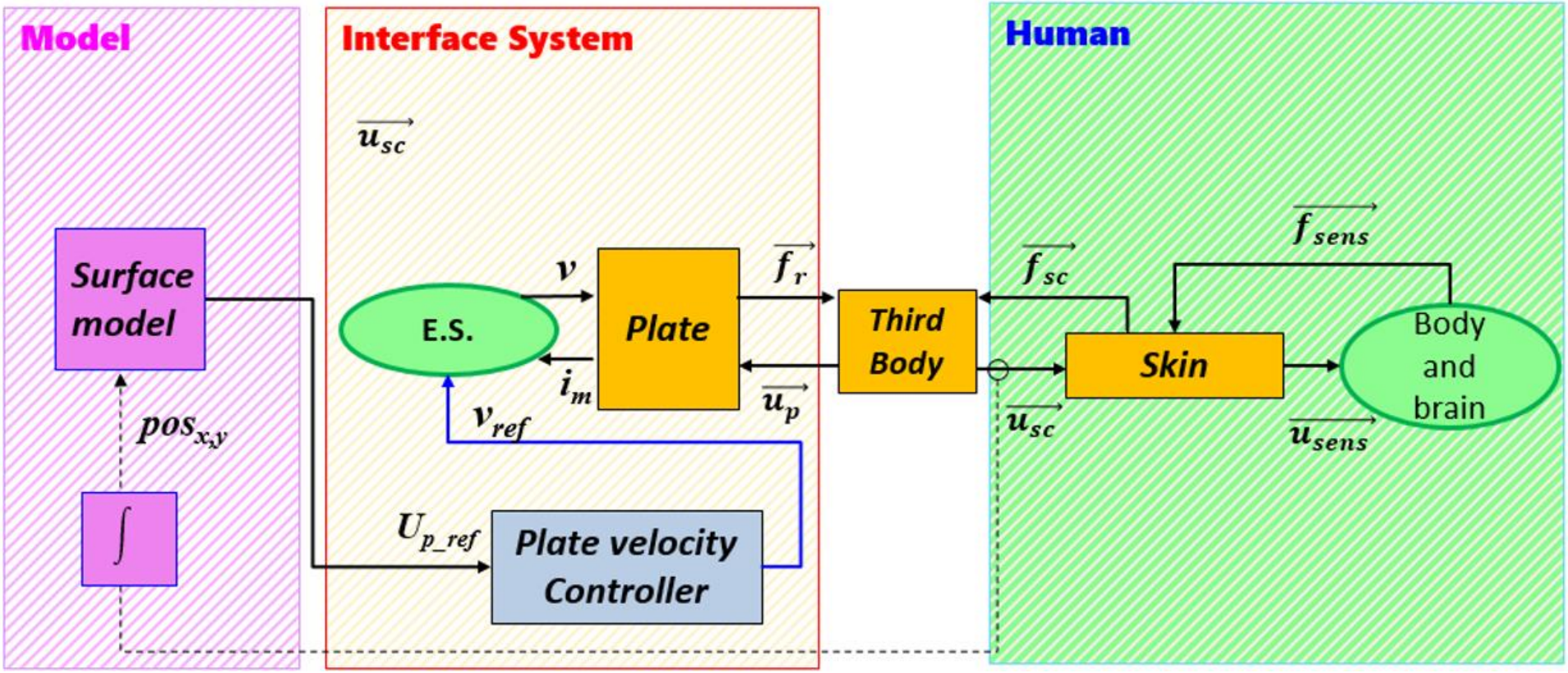
F_{Lbone}
F_{Nbone}

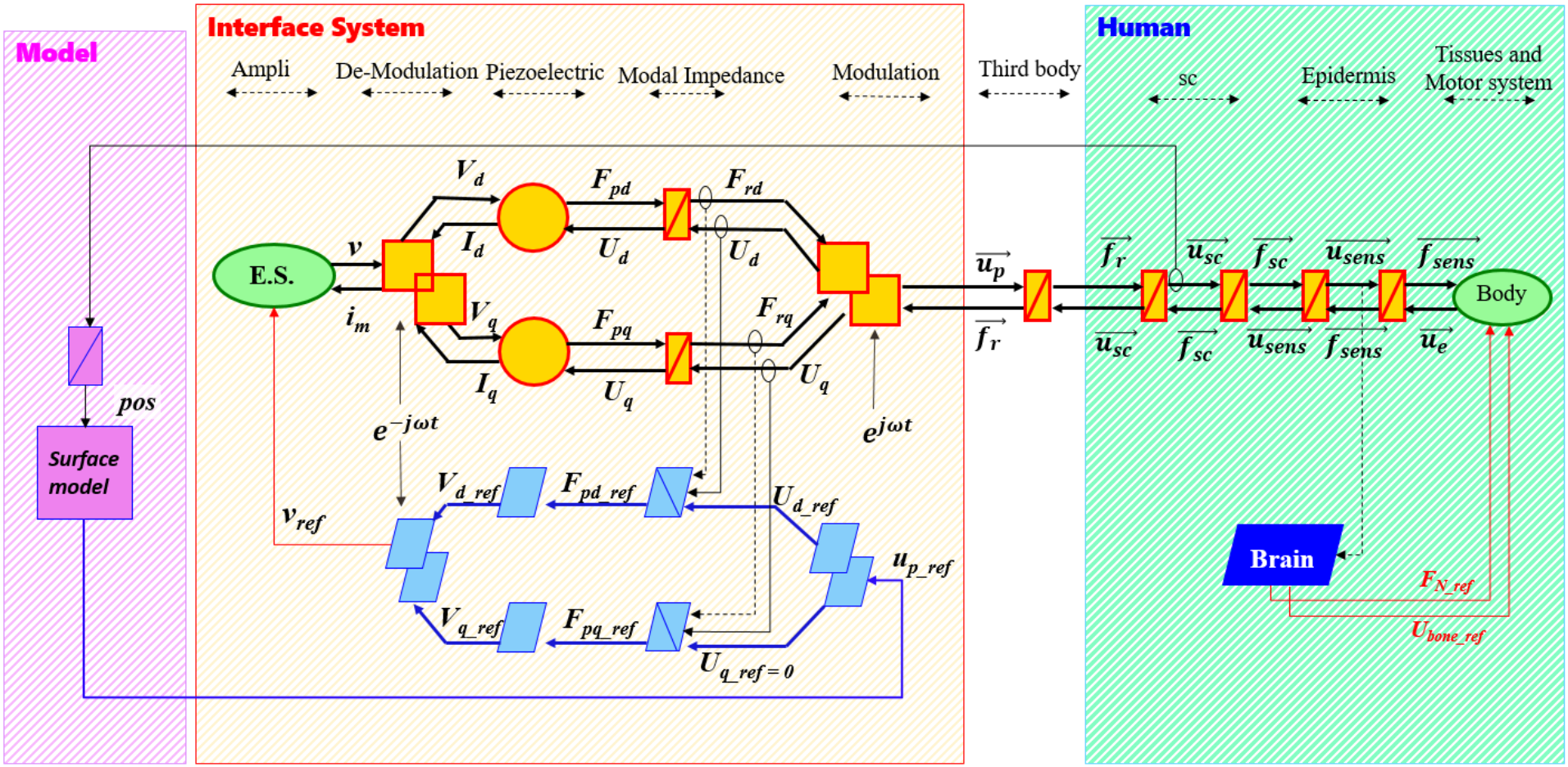
U_{bone}

Bone

Haptic device

Parts of the causal model: Energy flow




Model
Interface System
Human
Ampli
De-Modulation
Piezoelectric
Modal Impedance
Modulation
Third body
sc
Epidermis
Tissues and Motor system
E.S.
Body
Brain
Surface model
