ENPM667 Project 1

Adaptive Control of Time-Varying Parameter Systems With Asymptotic Tracking

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Content:

Introduction

Paper Selection:
Adaptive Control of Time-Varying Parameter Systems With Asymptotic Tracking
Authors :Omkar Sudhir Patil ,, Runhan Sun ,Shubhendu Bhasin , and Warren E. Dixon .

Motivation:

To develop a approach to converge the asymptotic error of a non linear dynamical system with linearly parameterizable uncertain time-varying parameters.

Workflow

Initial Workflow:

Getting all the resources and references required to understand the paper.

Organizing and splitting the resources among the group to get brief information of individual topics

Debriefing the important concepts and methods.

Introducing prerequisites for the paper

We researched about the following important topics to start the paper

Nonlinear systems

Time Varying Uncertainties

Euler-Lagrange Equations

Dynamic Model

Stability of System

Lyapunov Stability

UUB(Uniform Ultimate Boundedness)

Nonlinear Systems

We are considering our system as nonlinear i.e the output change is not proportional to the input. Further the system parameters are uncertain and unknown i.e the parameters may or may not affect the output of the system. In such systems it is difficult to apply a control input to get a desired output without having additional error reducing methods that will be discussed in subsequent analysis.

Time -Varying Uncertainties

Time varying uncertainties are the disturbances that are introduced in the system that are not constant . The constant uncertainties can be compensated by a equivalent constant input whenever such uncertainties occur however the time varying nature of such uncertainties makes it difficult to predict the values for future time intervals. This requires a adaptive control system that we will be discussing in the further section.

Euler Lagrange Equations

Euler–Lagrange equations are a system of second-order ordinary differential equations whose solutions are stationary points of the given action functional. It is equivalent to Newton's laws of motion.This is particularly useful when analyzing systems whose force vectors are particularly complicated. It has the advantage that it takes the same form in any system of generalized coordinates, and it is better suited to generalizations.Here we develop our dynamical model using the EL dynamical model of the following form.

$$D(q)\ddot{q} + C(q,\dot{q})\dot{q} + g(q) = \tau$$

Dynamic Model

Dynamic models are mathematical representations of some real-world entity, in form of differential equations. The dynamical model setup in our paper is using the Euler-Lagrange method, as discussed in previous slide, which takes into consideration physical parameters like Moment of Inertia,Centrifugal Force,Coriolis Force,etc to make a generalized model for subsequent analysis.

$$M(q(t),t)\ddot{q}(t) + V_m(q(t),\dot{q}(t),t)\dot{q}(t) + G(q(t),t) + F(\dot{q}(t),t) + \tau_d(t) = \tau(t)$$

Details of each terms is mentioned in the report

Stability

Further we discuss the stability of a system. For a system to be stable the output of the system should be bounded for bounded input at each and every instant of time. The notion of boundedness of the system will be further used to define ultimate boundedness in further analysis of the paper.

The stability of a system can be checked using differentiate methods one of them is the Lyapunov Stability Analysis which we will be using to determine the stability of our controller design.

UUB (Uniform Ultimate Bound)

A system generally has two kinds of response transient response that is sometimes a overshoot in the output that results in large bounds for the output function and steady state response after passing of some definite time interval that leads to a much smaller bound on the output. This bound of the output response after a definite time is termed as UUB (Uniform Ultimate Bound).

The mathematical representation is given as

- uniformly ultimately bounded with ultimate bound $\boldsymbol{b}$ if $\exists\ \boldsymbol{b}$ and $\boldsymbol{c}$ and for every $0 < \boldsymbol{a} < \boldsymbol{c},\ \exists\ \boldsymbol{T} = \boldsymbol{T}(\boldsymbol{a}, \boldsymbol{b}) \geq 0$ such that

$$\|\boldsymbol{x}(\boldsymbol{t_0})\| \leq \boldsymbol{a} \ \Rightarrow\ \|\boldsymbol{x}(\boldsymbol{t})\| \leq \boldsymbol{b}, \ \ \forall\, \boldsymbol{t} \geq \boldsymbol{t_0} + \boldsymbol{T}$$

Control Design

The motivation of the controller is to provide an input to the system such that it give a specific desired output. However, in al literal cases the output is not only driven by the controlled input but also some disturbance parameters. So it is necessary to compensate these disturbances to get rid of the error generated by these parameters. Hence we design a controller to detect,predict and resolve the error.

Error

The error can be mathematically represented as the difference between the desired output and the actual output. This error is filtered to make predictions and estimations of the future values of the disturbance parameters that generate the error. Such a system which takes into consideration the error and feeds the input depending upon the error is called as a closed loop system.

Control and Update Law

Once we define the error we further move to develop the control and update law. Here, we use mathematical tools to design the gains of the system which are functions of the unknown uncertain time varying parameters. Such gains are helpful to reduce the error as they come into play only when the system is affected by the disturbances.

Stability Analysis

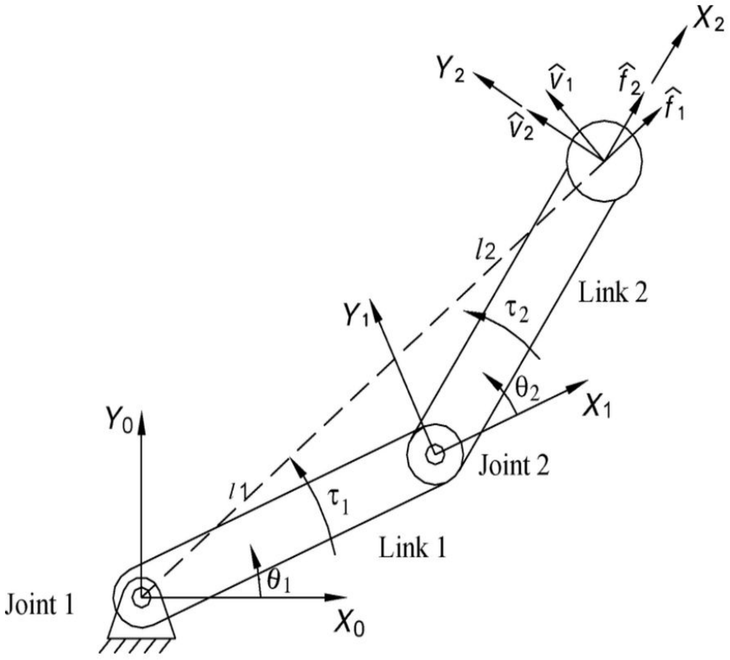
Once we develop our control law we move to to the stability analysis using Lyapunov analysis, and we show that all the outputs of our system are bounded

