Rehabilitation robotics using Central Pattern Generators

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Master Project
Mid-term Presentation
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Goals of the project

▶ **Investigation of a rehabilitation protocol based on the theory of adaptive oscillator.**

▶ **Implementation of the method on the Knee orthosis**

▶ **Test of the method with various movements**

▶ **Validation of the method on healthy people**

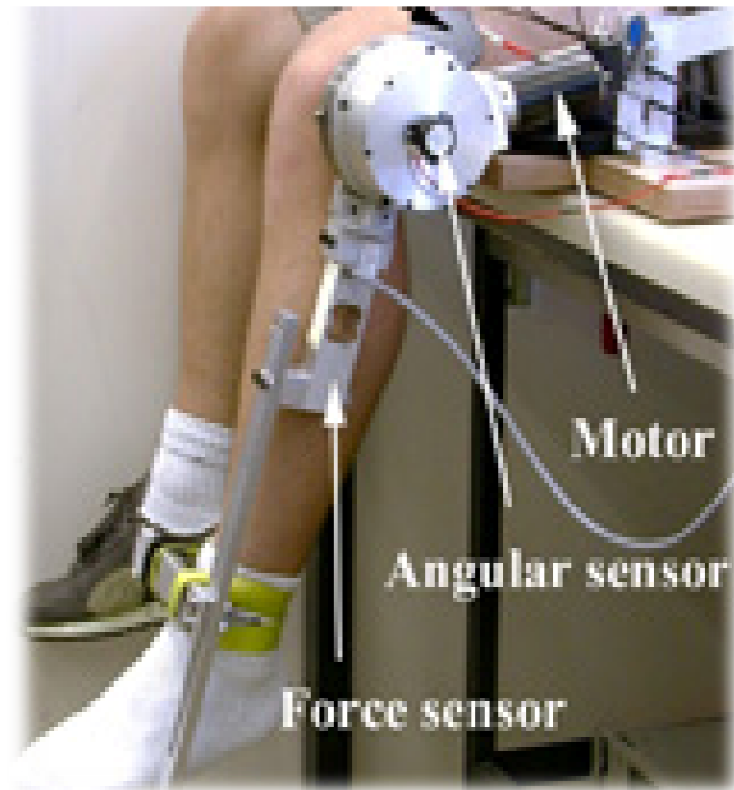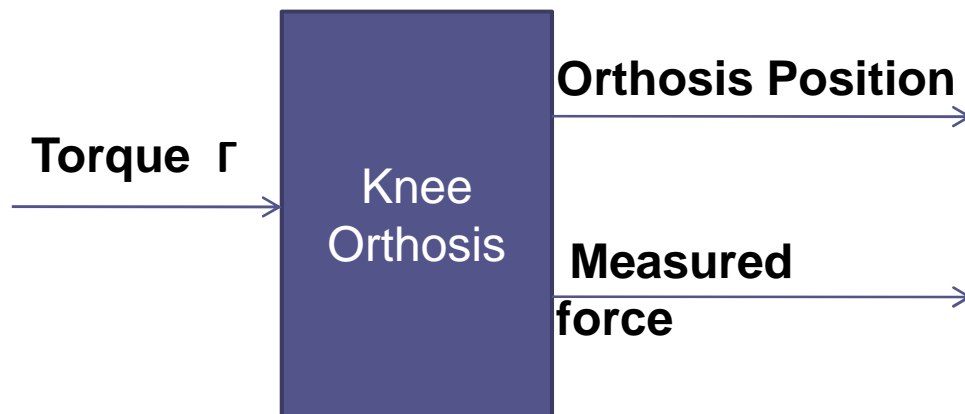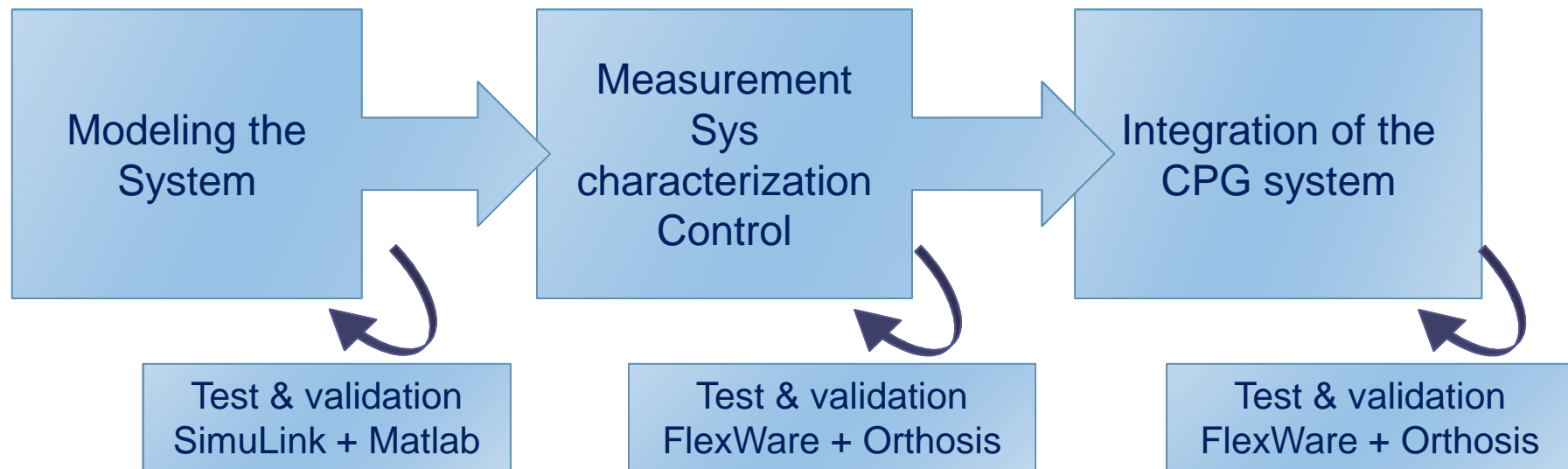▶ **Design of a preliminary rehabilitation protocol.**

