

Robust Zero-Crossing Detection with Persistent Homology

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Nov 11, 2022
DISC 2022
Lansing, MI

Contributors



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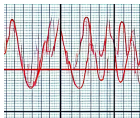
Firas A. Khasawneh



Elizabeth Munch

Motivation

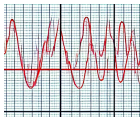
Motivation



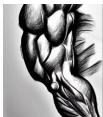
Frequency Determination¹

¹Vladimir Friedman. "A Zero Crossing Algorithm for the Estimation of the Frequency of a Single Sinusoid in White Noise". In: *IEEE Transactions on Signal Processing* 42 (6 1994), pp. 1565–1569. ISSN: 19410476. DOI: 10.1109/78.286978.

Motivation



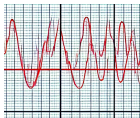
Frequency Determination



Muscle Fatigue²

²Tadashi Masuda, Hisao Miyano, and Tsugutake Sadoyama. "The Measurement of Muscle Fiber Conduction Velocity Using a Gradient Threshold Zero-Crossing Method". In: [IEEE Transactions on Biomedical Engineering BME-29 \(10 1982\)](#), pp. 673–678. ISSN: 15582531. DOI: 10.1109/TBME.1982.324859.

Motivation



Frequency Determination



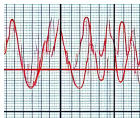
Motor Faults³



Muscle Fatigue

³Abhishek Ukil, Shuo Chen, and Andrea Andenna. "Detection of stator short circuit faults in three-phase induction motors using motor current zero-crossing instants". In: *Electric Power Systems Research* (2011). DOI: [10.1016/j.epsr.2010.12.003](https://doi.org/10.1016/j.epsr.2010.12.003).

Motivation



Frequency Determination



Motor Faults



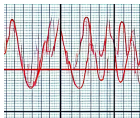
Muscle Fatigue



Speed Measurement⁴

⁴P. Misans and M. Terauds. "CW doppler radar based land vehicle speed measurement algorithm using zero crossing and least squares method". In: 2012, pp. 161–164. ISBN: 9781467327749. DOI: 10.1109/BEC.2012.6376841.

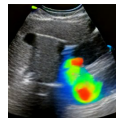
Motivation



Frequency Determination



Motor Faults



Elastography Strain⁵



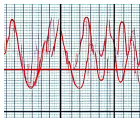
Muscle Fatigue



Speed Measurement

⁵S. Srinivasan and J. Ophir. "A zero-crossing strain estimator for elastography". In: *Ultrasound in Medicine Biology* 29.2 (2003), pp. 227–238. ISSN: 0301-5629. DOI: [https://doi.org/10.1016/S0301-5629\(02\)00697-X](https://doi.org/10.1016/S0301-5629(02)00697-X). URL: <https://www.sciencedirect.com/science/article/pii/S030156290200697X>.