Also we show that the time-varying uncertain approximation error converges to zero, and thus we get the desired asymptotic convergence of error tracking.

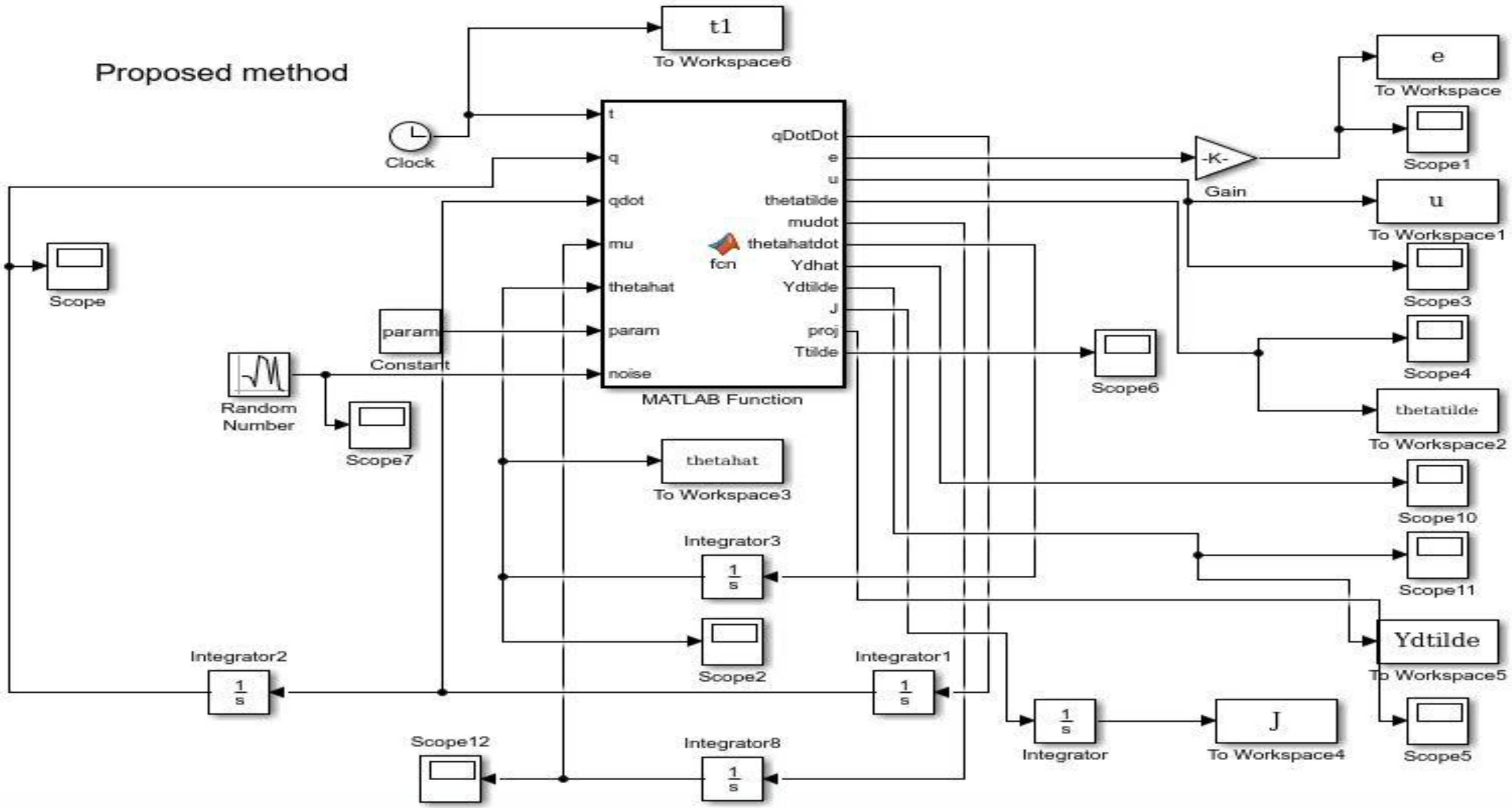
Simulation

Now that we have developed the understanding and validated our control model we further try to implement it on a two link manipulator.