pos
v
i_m
V_d
I_d
F_pd
U_d
F_rd
U_d
V_q
I_q
F_pq
U_q
F_rq
U_q
u_p
f_r
u_sc
f_sc
u_sens
f_sens
u_e
e^{-jωt}
e^{jωt}
v_ref
V_d_ref
F_pd_ref
U_d_ref
u_p_ref
V_q_ref
F_pq_ref
U_q_ref = 0
F_N_ref
U_bone_ref

«Controller adaption to improve perception?»

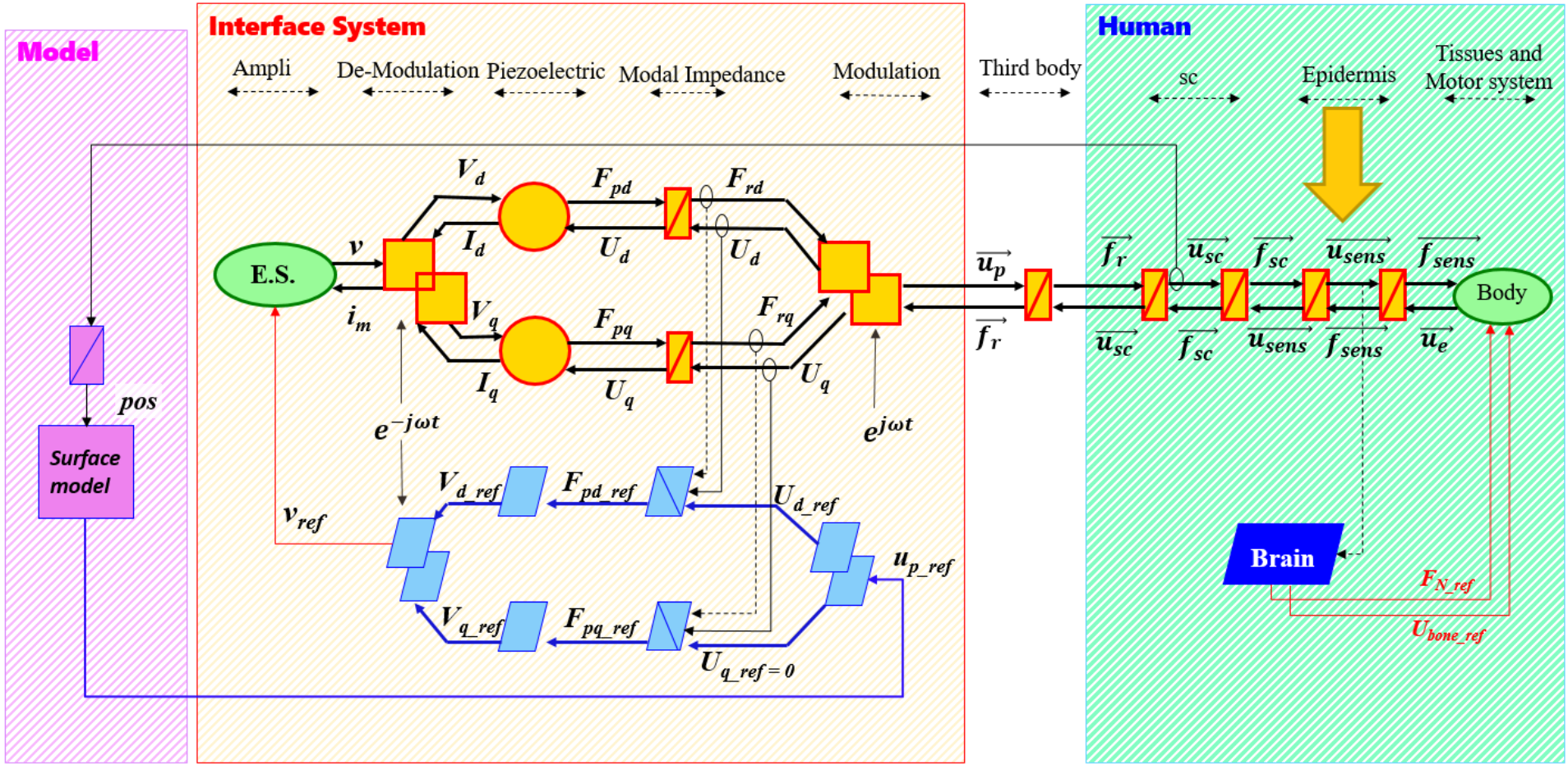
Controller adaption to improve perception

