EMBEDDED IMPLEMENTATION OF A REAL-TIME SWITCHING CONTROLLER ON A ROBOTIC ARM

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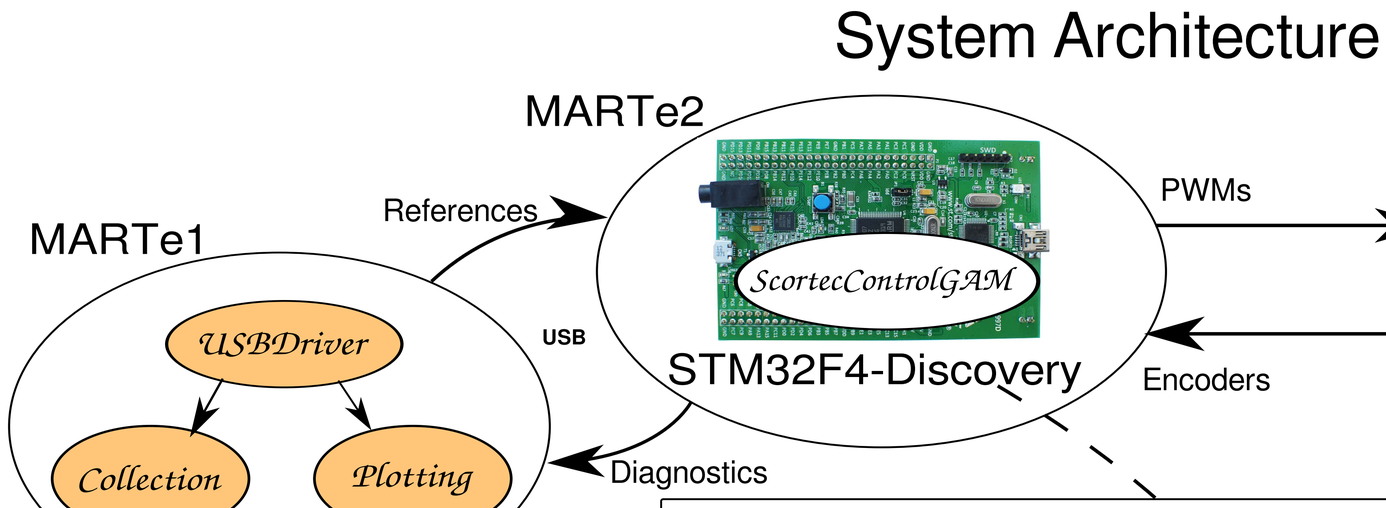
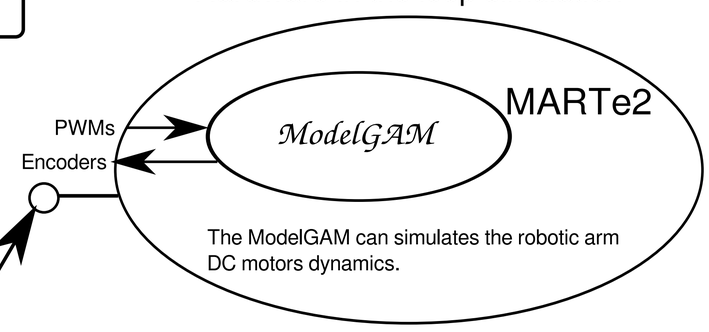
- New version of MARTe C++ framework has been developed with a software architecture aiming at enabling the execution of the same code across different bare-metal systems.
- The control algorithm to drive the DC motors of the robotic arm is based on a switching PID theory.
- Hardware in the loop control system simulation has been implemented.
- This work presents and compares the performance of the control algorithm implementation on a bare-metal and on a FreeRTOS deployment.

System Architecture

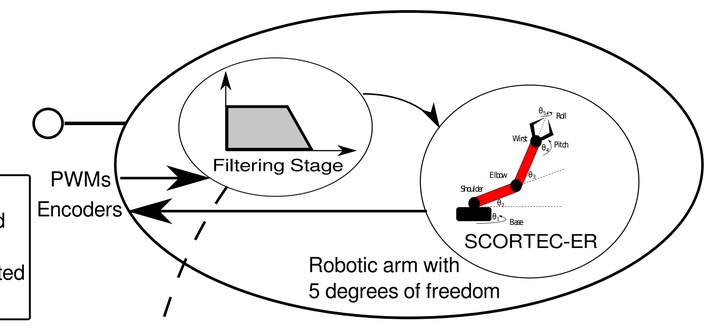


Two applications have been developed:
-**Application-1**: The ScortecControlGAM is directly linked to the hardware encoder counters and PWM signal sources.
-**Application-2**: Performs a hardware-in-the-loop simulation including a ModelGAM interconnected with the ScortecControlGAM to simulate the robotic arm.