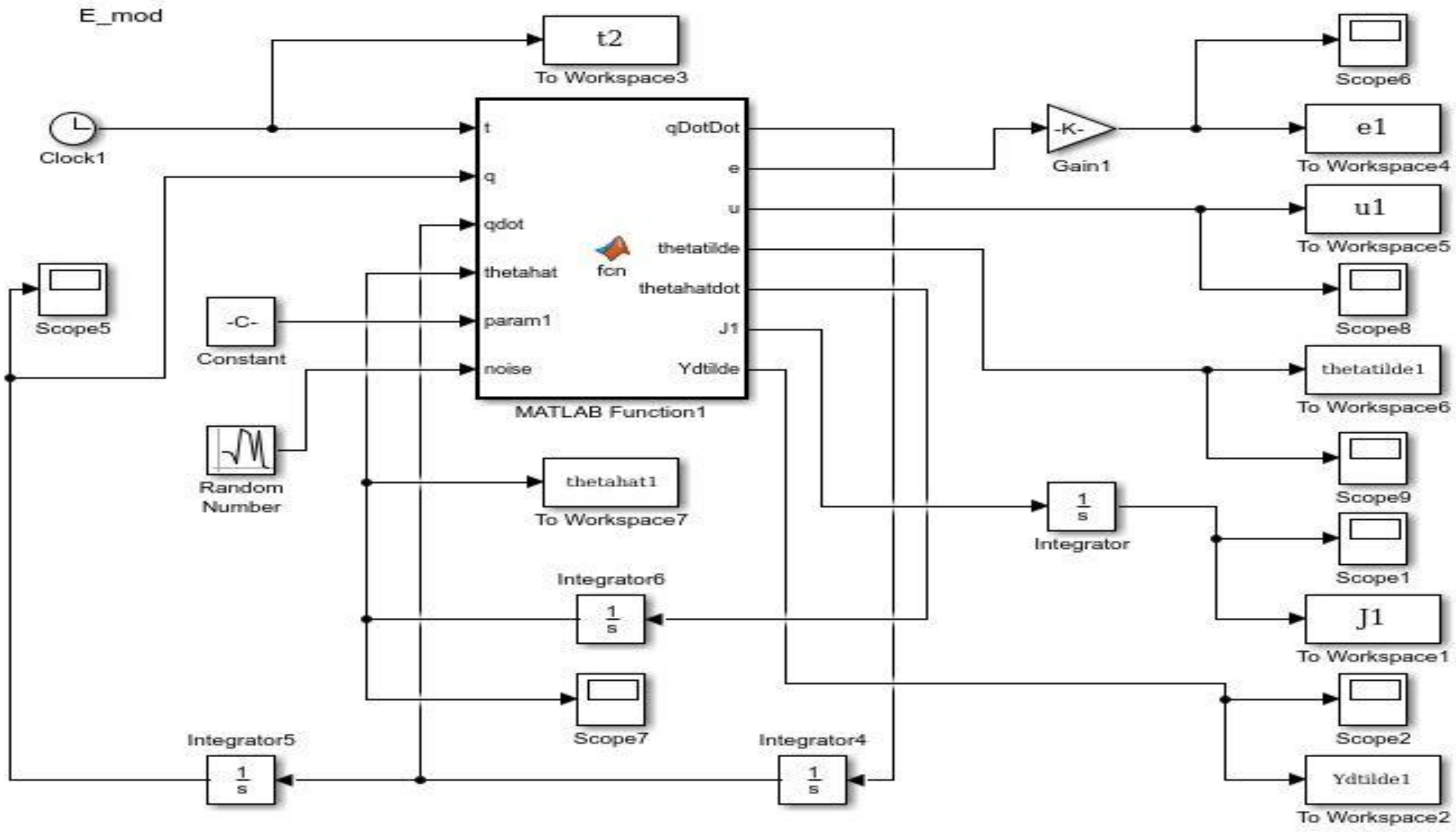
A two link manipulator is a simple robot whose trajectory is controlled by providing torque to its respective joints we add a few uncertain time varying parameter that we design mathematically and input the into the system as disturbances. We compare our model with another model known as a e-modification control model to show how it can be advantageous to use a adaptive control like we have proposed.



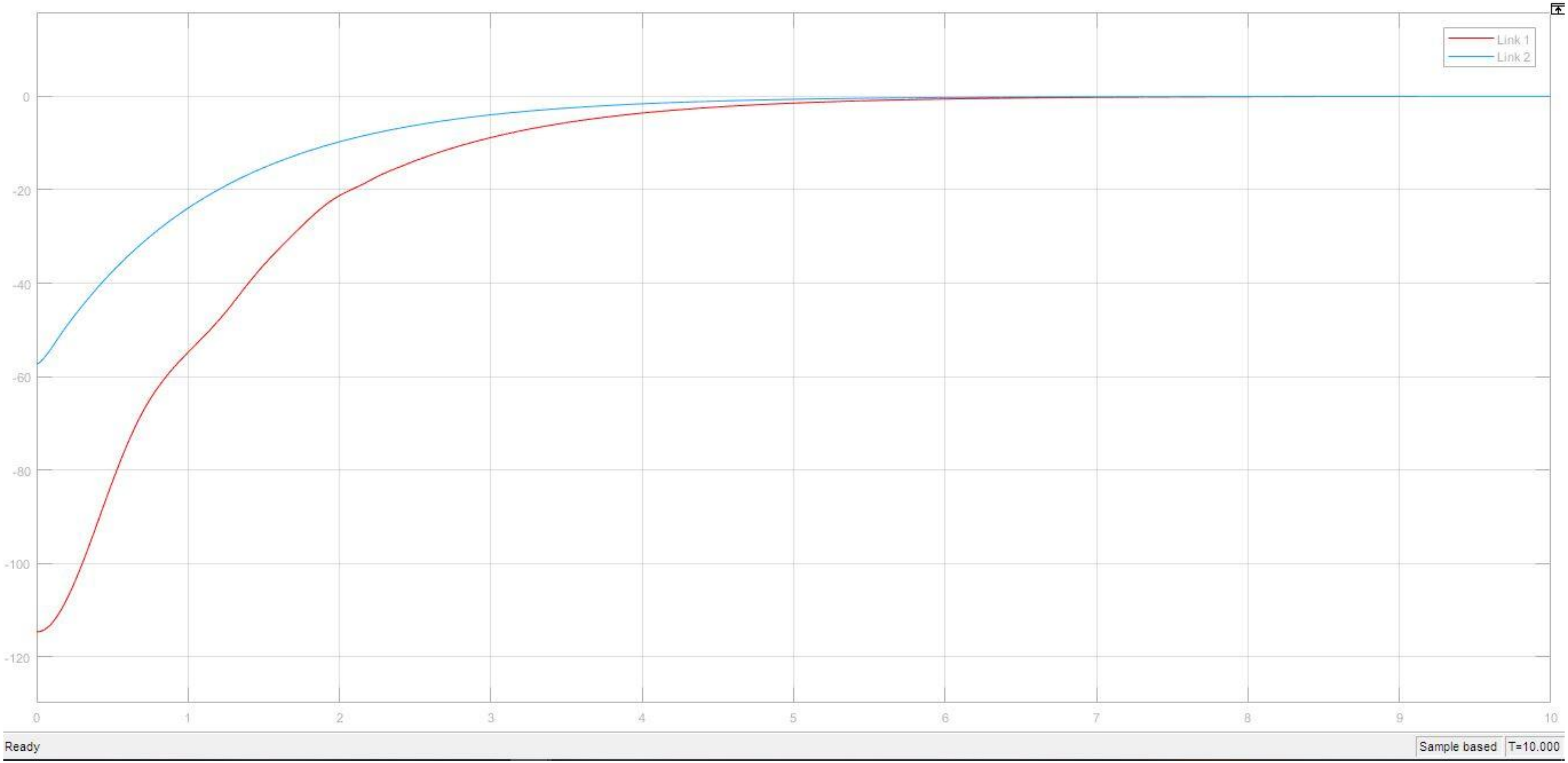
Simulink Model developed for Proposed method