Plan

▶ **Presentation of the Knee orthosis**

▶ **SIMULINK modeling**

▶ **Preliminary work on the Knee-orthosis**

▶ **First implementation : transparent mode**

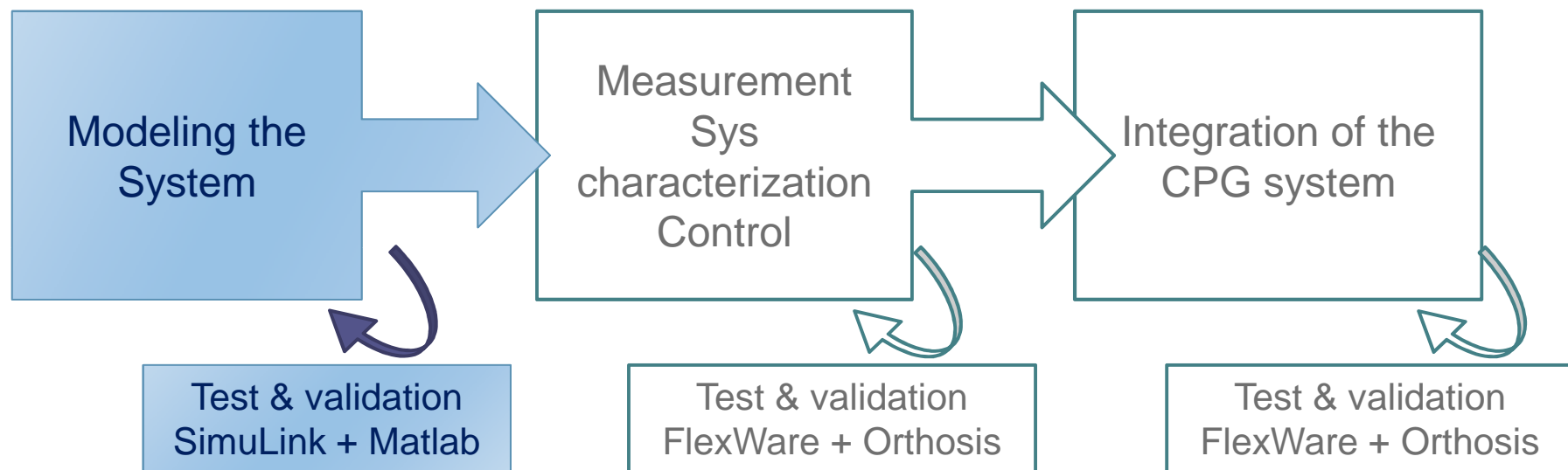▶ **Conclusion and future work**

Environment : Knee Orthosis

▸ Rehabilitation robot

▸ One degree of freedom

▸ Position and force sensors

Torque Γ → **Knee Orthosis** → **Orthosis Position**, **Measured force**

Motor
Angular sensor
Force sensor

Timeline

Modeling the System

Measurement Sys characterization Control

Integration of the CPG system

Test & validation SimuLink + Matlab

Test & validation FlexWare + Orthosis

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Timeline : MatLab – Simulink implementation

Modeling the System → Measurement Sys characterization Control → Integration of the CPG system