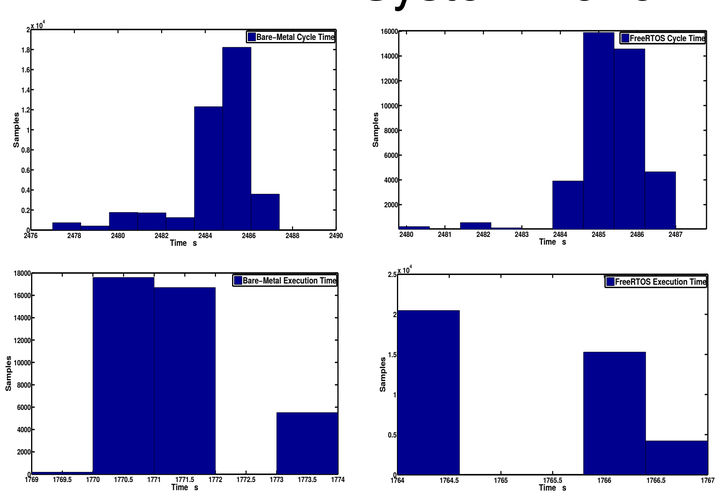
Hardware in the loop simulation



Robot phisically connected



System Performance



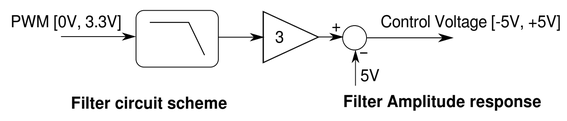
Cycle Time synchronised on 2.5ms

Bare-Metal Mean:2.484ms St.Deviation:2us
FreeRTOS Mean:2.485ms St.Deviation:1us

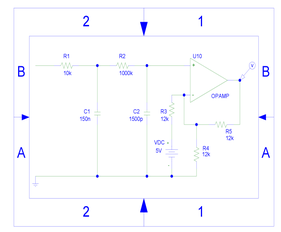
Cycle Execution Time

Bare-Metal Mean:1.772ms St.Deviation:1us
FreeRTOS Mean:1.765ms St.Deviation:1us

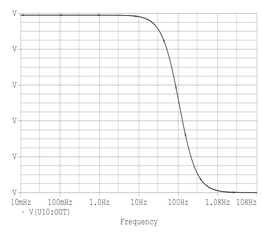
Filtering Stage



Filter circuit scheme



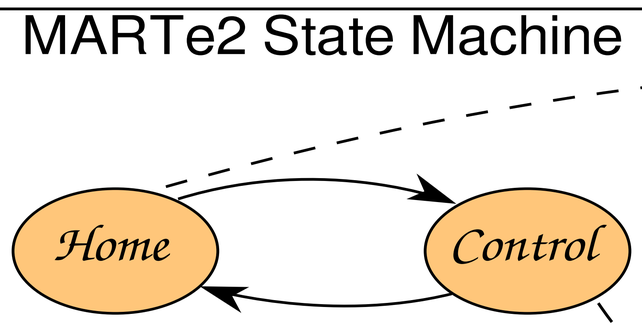
Filter Amplitude response



It is highly recommended to choose a PWM frequency greater than 1KHz.

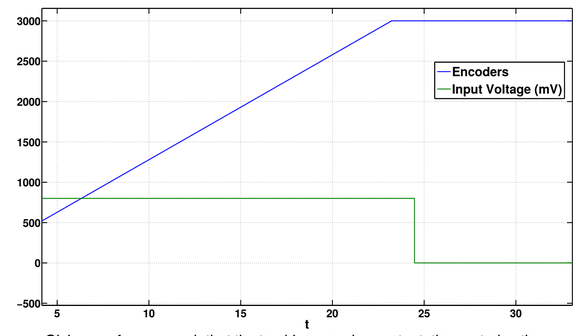
The **ScortecControlGAM** has a different behavior depending on the MARTe2 state.
State-1: the robot is driven to its **home** position (each joint to its limit switch)
State-switch: triggered by the user pressing STM32F4 user button. Encoders are set to zero for each robot joint
State-2: the robot can be controlled by the user.