In surface haptics: the objective is to emulate a real texture

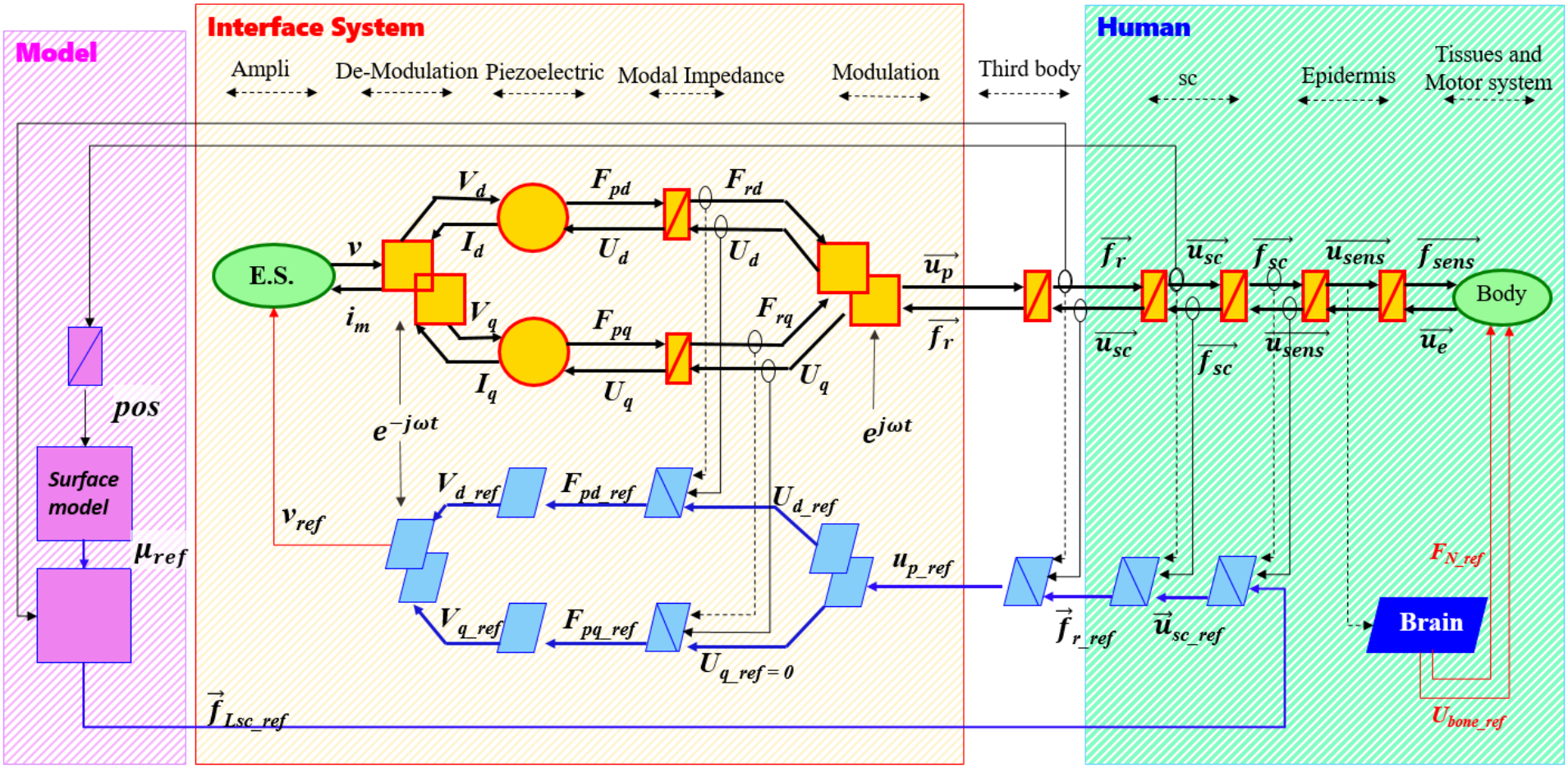
- The human performs an action on the interface – *Push, slide, rub, tap*
- The action elicits a physycal input on the device – *Force, position, velocity, trajectory*
- The device responds with a stimulus designed to transmit an information – ***Vibration***
- *Is the stimulus perceived?*
- *Is the information understood?*

Rendering -> Can we control how much the forces acting on the finger are modified?

