Nonlinear Tracking Differentiator for Velocity Estimation from Shaft Encoder

Auralius Manurung

RIS-Lab

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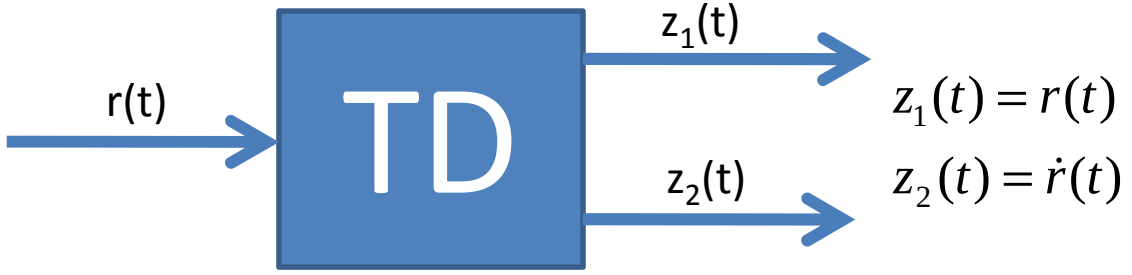
Definition

- Numerically reconstruct velocity / acceleration signal from position measurement.



- Numerical integration has better precision than numerical differentiation in the presence of noise [1,2].

Formulation

- A second-order TD can be expressed as [3]:

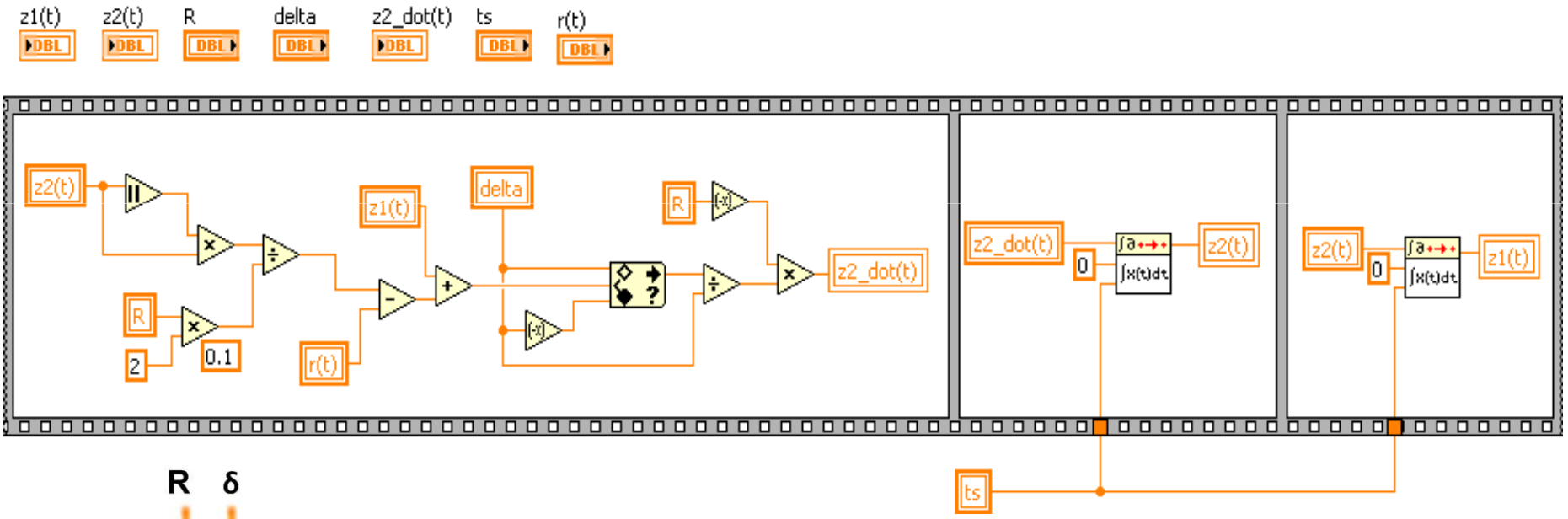
$$\dot{z}_1 = z_2$$
$$\dot{z}_2 = -Rsat\left(z_1 - r + \frac{z_2|z_2|}{2R}, \delta\right)$$