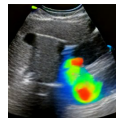
Motivation



Frequency Determination



Motor Faults



Elastography Strain



Muscle Fatigue



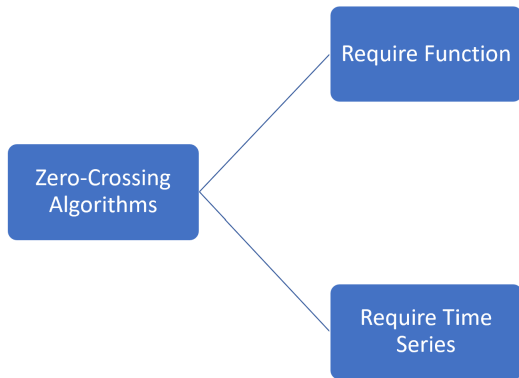
Speed Measurement

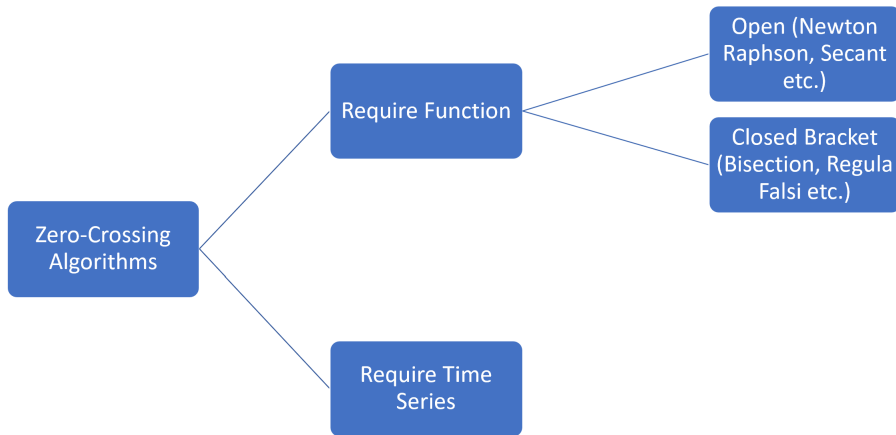


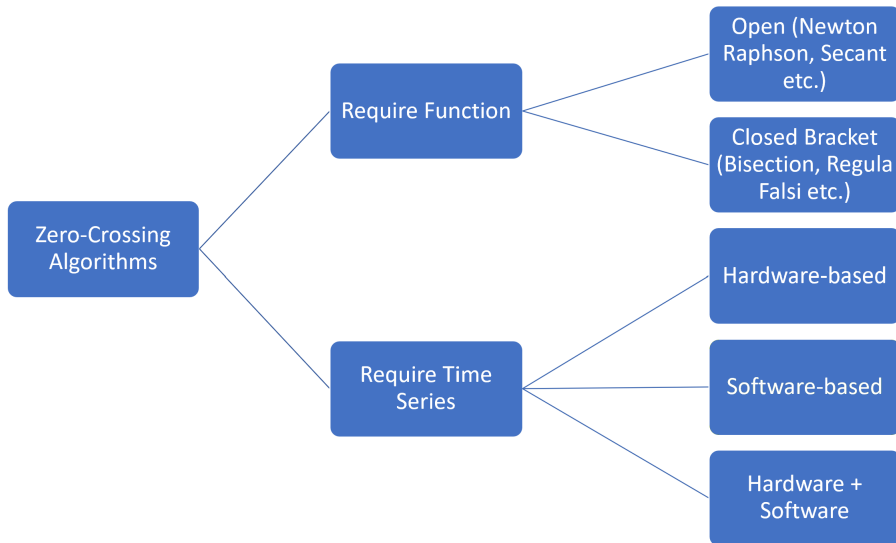
Character Recognition⁶

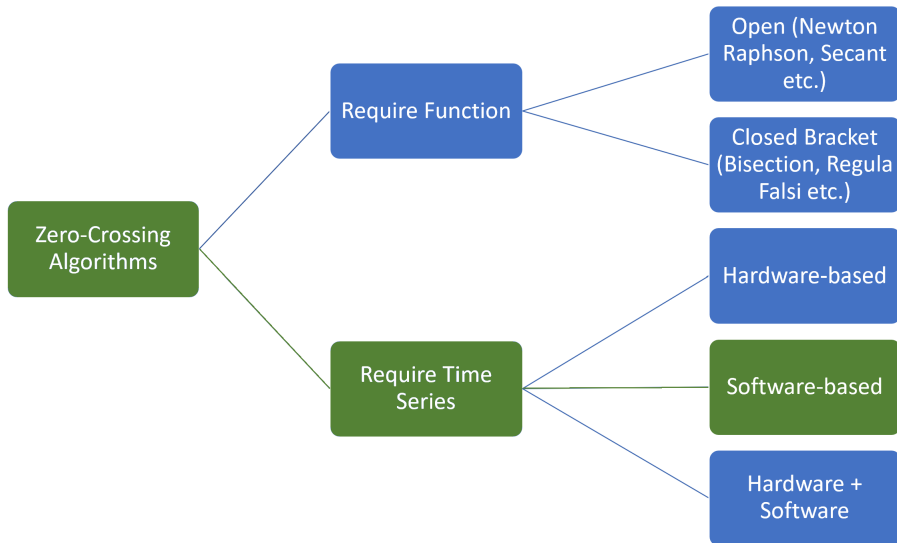
⁶G. Raju. "Recognition of unconstrained handwritten Malayalam characters using zero-crossing of wavelet coefficients". In: 2006, pp. 217–221. ISBN: 142440715X. DOI: 10.1109/ADCOM.2006.4289886.