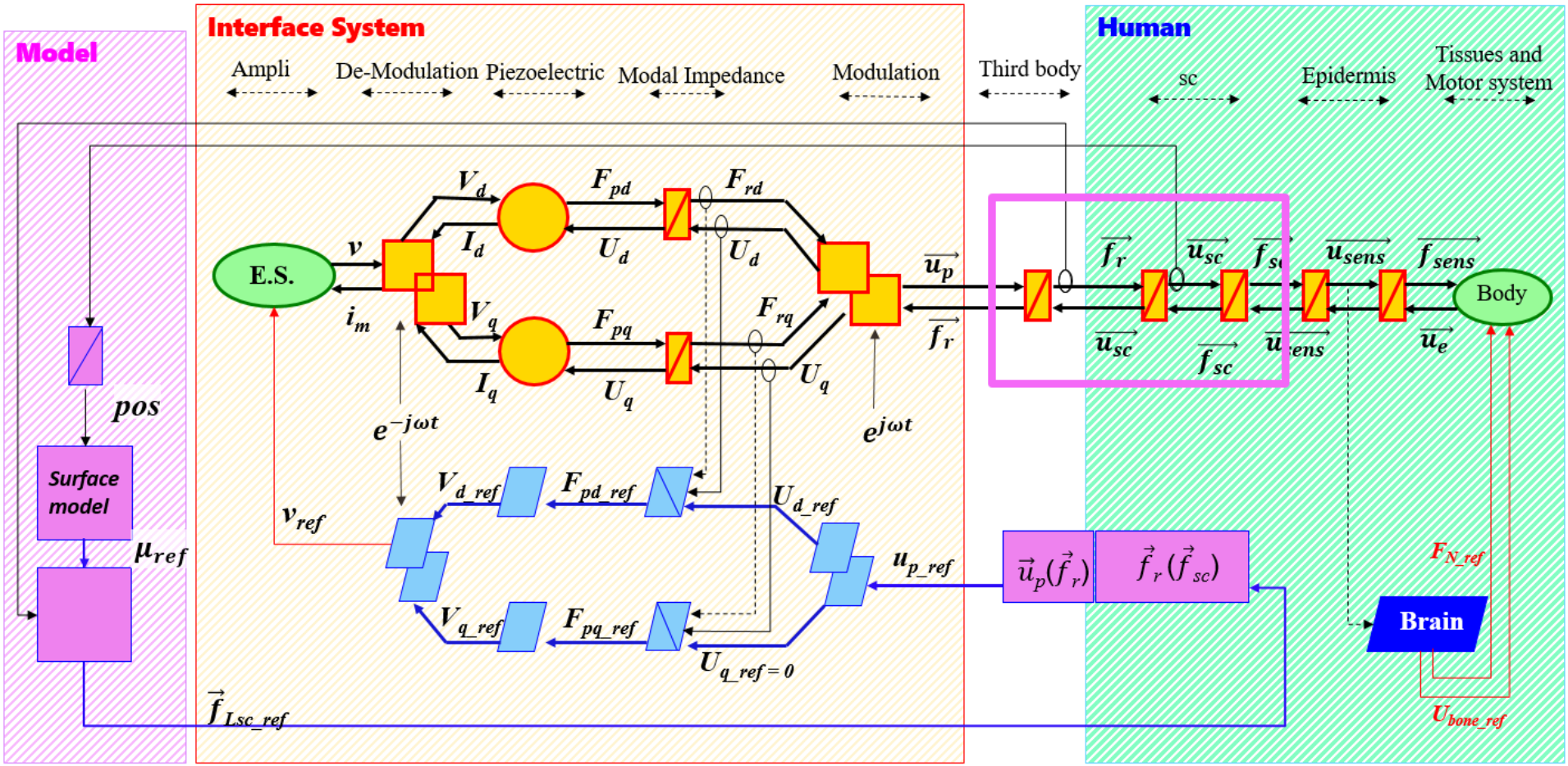
The friction depends on the human touching the device



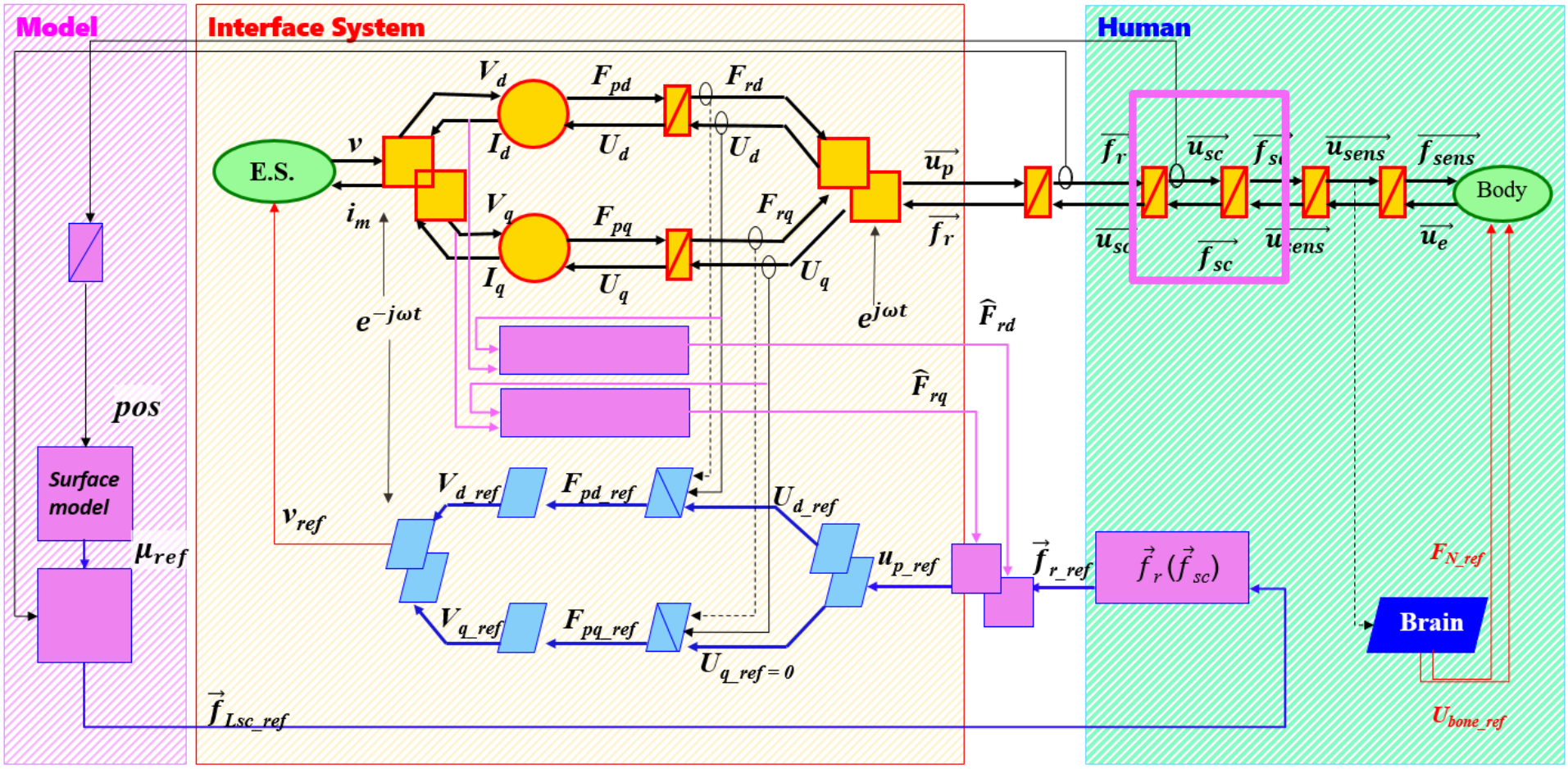
Alternative: MCS for the longitudinal force control at the sensing level