Test & validation SimuLink + Matlab

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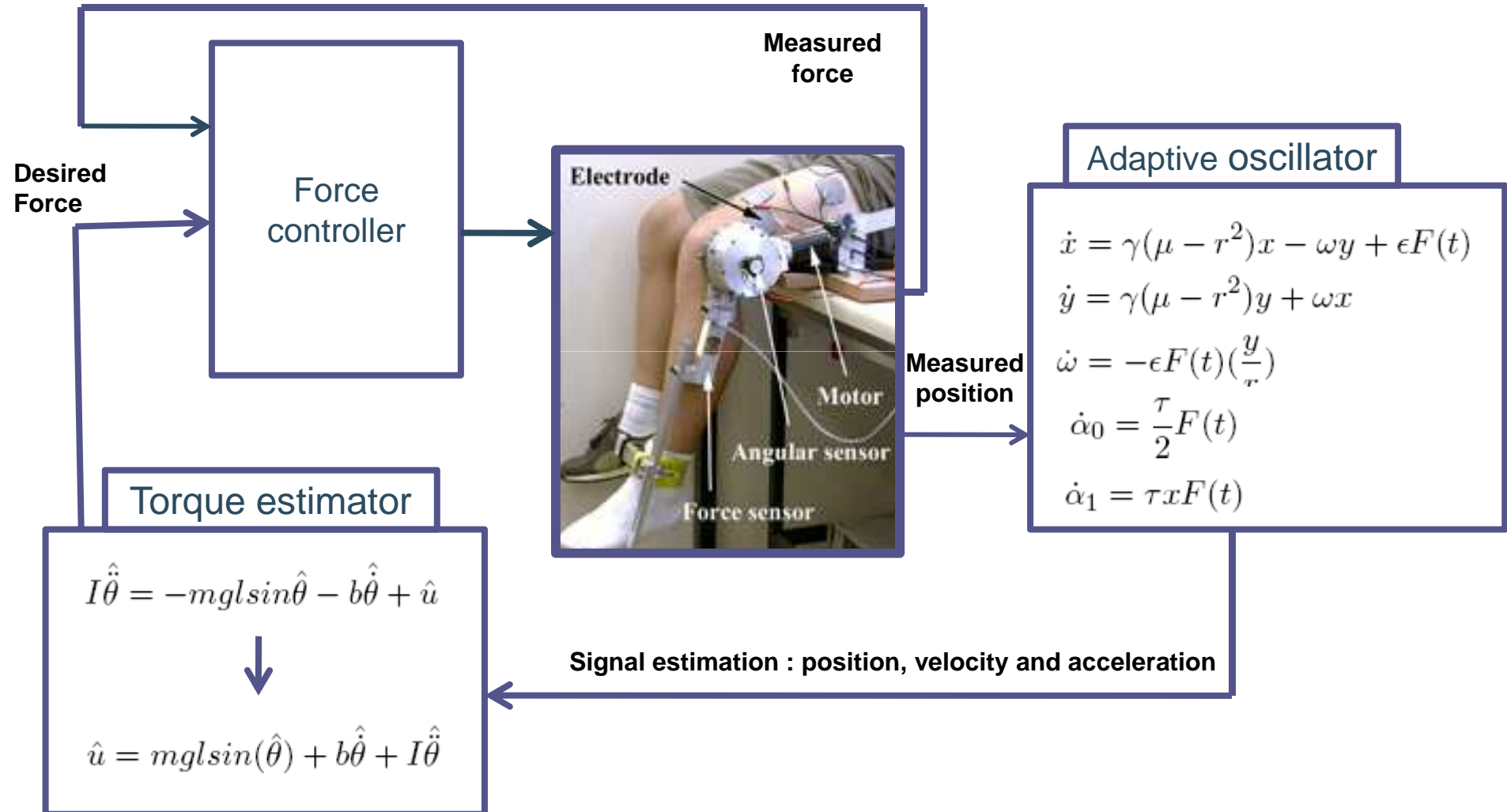
Model and simulation
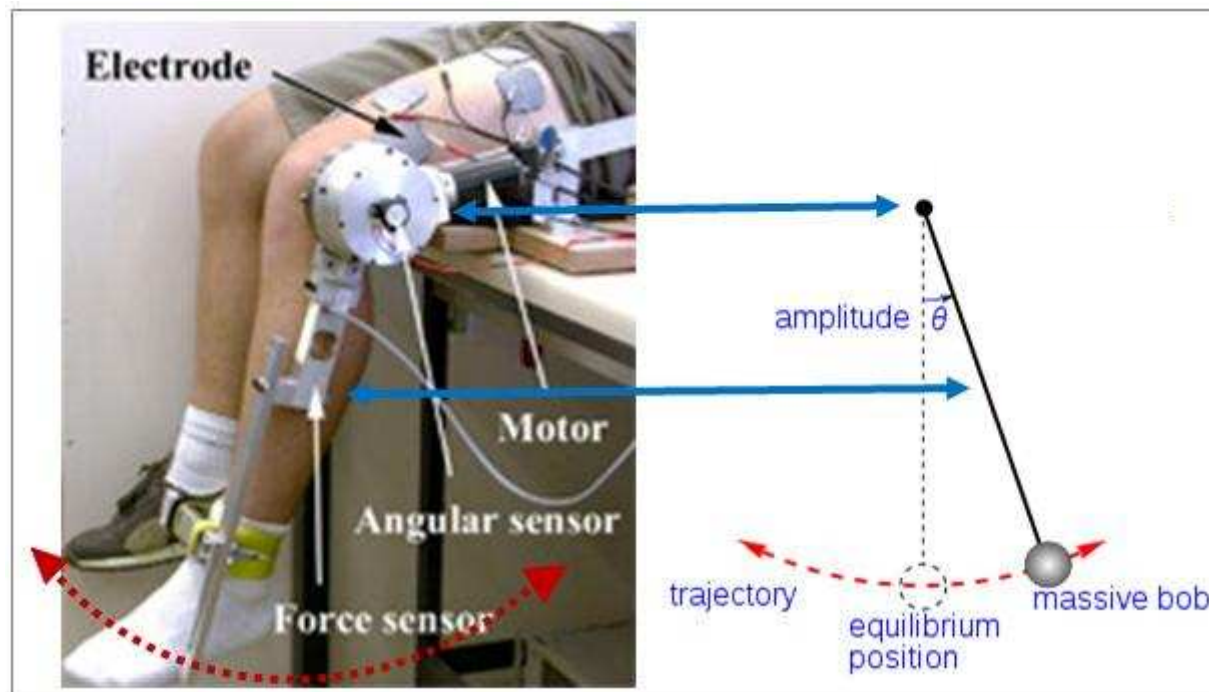
$$I\ddot{\theta} = -mgl\sin\theta - b\dot{\theta} + u$$