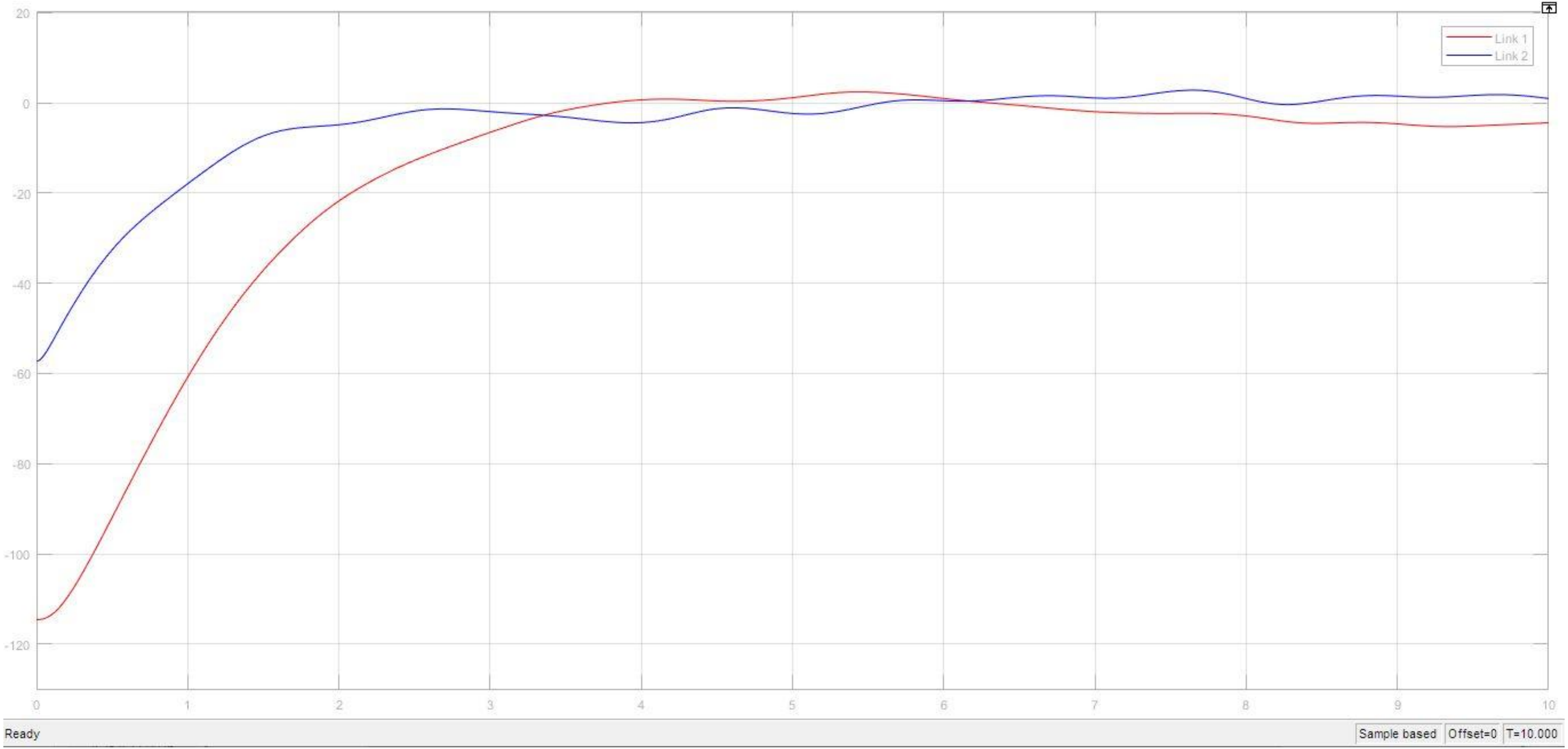
Simulink Model developed for E_mod method