A statistical model can help complete the loop?

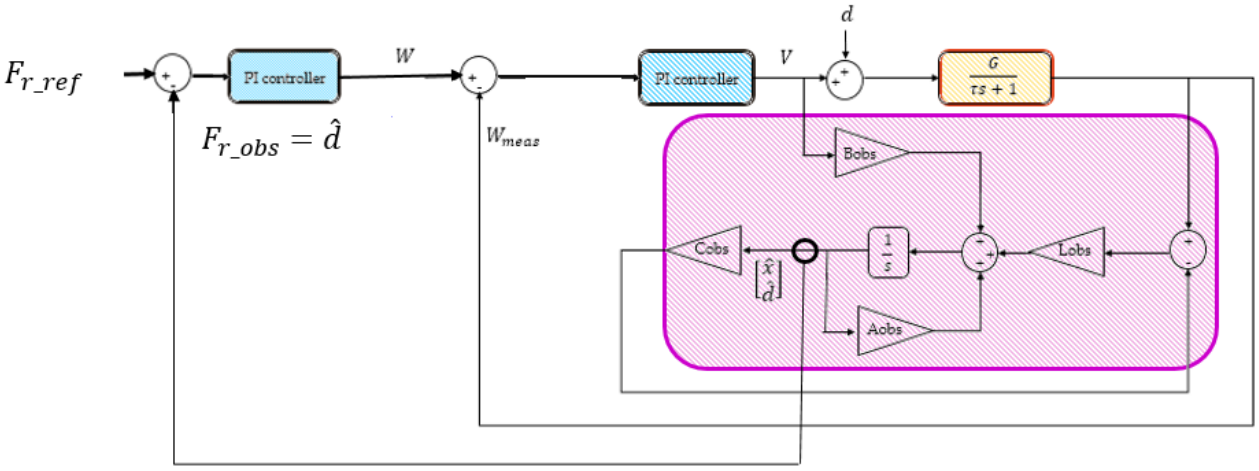


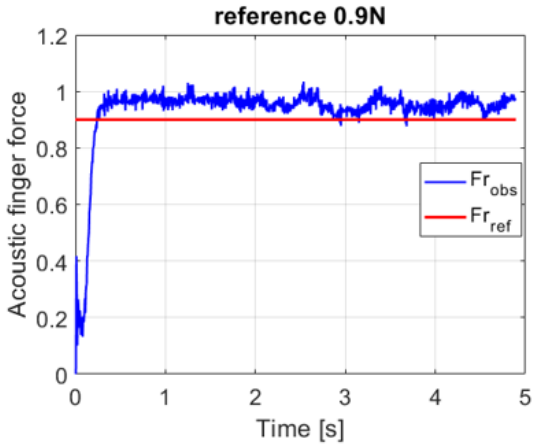
Real time acoustic force observation can help simplify the model