Torque

CPG & torque estimator

Desired Force

Force controller

Measured force

Electrode

Motor

Angular sensor

Force sensor

Measured position

Adaptive oscillator

$$\dot{x} = \gamma(\mu - r^2)x - \omega y + \epsilon F(t)$$

$$\dot{y} = \gamma(\mu - r^2)y + \omega x$$

$$\dot{\omega} = -\epsilon F(t)(\frac{y}{r})$$

$$\dot{\alpha}_0 = \frac{\tau}{2}F(t)$$

$$\dot{\alpha}_1 = \tau x F(t)$$

Torque estimator

$$I\ddot{\hat{\theta}} = -mgl\sin\hat{\theta} - b\dot{\hat{\theta}} + \hat{u}$$

$$\hat{u} = mgl\sin(\hat{\theta}) + b\dot{\hat{\theta}} + I\ddot{\hat{\theta}}$$

Signal estimation : position, velocity and acceleration

CPG & torque estimator

Dynamical model +
Orthosis Position controller

Electrode

Motor

Angular sensor

Force sensor

Measured position

Adaptive oscillator

$$\dot{x} = \gamma(\mu - r^2)x - \omega y + \epsilon F(t)$$

$$\dot{y} = \gamma(\mu - r^2)y + \omega x$$

$$\dot{\omega} = -\epsilon F(t)\left(\frac{y}{r}\right)$$

$$\dot{\alpha}_0 = \frac{\tau}{2}F(t)$$

$$\dot{\alpha}_1 = \tau x F(t)$$

x

y

w

Offset

Amplitude

Signal Estimator

Position

Velocity

Acceleration

Timeline: Force

Modeling the System	→	Measurement Sys characterization Control	→	Integration of the CPG system