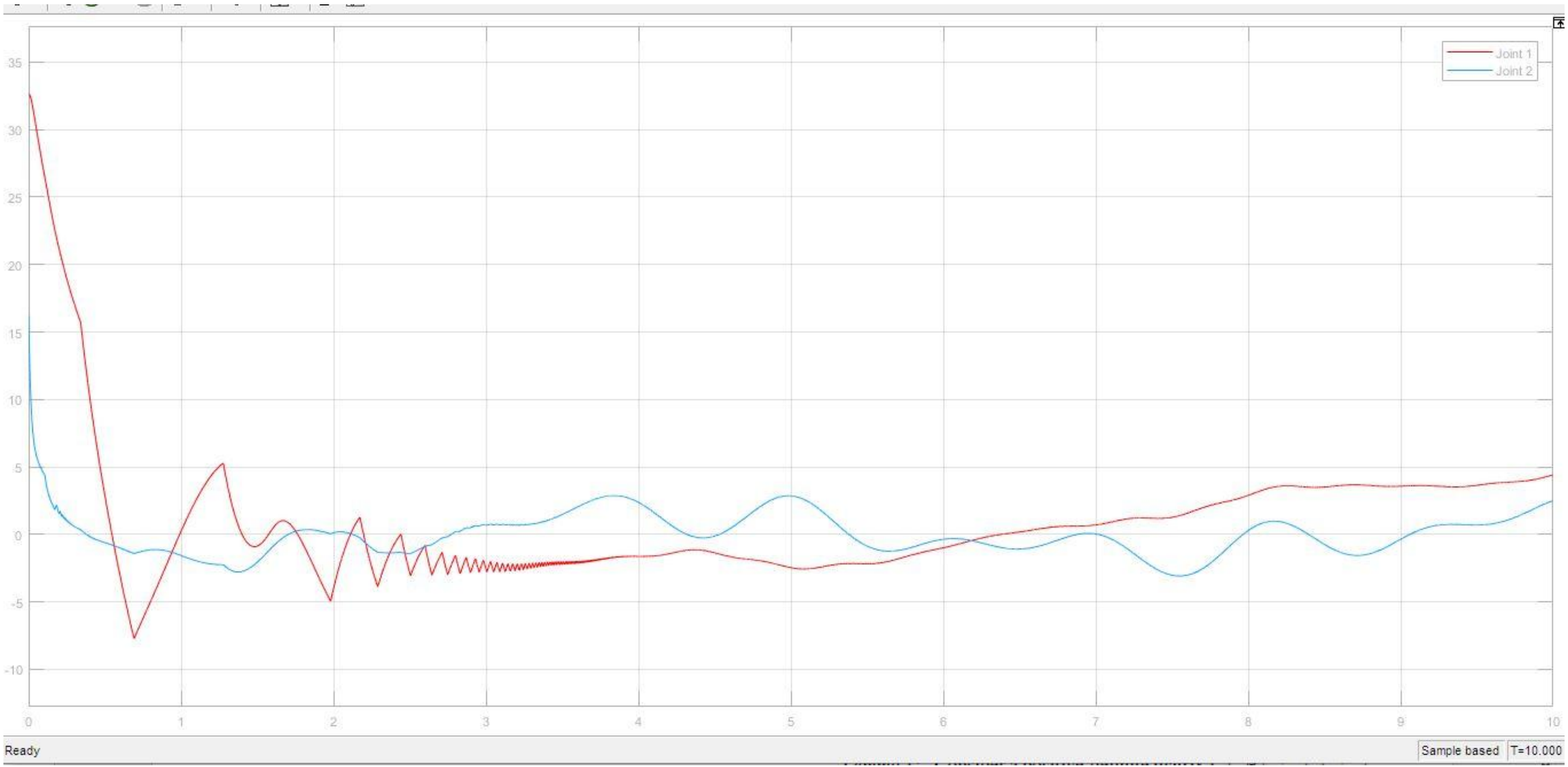
Tracking Error using proposed method:



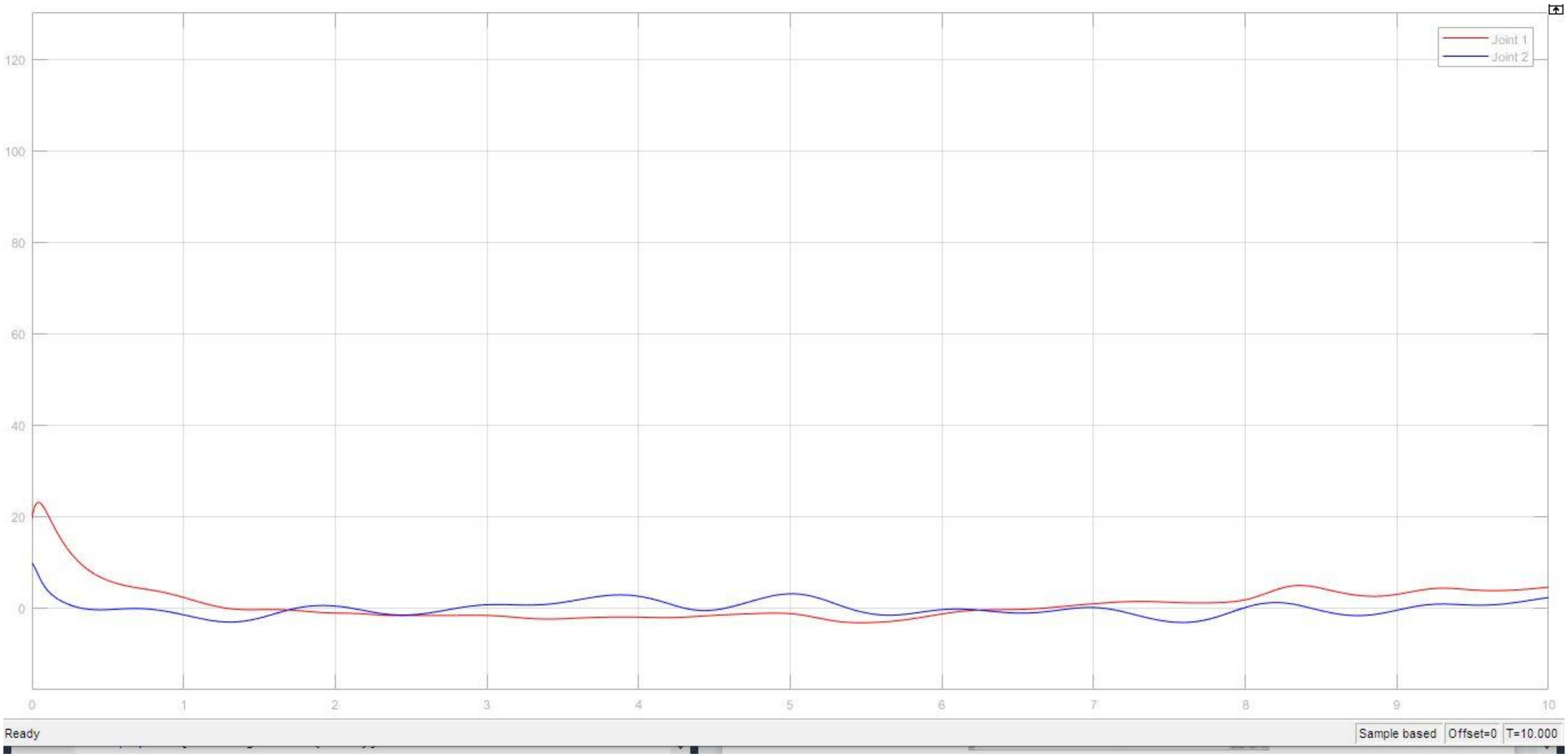
Tracking Error using e_mod method:



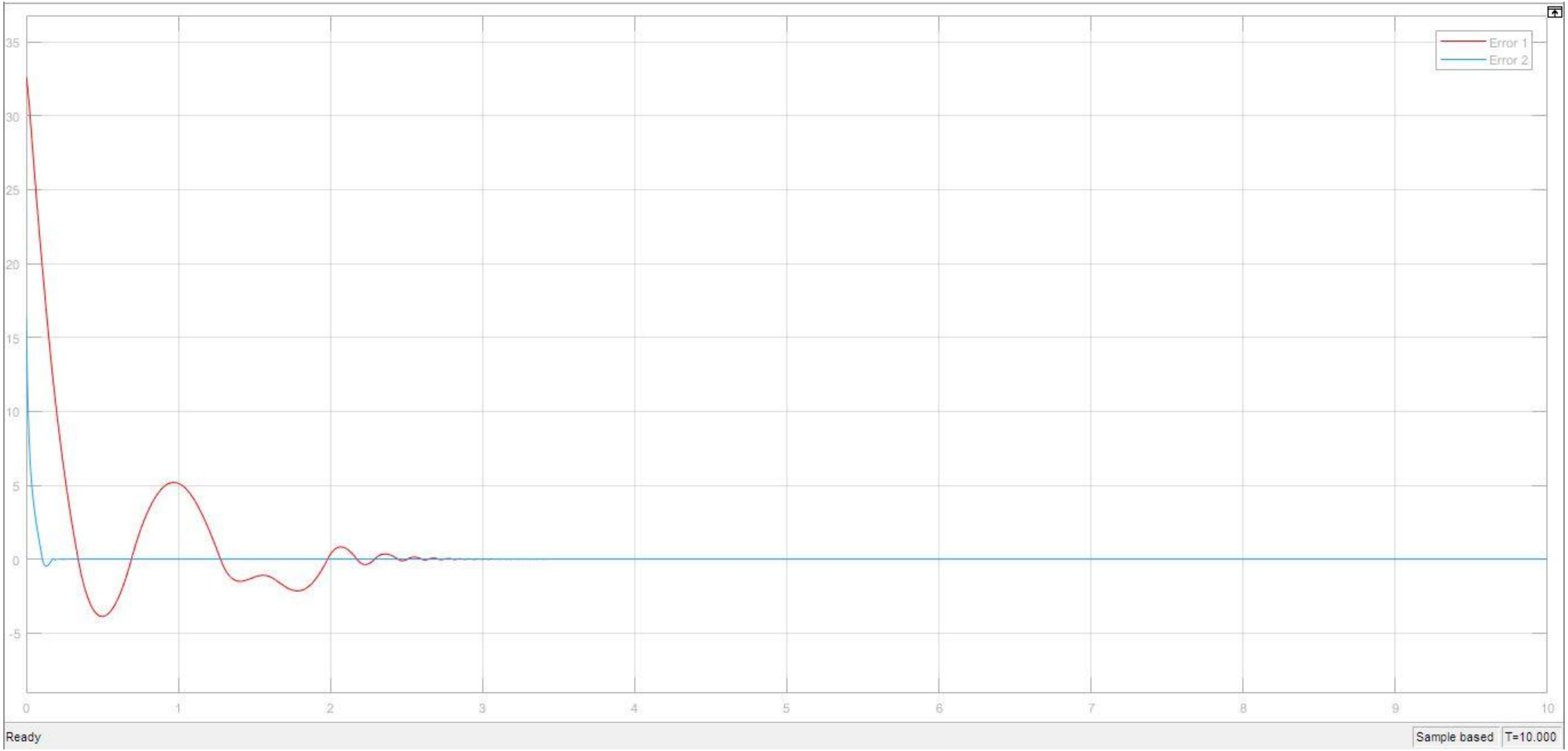
Torque performance proposed method



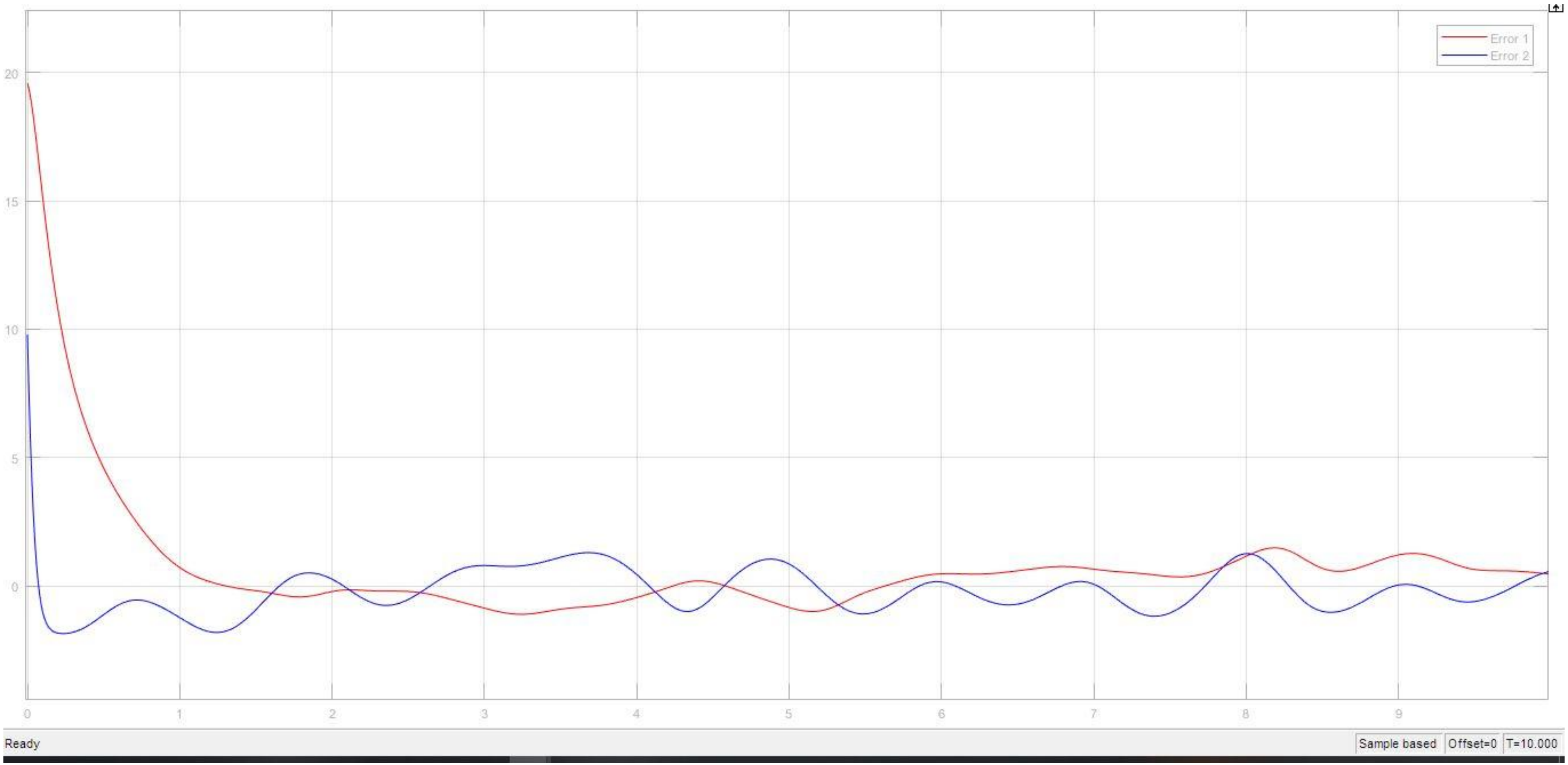