Zero-Crossing
Algorithms



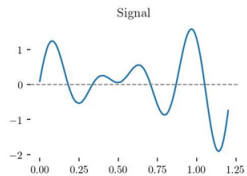




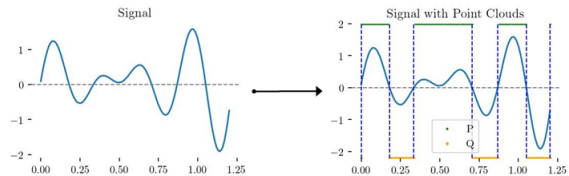


0-Dimensional Persistent Homology

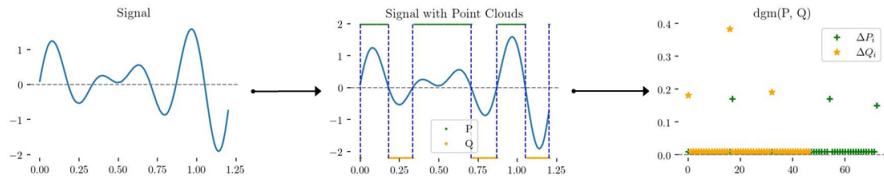
Algorithm



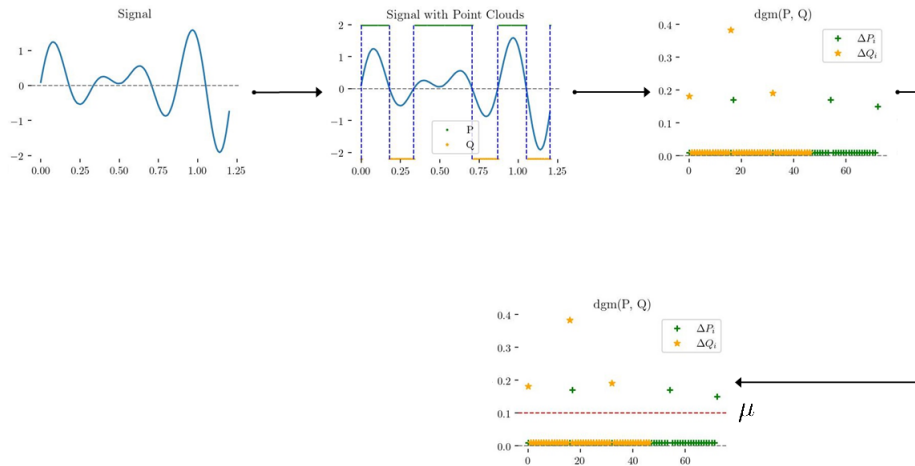
Algorithm



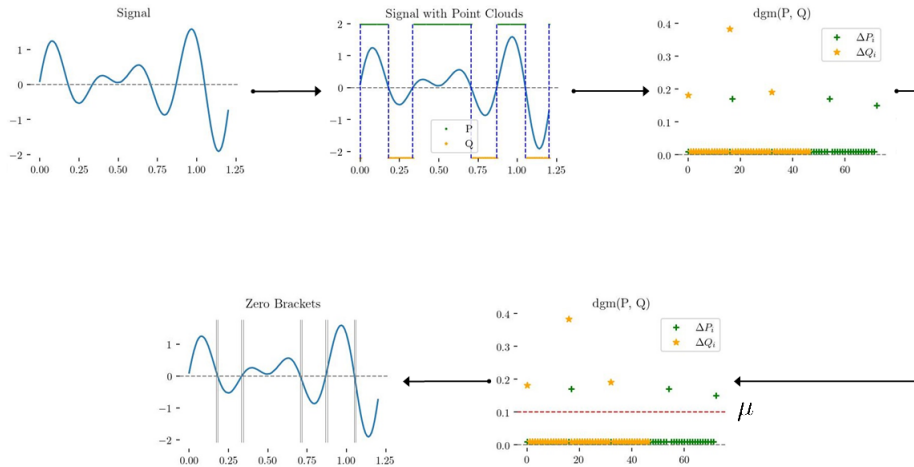
Algorithm



Algorithm



Algorithm



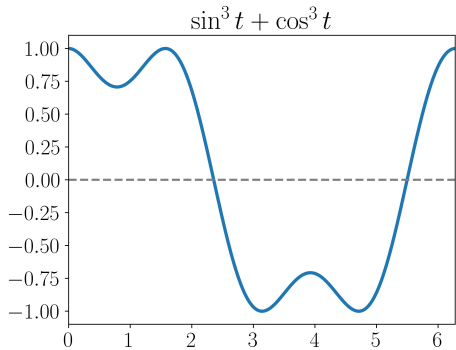
Effect of Persistence Threshold

Zero Crossing Detection in Digitized Signals¹

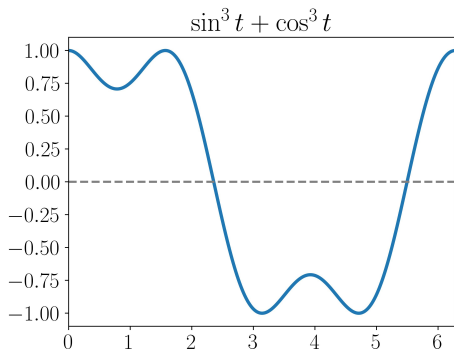
¹A. Molinaro and Ya.D. Sergeyev. "An efficient algorithm for the zero crossing detection in digitized measurement signal". In: [Measurement](#) 30.3 (2001), pp. 187–196. DOI: 10.1016/s0263-2241(01)00002-1.