Test & validation
SimuLink + Matlab

Test & validation
FlexWare + Orthosis

Test & validation
FlexWare + Orthosis

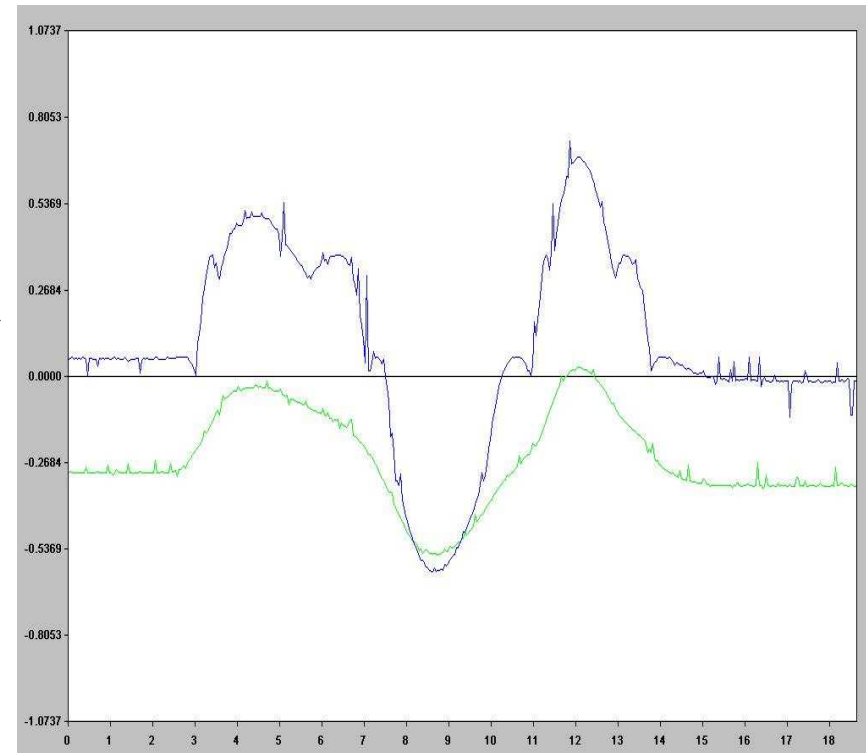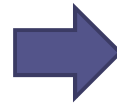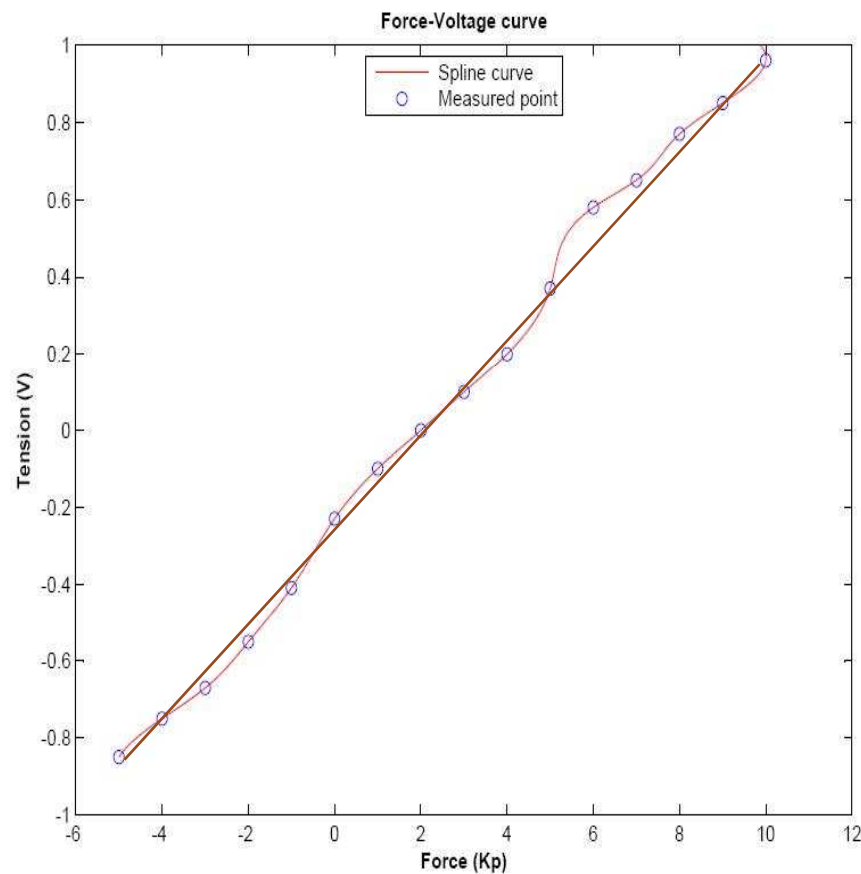# Implementation : Material
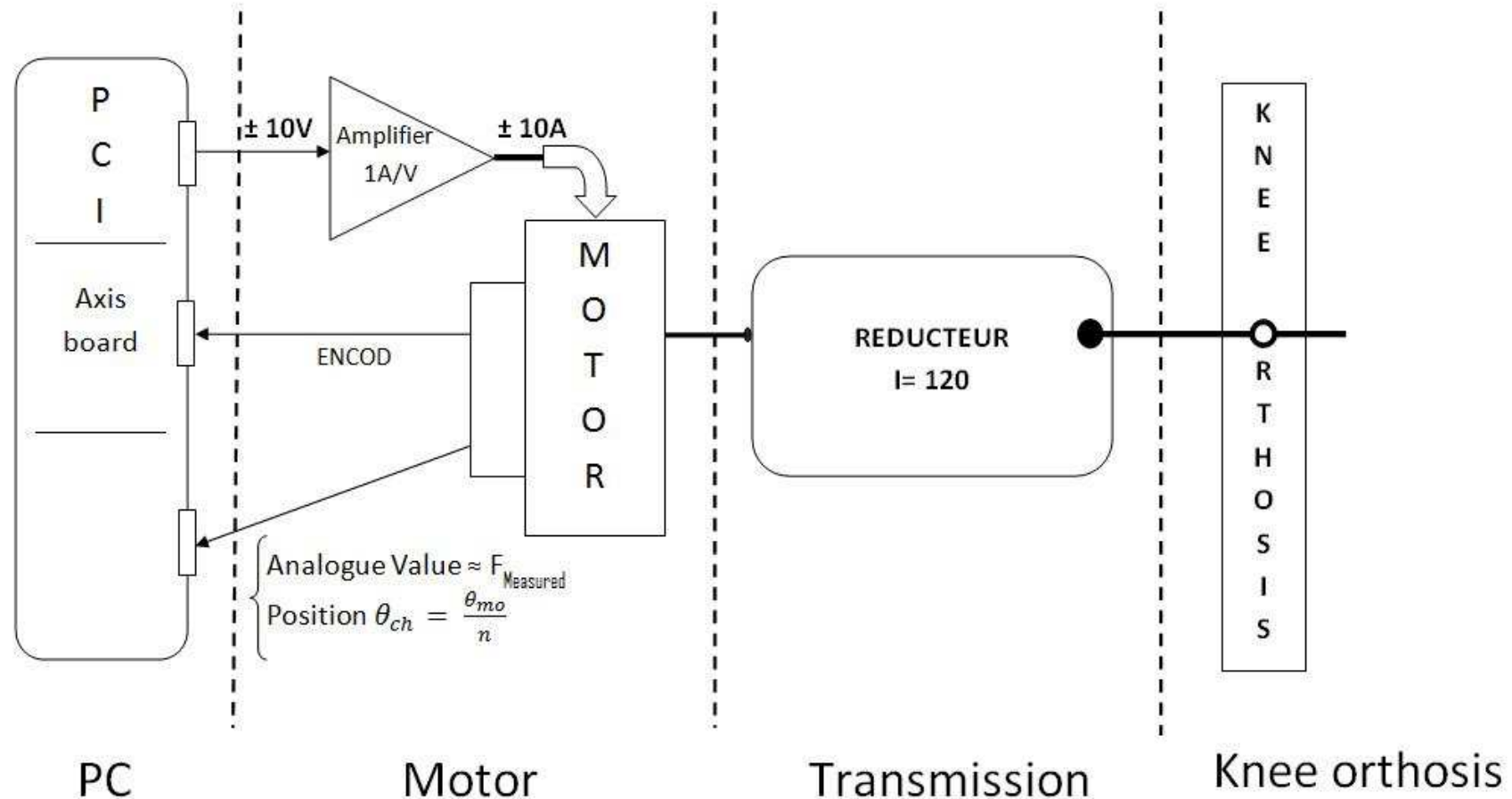
Implementation: Transparent mode

▸ 1st Objective:

Make the orthosis transparent for the user

▸ 5 Steps :
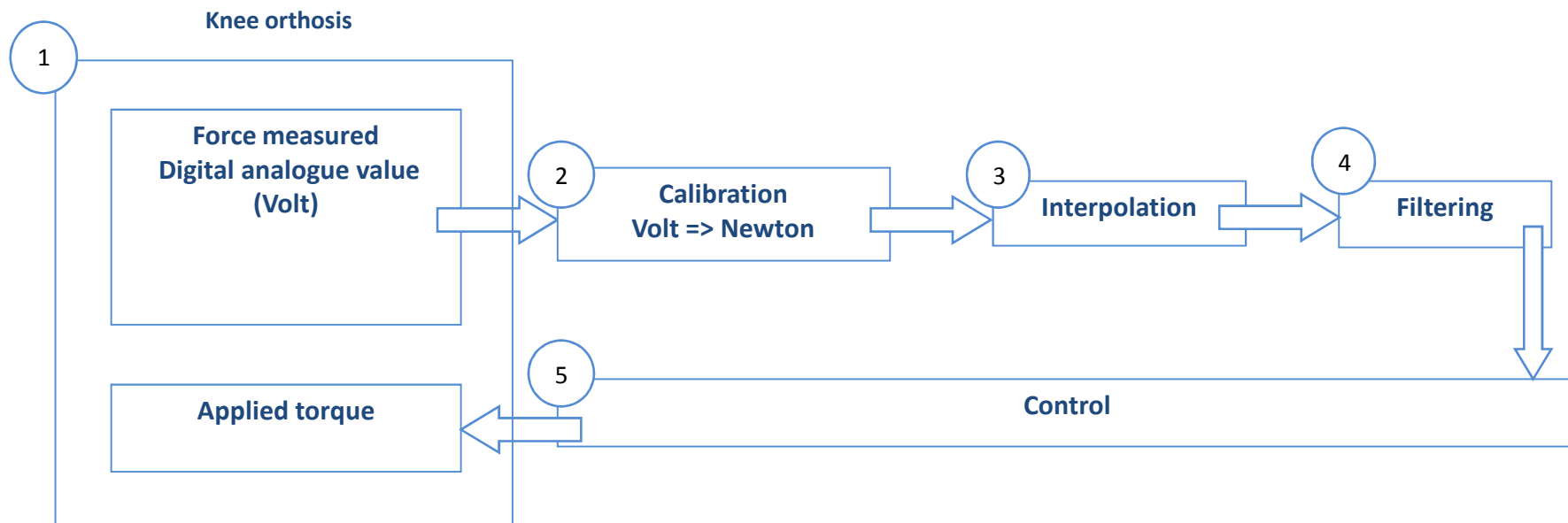
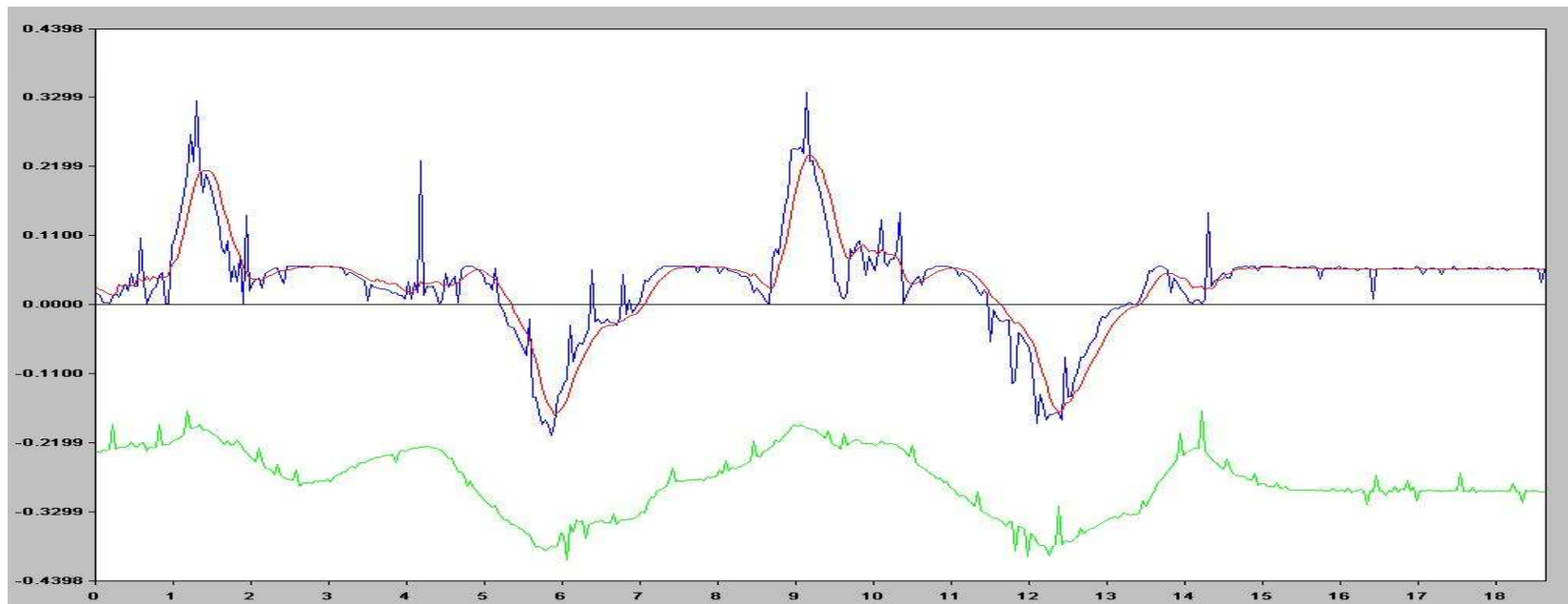# Implementation: Calibration & Interpolation