Torque performance e_mod method



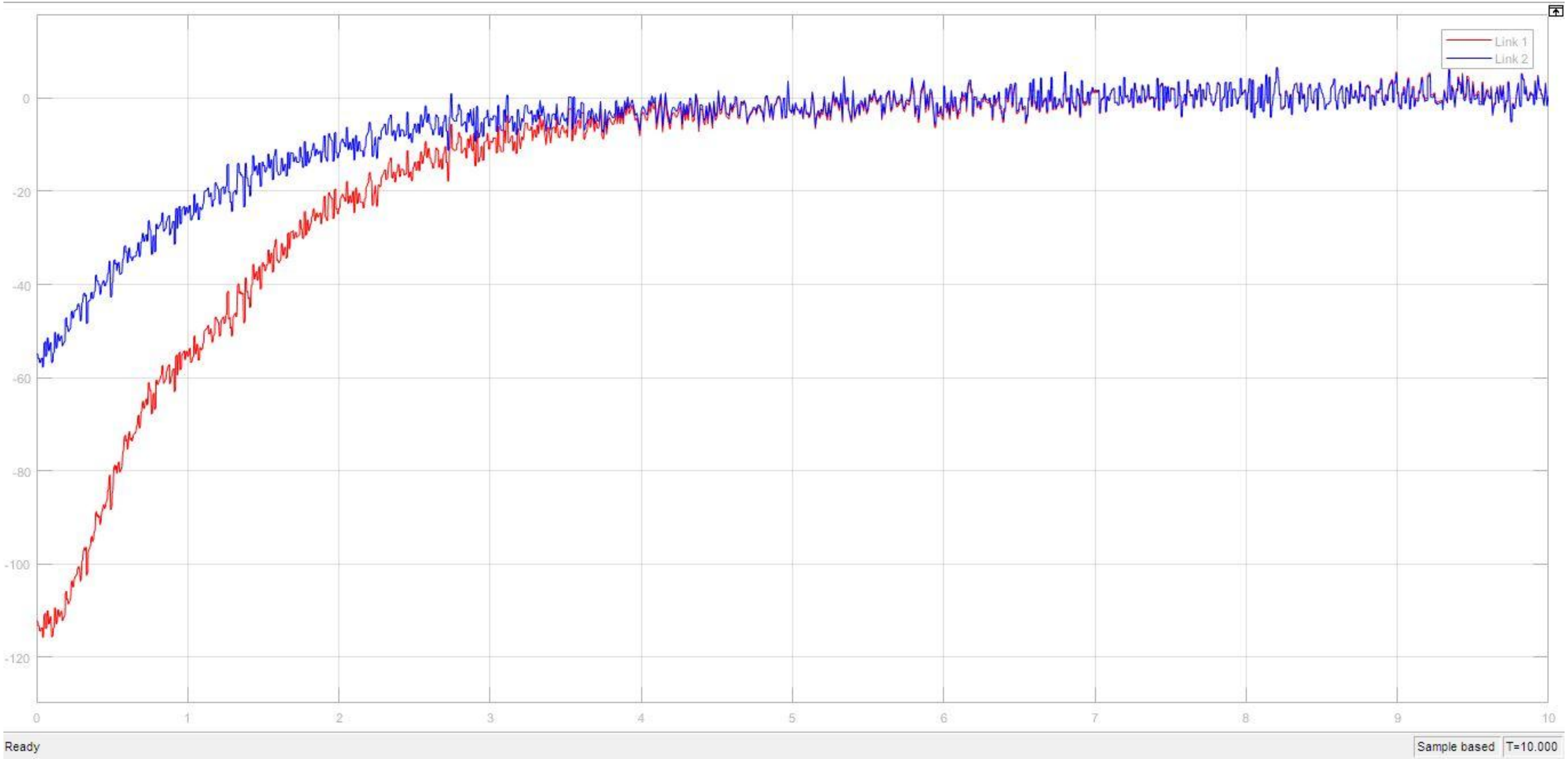
Function estimation error Proposed method