Comparison

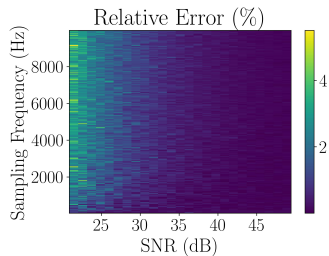
Comparison



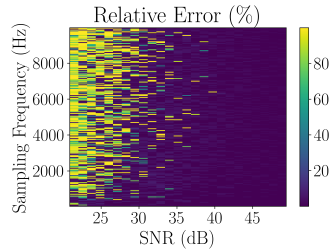
Comparison



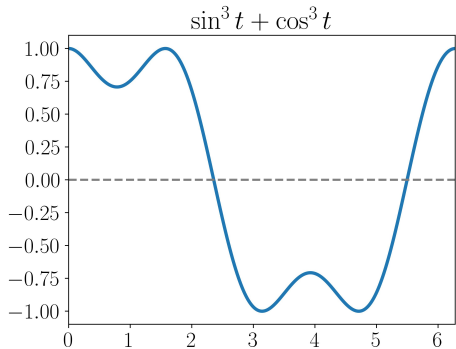
0D Persistence



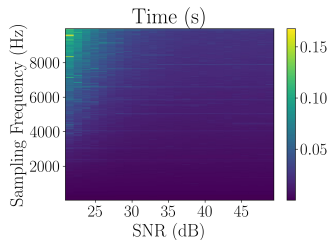
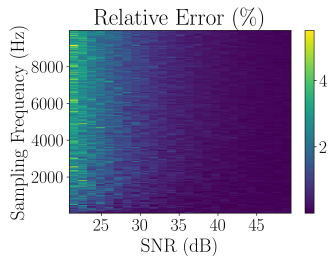
Molinaro et. al



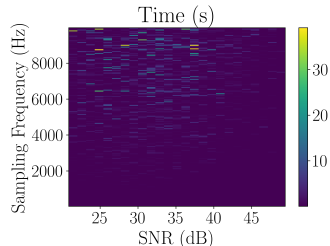
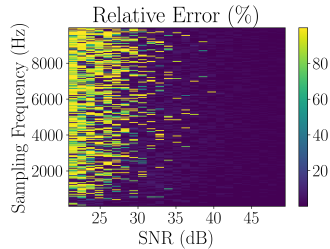
Comparison



0D Persistence



Molinaro et. al



Conclusion

Conclusion

Pros

Conclusion

Pros

Generally faster

Conclusion

Pros

Generally faster

Lower relative error

Conclusion

Pros

Generally faster

Lower relative error

All zeros

Conclusion

Pros

Generally faster

Lower relative error

All zeros

Cons

Conclusion

Pros

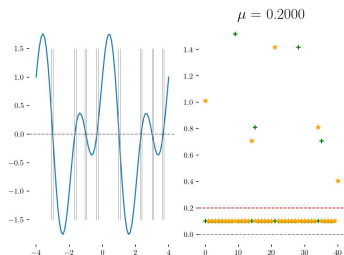
Generally faster

Lower relative error

All zeros

Cons

Critical μ



Conclusion

Pros

Generally faster

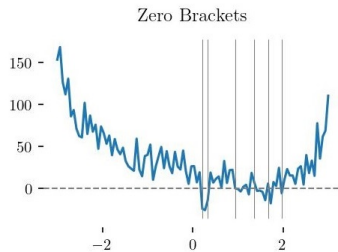
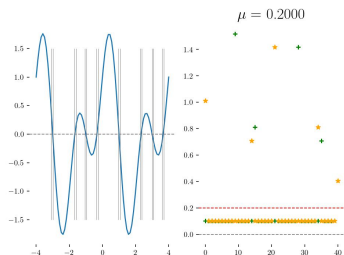
Lower relative error

All zeros

Cons

Critical μ

Artificial root



Thank you!