Implementation: Filtering

Using the following filter : $\quad \tau = \dfrac{1}{B_p} \quad \Rightarrow \quad B_p = 20 \text{ Hz}$

$$\frac{y_f}{y} = \frac{1}{1 + \tau s} \quad \Rightarrow \quad y_f = \frac{\tau}{T_e + \tau} y_f^- + \frac{T_e}{T_e + \tau} y$$
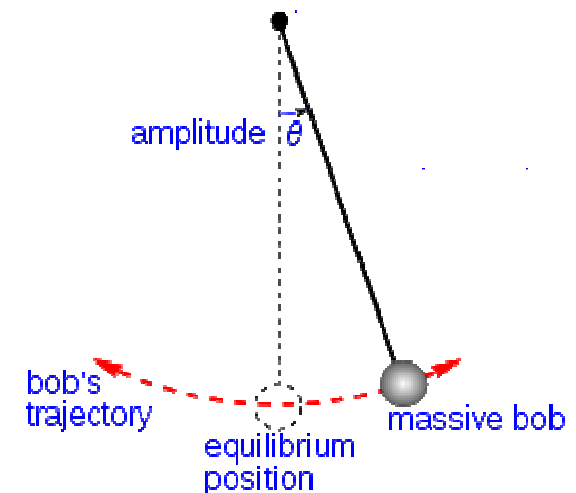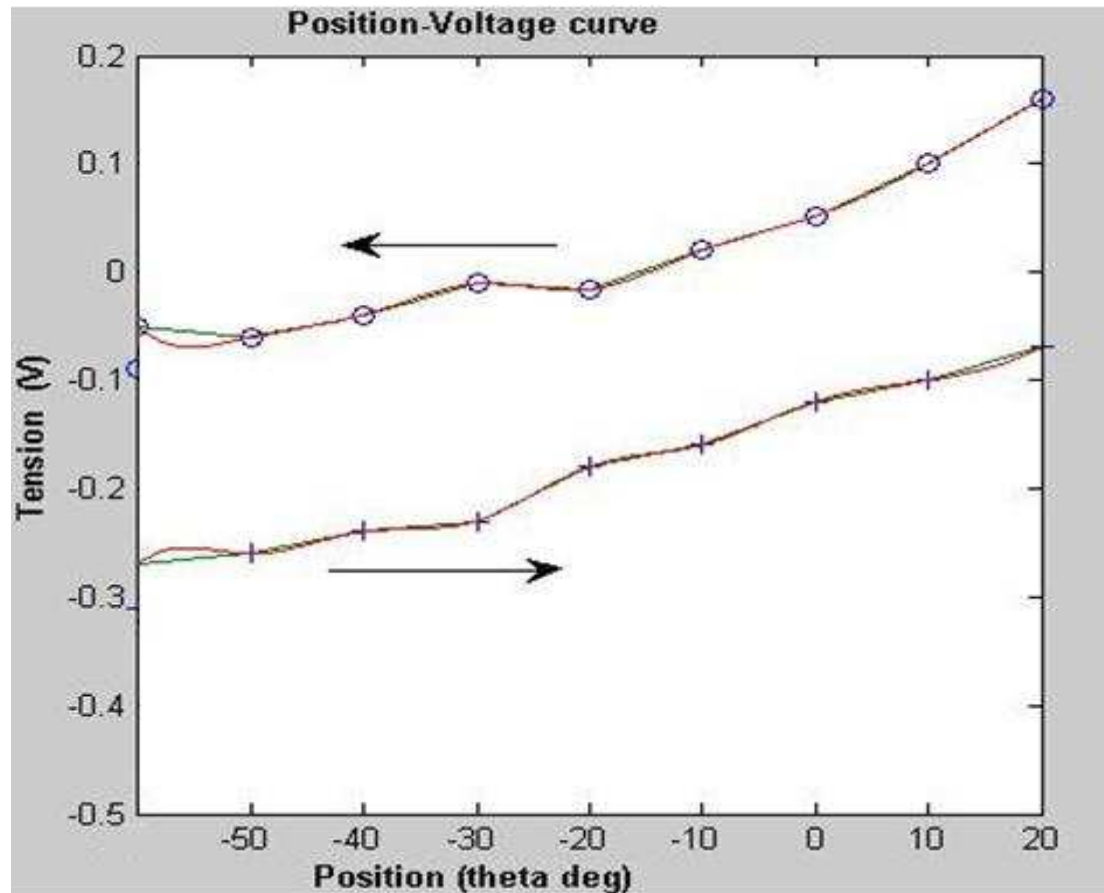
Implementation: Filtering