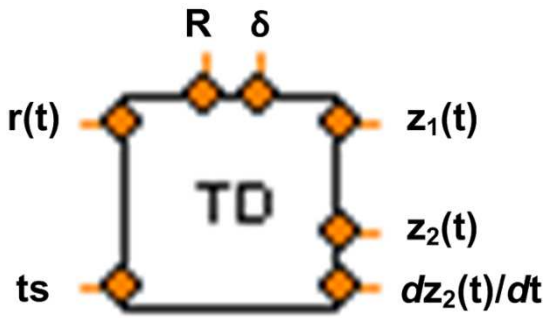
- R is velocity factor and δ is filtering factor. Saturation function sat(A, δ) is nonlinear saturation function:

$$sat(A,\delta)\begin{cases} \mathrm{sgn}(A), |A| > \delta \\ \dfrac{A}{\delta}, |A| < \delta \end{cases}$$

Implementation

- LabVIEW block diagram:



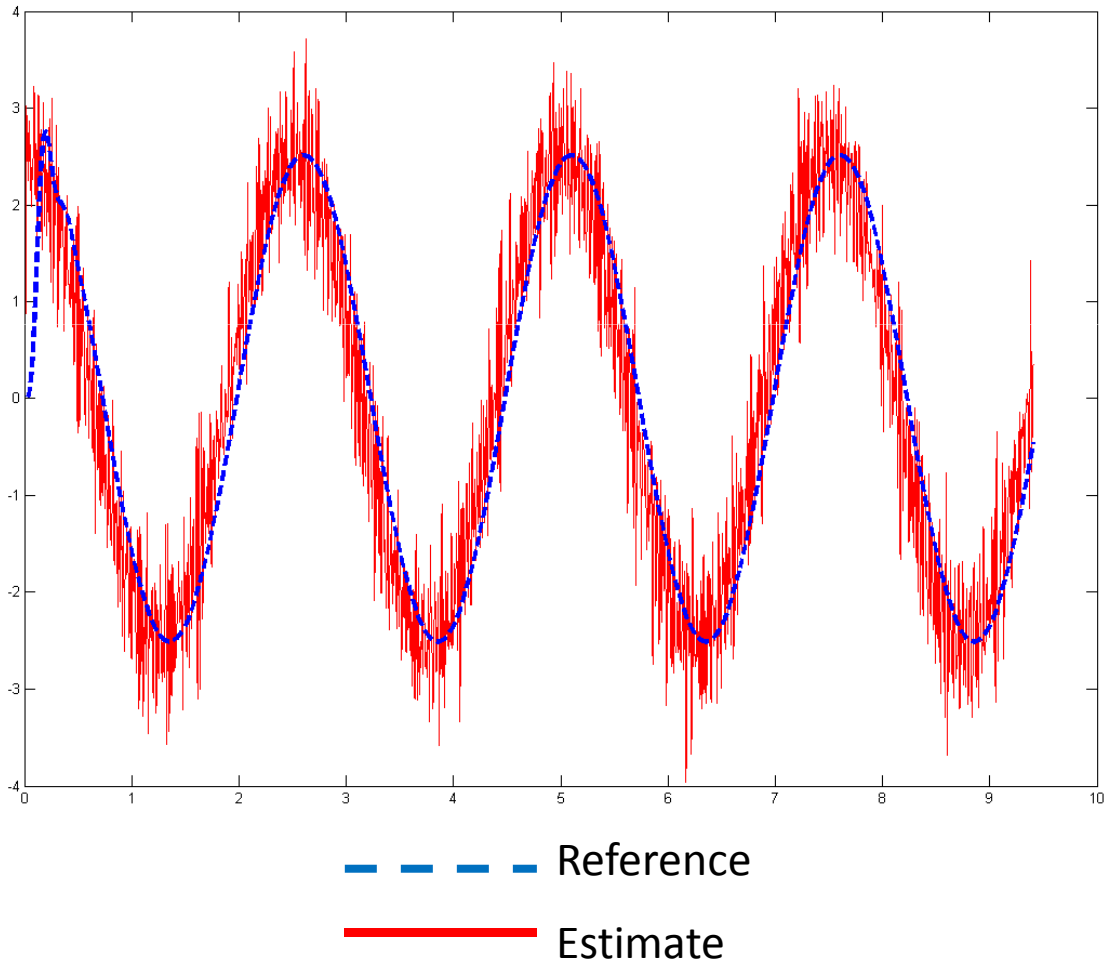


Simulation

- Position signal (sinusoid) corrupted by uniform white noise with maximum amplitude of 0.01.
- TD was set with $R = 20$ and $\delta = 0.001$.
- Simulation was run in LabVIEW at time sampling $Ts = 0.002$.
- TD result was compared with result from backward differentiator with low pass filter.