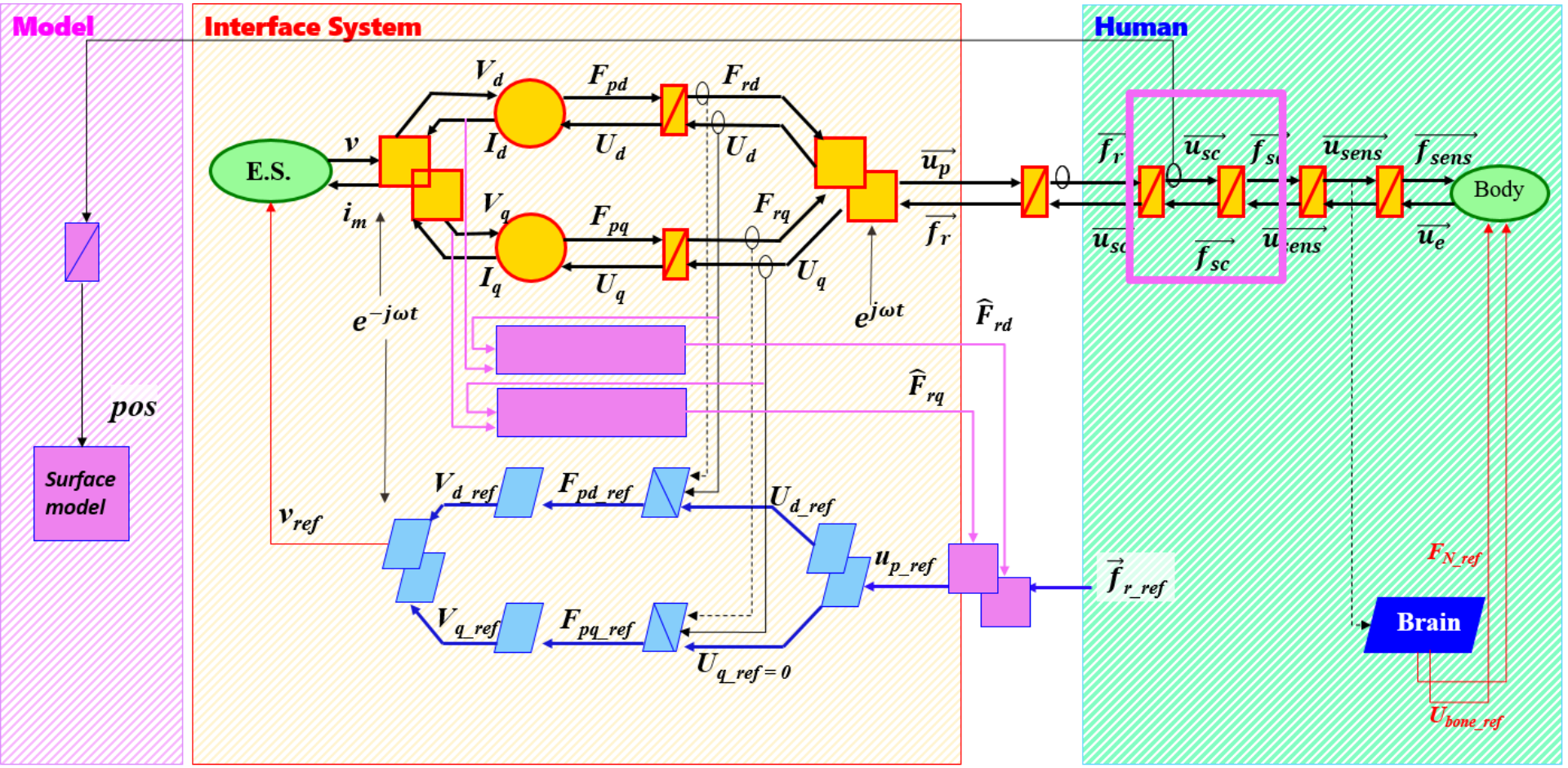
Finger Force Observer

Representation of a single axe in the dq frame, with *Fr* modelled as a controlled input disturbance





Where we are: Closed loop Fr achieved



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«Human in the loop for tactile interfaces: Next steps»

In surface haptics:

INFORMATION!

- The human elicits an action on the interface – *Push, slide, rub, tap*
- The action elicits a physycal input on the device – *Force, position, velocity, trajectory*
- The device responds with a stimulus designed to transmit an information – ***Force?***
- The stimulus is perceived – *How to verify?*
- If the information is understood, the human modifies their behaviour accordingly

Controller adaption:

- *Biomechanics: Check if the controller adaption does improve perception*
- *Behaviour: Evaluate controller adaption from behaviour*
- *Models: Use new techniques to look into improving surface models*

Human :

- *Use HiL as an assistance tool for training, learning or recovery from disease*

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From October 2018 she is research assistant at L2EP-IRCICA Laboratory working on her PhD Thesis. Her domains of re-search deal with the modeling and control of piezoelectric actua-tors for positioning and force feedback applications, and Hu-man-in-the-Loop analysis for ultrasonic surface tactile display design.

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[Bouscayrol 2012] A. Bouscayrol, J. P. Hautier, B. Lemaire-Semail, "Graphic Formalisms for the Control of Multi-Physical Energetic Systems", Systemic Design Methodologies for Electrical Energy, tome 1, Analysis, Synthesis and Management, Chapter 3, ISTE Willey editions, October 2012, ISBN: 9781848213883

[|Lhomme 2014] W. Lhomme, P. Delarue, A. Bouscayrol, P. Barrade, "La REM, formalismes multiphysique de commande des systèmes énergétiques", Les Techniques de l'Ingénieur, Référence D3066, Novembre 2014 (text in French, lift example)

- References -

[Bouscayrol 2000] A. Bouscayrol, & al. "Multimachine Multiconverter System: application for electromechanical drives", *European Physics Journal - Applied Physics,* vol. 10, no. 2, May 2000, pp. 131-147 (common paper GREEN Nancy, L2EP Lille and LEEI Toulouse, according to the SMM project of the GDR-SDSE).

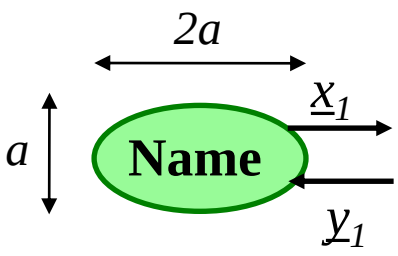
[Bouscayrol 2012] A. Bouscayrol, J. P. Hautier, B. Lemaire-Semail, "Graphic Formalisms for the Control of Multi-Physical Energetic Systems", Systemic Design Methodologies for Electrical Energy, tome 1, Analysis, Synthesis and Management, Chapter 3, ISTE Willey editions, October 2012, ISBN: 9781848213883

[|Lhomme 2014] W. Lhomme, P. Delarue, A. Bouscayrol, P. Barrade, "La REM, formalismes multiphysique de commande des systèmes énergétiques", Les Techniques de l'Ingénieur, Référence D3066, Novembre 2014 (text in French, lift example)