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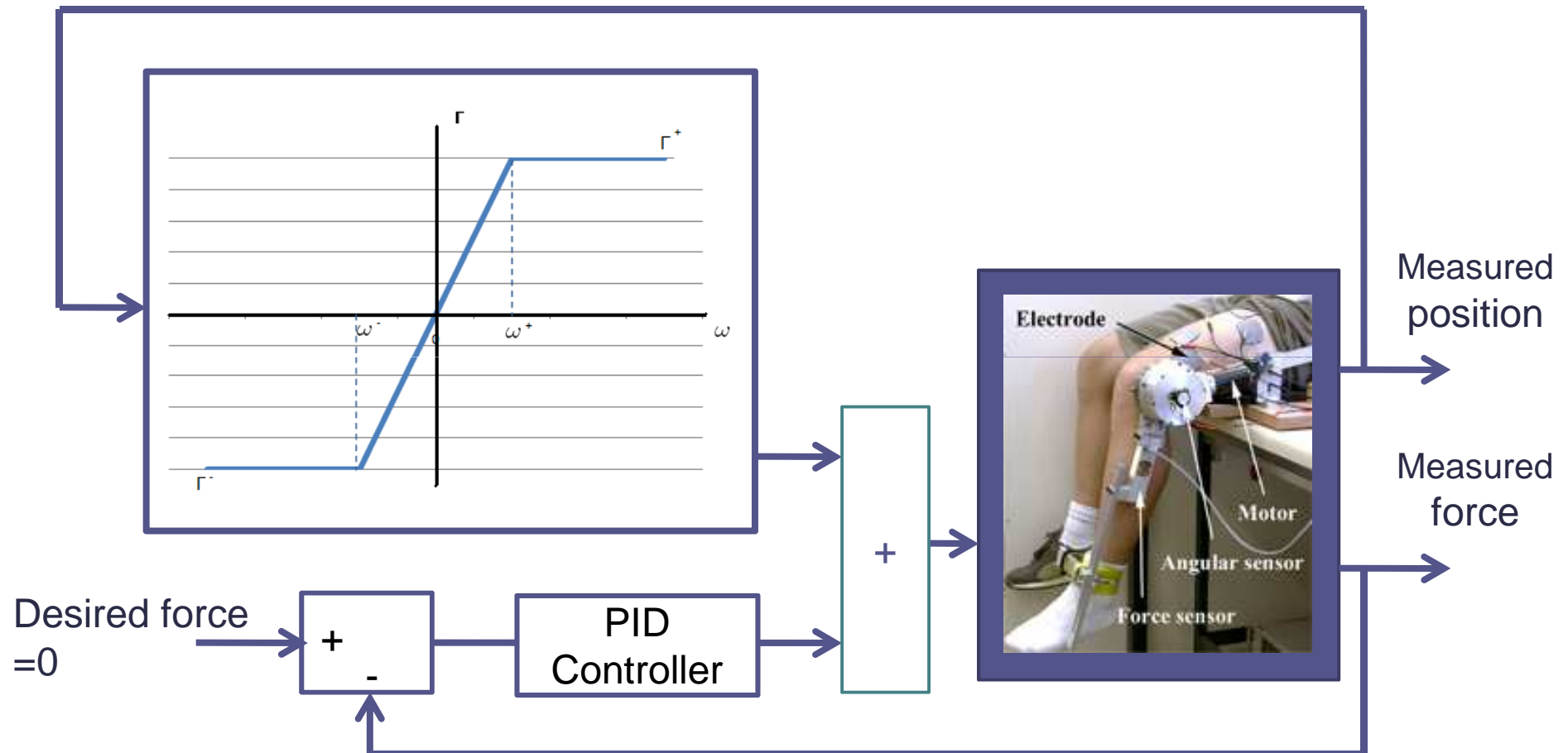
Implementation: Transparent mode

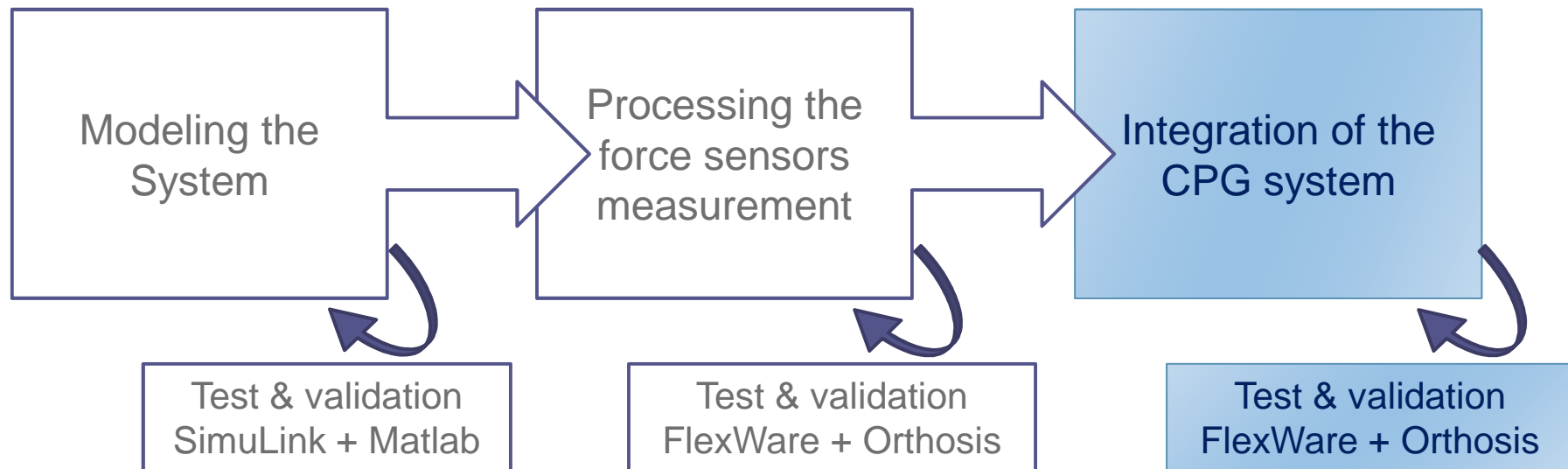## Measuring the stabilization tension for a set of position

Implementation: Transparent mode

Implementation: Transparent mode

Timeline : Integrating CPG

Modeling the System

Processing the force sensors measurement

Integration of the CPG system

Test & validation SimuLink + Matlab

Test & validation FlexWare + Orthosis

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Future work

▸ Test of the method with various movements

▸ Validation of the method on healthy people

▸ Design of a preliminary rehabilitation protocol.

▸ Work on the LAMBDA robot

Questions ?