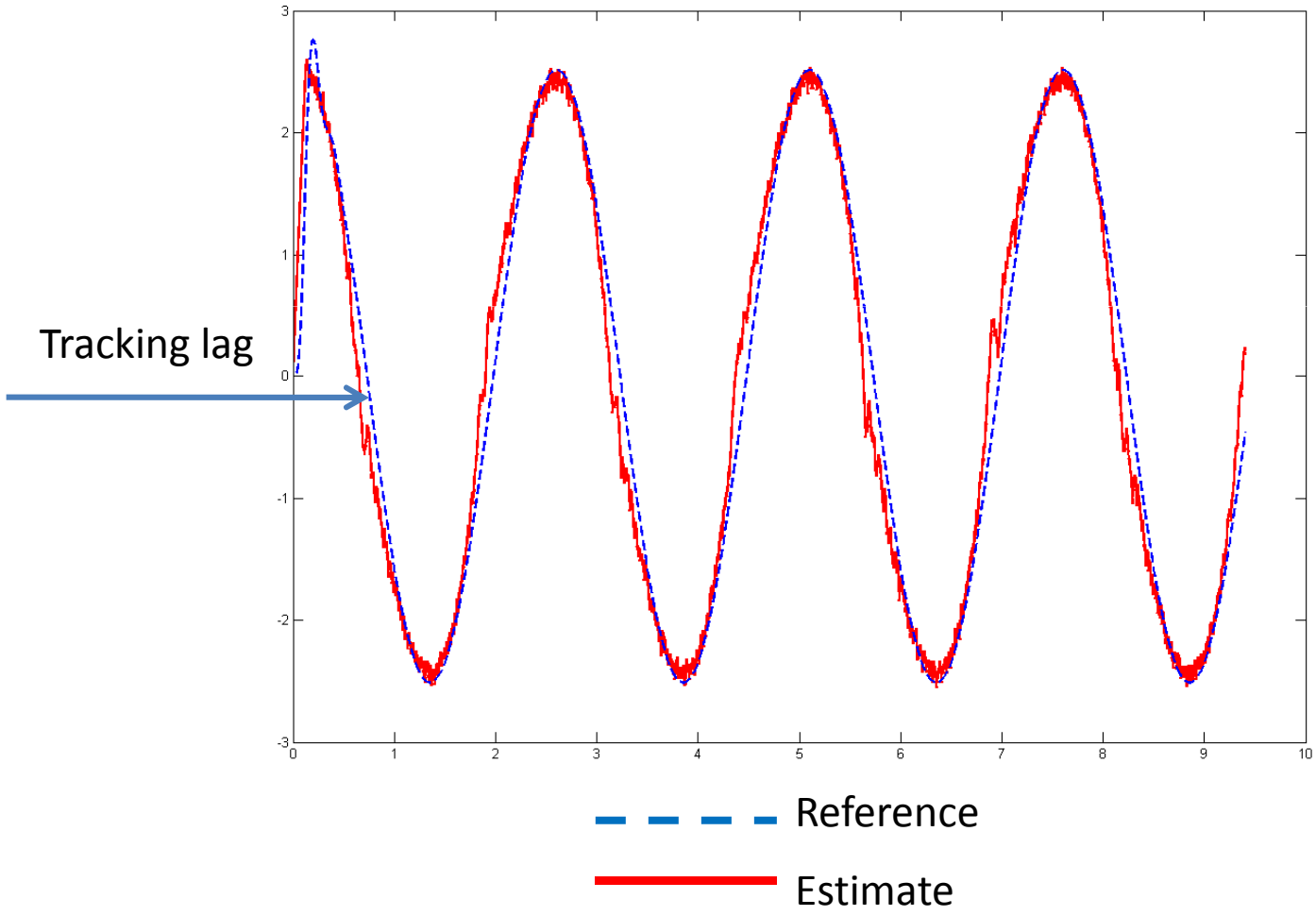
Simulation (cont'd)

Velocity output with backward differentiator and low pass filter:



Simulation (cont'd)

Velocity output with nonlinear tracking differentiator:

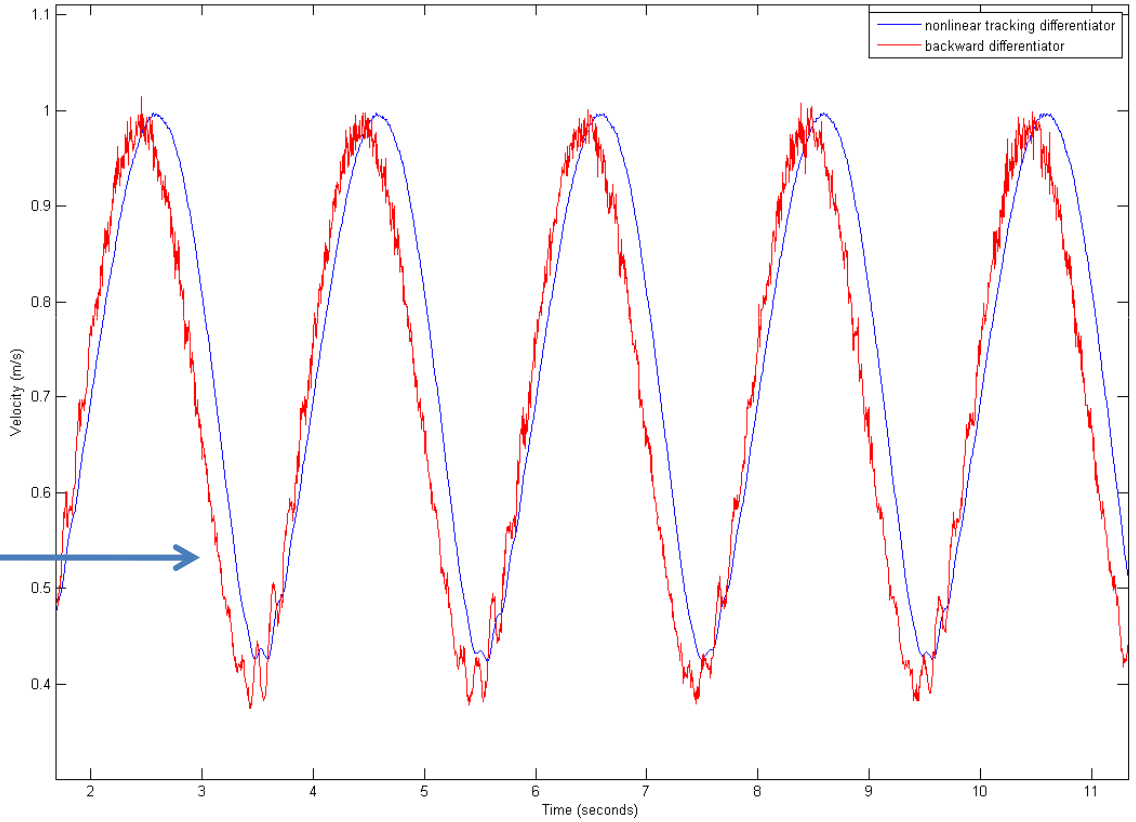


Experiment

- An AC motor was controlled using Sliding Mode Control programmed with LabVIEW on NI CompactRIO.
- Backward differentiator was programmed at FPGA level of NI CompactRIO controller to get a good performance of velocity .
- Result of backward differentiator was then compared with nonlinear tracking differentiator.

Experiment (cont'd)

Tracking lag



Conclusion

- Nonlinear tracking differentiator is simple and practical. It shows a better performance than backward differentiator for velocity estimation.
- Over its good performance, nonlinear tracking differentiator may cause lag when it tracks input signal. Smaller R will increase tracking speed, but tracking precision will be worse.

References

[1] Y. X. Shu, C. H. Zheng, D. Sun, B. Y. Duan, *An Enhanced Fuzzy PD Controller with Two Discrete Nonlinear Tracking Differentiators*, IEE Proc.-Control Theoty Appl., vol. 151, no.6, 2004

[2] Wang Xinhua, Chen Zengqiang, Yuan Zhuzhi, *Design and Analysis for New Discrete Tracking Differentiator*, Appl. Math. Chinese Univ. Ser. B, vol. 18, pp. 214-222, 2003

[3] Y. X. Shu, D. Sun, B. Y. Duan, *Design of An Enhanced Nonlinear PID Controller*, Mechatronics, vol. 15, pp. 1005-1024, 2005

[4] Pierre R. Belanger, *Estimation of Angular Velocity and Acceleration from Shaft Encoder Measurement*, IEEE Int. Conf. On Robotics and Automation, France, 1992

Appendix

- LabVIEW SubVI-file for nonlinear tracking differentiator is available at my website:

  http://sites.google.com/site/auraliusproject