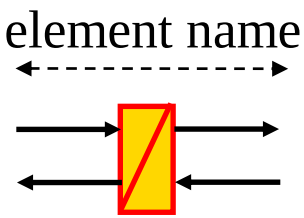
Power source	Power system	System model	System control	Control strategy
pale green	**gold**	**violet**	**sky blue**	**blue**
• light green background RGB = (152,251,152) « pale green » • dark green border RGB = (0,128,0) « greeen »	• orange background RGB = (255,215,0) « gold » • red border RGB = (255,0,0) « red »	• purple background RGB = (238,130,238) « violet » • dark blue border RGB = (0,0,255) « blue »	• light blue background RGB = (135,206,235) « sky blue » • dark blue border RGB = (0,0,255) « blue »	• dark blue background RGB = (0,0,255) « blue » • dark blue border RGB = (0,0,255) « blue »

Web X11 colour, standard colours on web pages
http://en.wikipedia.org/wiki/Web_colors

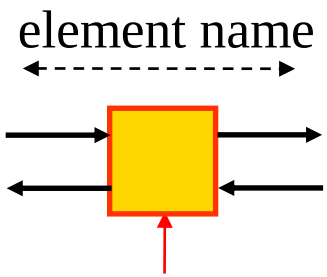
No equation number in slides



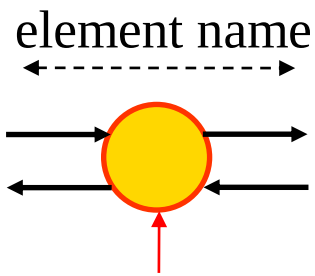
(2*a* x *a*)



(*a*/2 x *a*)



(*a* x *a*)

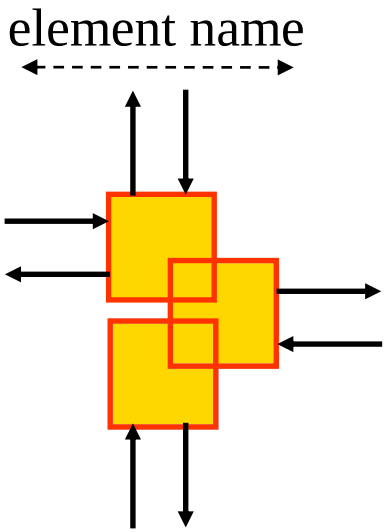


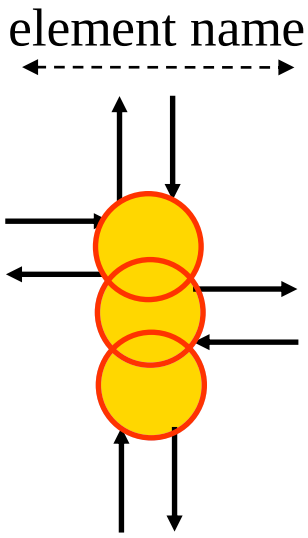
(radius= *a*)

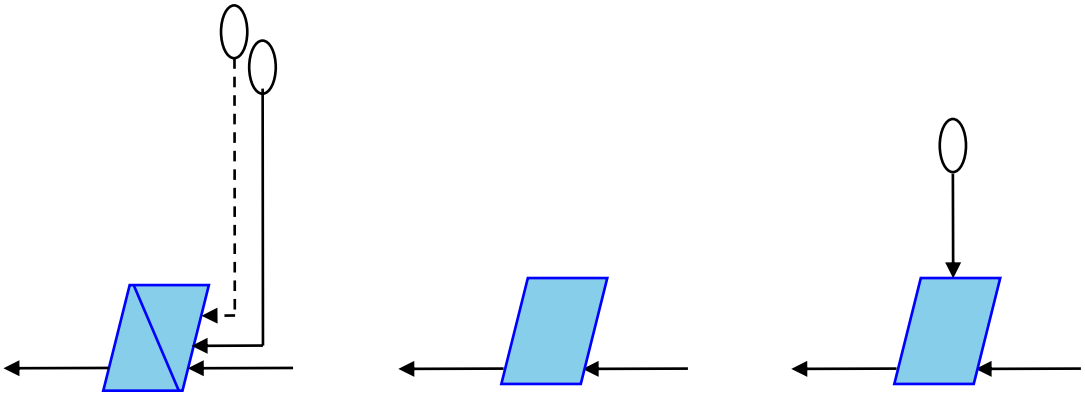
borders of power elements = *b* pt

power vectors (size *b*, full arrows)

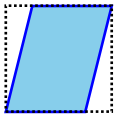
signal vectors (size *b*/2, empty arrows)







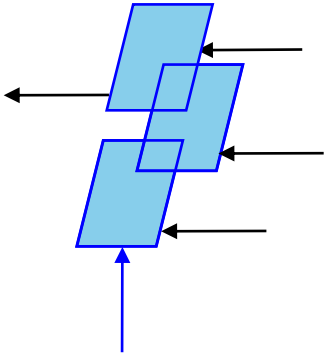
(same pictograms – same size -
with or without oblique bar)

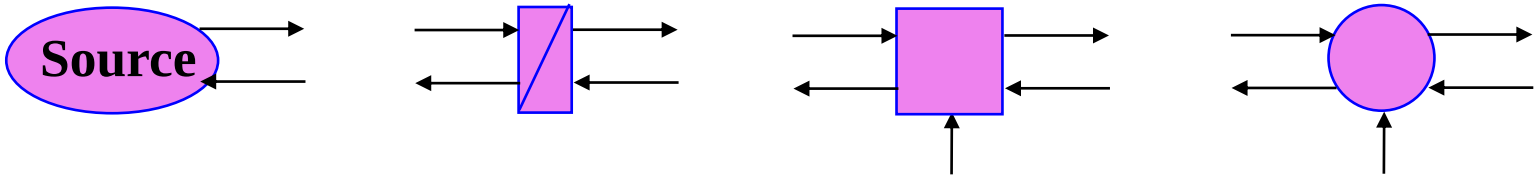


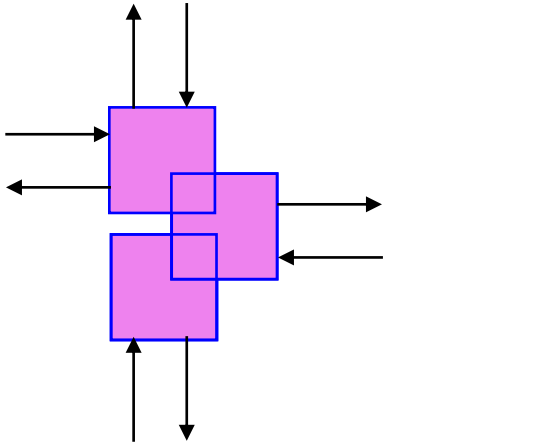
(support square
a x *a*)