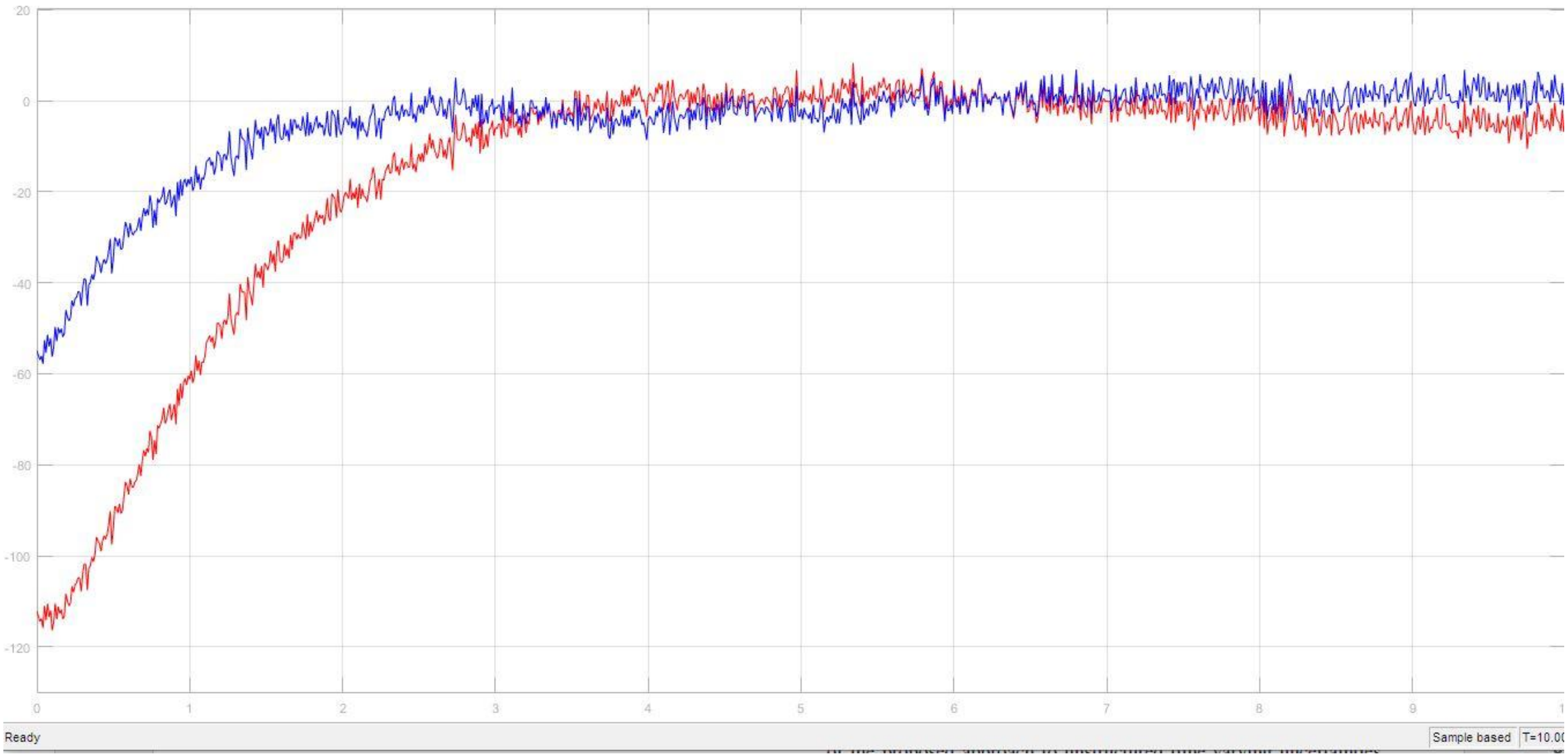
Function estimation error E_mod method



Proposed_method Error Tracking in presence of Additive White Gaussian (AWG) noise



E_mod Error Tracking in presence of AWG noise



Conclusion

A continuous adaptive control design with Asymptotic error tracking was presented.
We achieved this by using an adaptive feedforward term and a specialized feedback term.

We simulated our model for a 2 link manipulator and did the comparison of results with the e_modification control method detailed in the report.

The final results shows the Asymptotic result tracking and better performance than the e_mod method.

Acknowledgement

We thank the authors for their support in helping with the simulation validation.