MARTe2 State Machine



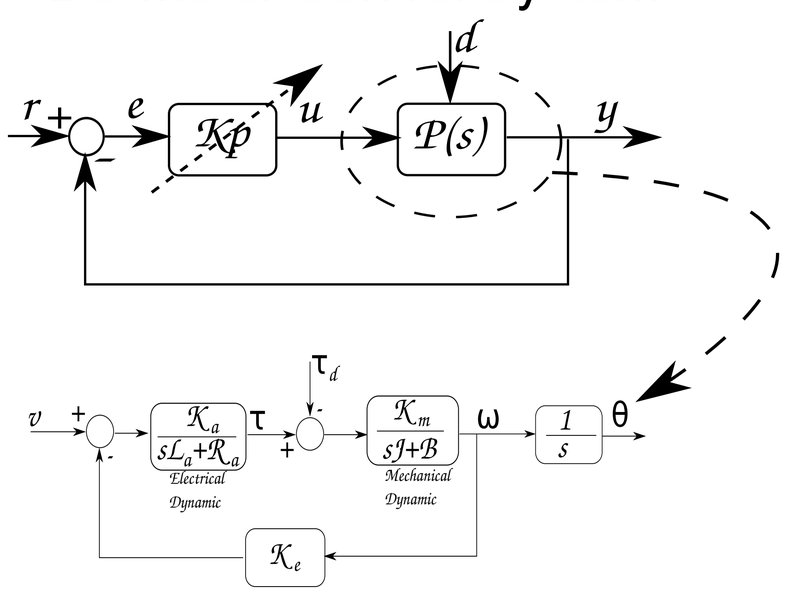
Hardware in the loop simulation

Home Procedure



Giving a reference such that the tracking error is constant, the control action brings the joint to its limit switch and then becomes zero.

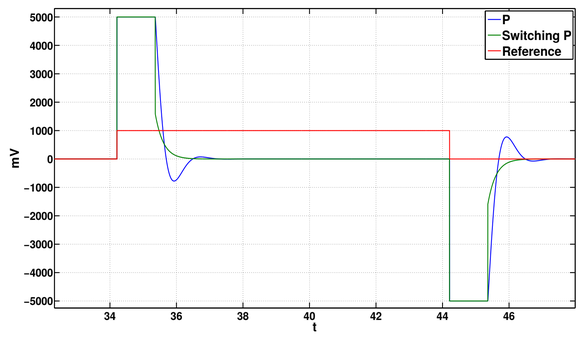
DC Motor Control System



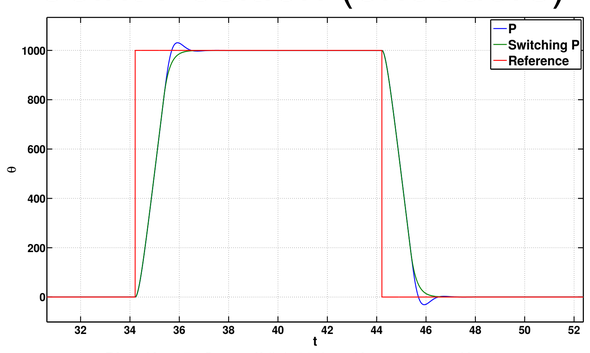
L_a, R_a = Motor armature intuctance and resistance
J = Momentum of Inertia
B = Viscosus friction
τ_d = Disturbance torque

K_e = Motor speed constant
K_a = Motor torque constant
K_m= Motor mechanical constant
K_p = Proportional controller gain

Input Voltage (mV)



Joint Position (encoders)



Blue: Kp=25 **Green**: if (|e|>200) --> Kp=25; else --> Kp =8

- FreeRTOS performance figures similar to Bare-Metal.
- Switching proportional controller can improve the transient responce performance (less overshoot, higher convergence speed).
- The same infrastructure can be used to develop similar real-time applications using this ecosystem.