borders of control
elements = *b/2* pt

↑ signal vectors
(size *b/2*, empty arrows)

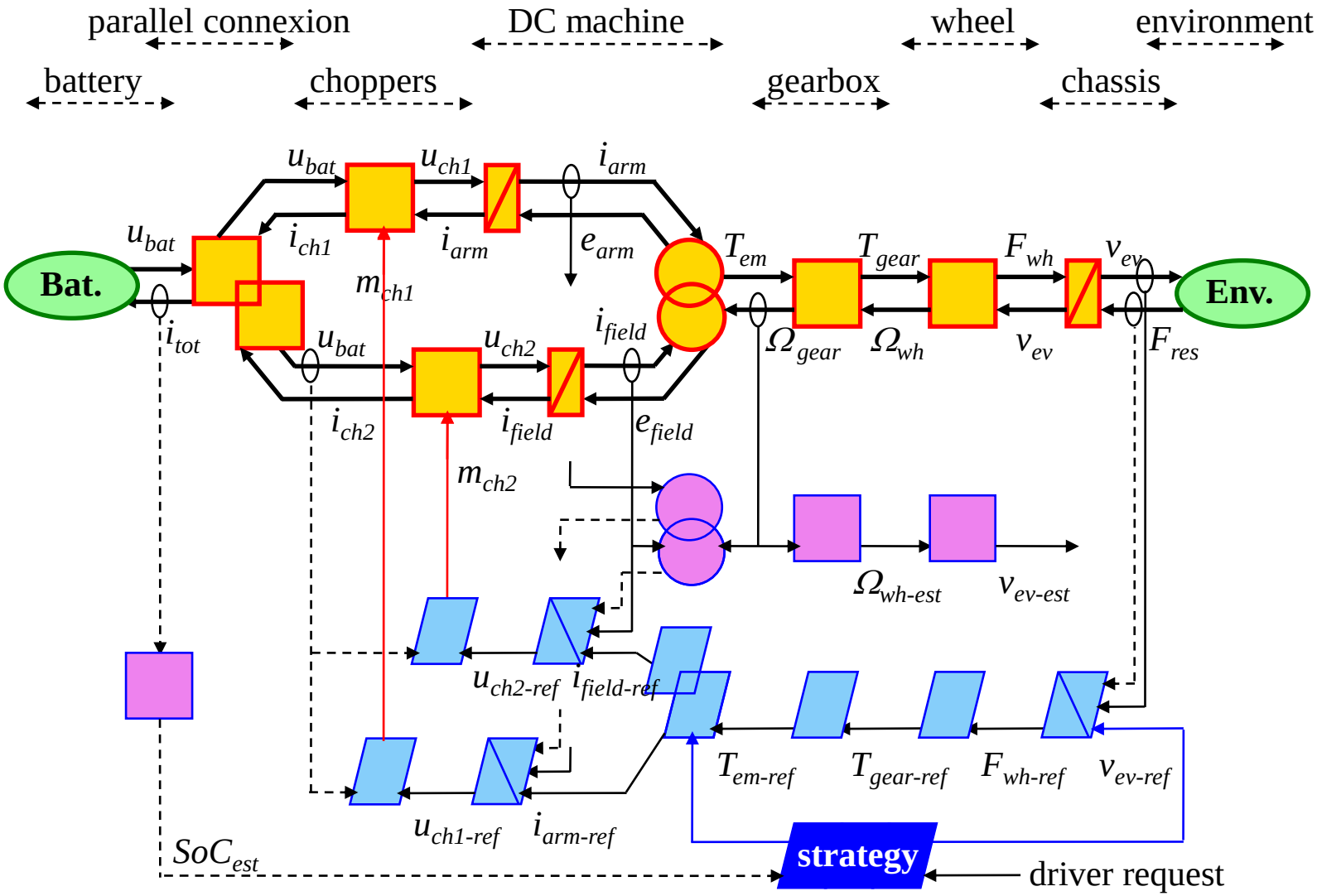






borders of estimation elements = *b/2* pt

signal vectors (size *b/2*, empty arrows)


parallel connexion
DC machine
wheel
environment
battery
choppers
gearbox
chassis
Bat.
Env.
u_{bat}
u_{ch1}
i_{arm}
i_{ch1}
e_{arm}
m_{ch1}
T_{em}
T_{gear}
F_{wh}
v_{ev}
i_{tot}
u_{ch2}
i_{field}
Ω_{gear}
Ω_{wh}
F_{res}
i_{ch2}
e_{field}
m_{ch2}
$\Omega_{wh\text{-}est}$
$v_{ev\text{-}est}$
$u_{ch2\text{-}ref}$
$i_{field\text{-}ref}$
$T_{em\text{-}ref}$
$T_{gear\text{-}ref}$
$F_{wh\text{-}ref}$
$v_{ev\text{-}ref}$
$u_{ch1\text{-}ref}$
$i_{arm\text{-}ref}$
SoC_{est}
strategy
driver request