

Universidade Federal de Minas Gerais
Escola de Engenharia
Programa de Pós-Graduação em Engenharia Elétrica
Laboratório de Modelagem, Análise e Controle de Sistemas Não-Lineares

SENSOR FUSION FOR IRREGULAR SAMPLED SYSTEMS

Taiguara Melo Tupinambás

Dissertação apresentada ao Programa de Pós-Graduação em Engenharia Elétrica da Universidade Federal de Minas Gerais como requisito parcial para a obtenção do grau de Mestre em Engenharia Elétrica

Orientador: Prof. Dr. Bruno Otávio Soares Teixeira

Co-Orientador: Prof. Dr. Leonardo Antônio Borges Tôrres

Belo Horizonte - MG

2018

Contents

1	Introduction	2
1.1	<i>Motivations</i>	2
1.2	<i>Problem Formulation</i>	2
1.3	<i>Objectives</i>	2
1.4	<i>Thesis Structure</i>	2
2	Literature Review	3
2.1	<i>Multi-Sensor Sytems</i>	3
2.2	<i>Irregular Sampled Systems</i>	3
2.3	<i>State Estimation Under Irregular Sampling</i>	3
2.3.1	Known Measurement Instance	3
2.3.2	Unknown Measurement Instance	3
3	Material and Methods	4
3.1	<i>Unscented Kalman Filter</i>	4
3.2	<i>Estimation With Timestamp</i>	4
3.3	<i>Estimation Without Timestamp</i>	4
4	Results	5
4.1	<i>Unicycle Position Estimation</i>	5
4.1.1	Measurement Signal-to-Noise Ratio Variation	5
4.1.2	Average Sampling Rate Variation	5
4.1.3	Regular and Average Irregular Time Interval Relation Variation . .	5
5	Conclusion	6
	Bibliography	7

1 Introduction

1.1 Motivations

1.2 Problem Formulation

Apresentação matemática do problema, de forma ampla. Descrever as premissas adotadas.

1.3 Objectives

1 frase para o objetivo geral Objetivos específicos

1.4 Thesis Structure

2 Literature Review

2.1 Multi-Sensor Systems

2.2 Irregular Sampled Systems

2.3 State Estimation Under Irregular Sampling

2.3.1 Known Measurement Instance

2.3.2 Unknown Measurement Instance

3 Material and Methods

3.1 Unscented Kalman Filter

3.2 Estimation With Timestamp

3.3 Estimation Without Timestamp

4 Results

4.1 *Unicycle Position Estimation*

4.1.1 Measurement Signal-to-Noise Ratio Variation

4.1.2 Average Sampling Rate Variation

4.1.3 Regular and Average Irregular Time Interval Relation Variation

5 Conclusion

Bibliography

- ANXI, Y. et al. A Unified Out-of-sequence Measurements Filter. In: *IEE International Radar Conference*. [S.l.: s.n.], 2005. v. 00, n. C. Nenhuma citação no texto.
- BAR-SHALOM, Y. Update with out-of-sequence measurements in tracking: Exact solution. *Proceedings of SPIE*, v. 4048, n. 3, p. 769–778, 2000. Nenhuma citação no texto.
- BAR-SHALOM, Y.; Rong Li, X.; KIRUBARAJAN, T. *Estimation with Applications to Tracking and Navigation: Theory Algorithms and Software*. [S.l.]: John Wiley & Sons, Inc, 2001. 548 p. Nenhuma citação no texto.
- FATEHI, A.; HUANG, B. Kalman filtering approach to multi-rate information fusion in the presence of irregular sampling rate and variable measurement delay. *Journal of Process Control*, Elsevier Ltd, v. 53, p. 15–25, 2017. Nenhuma citação no texto.
- GOPALAKRISHNAN, A.; KAISARE, N. S.; NARASIMHAN, S. Incorporating delayed and infrequent measurements in Extended Kalman Filter based nonlinear state estimation. *Journal of Process Control*, v. 21, p. 119–129, 2010. Nenhuma citação no texto.
- HALL, D. L.; LLINAS, J. An introduction to multisensor data fusion. *Proceedings of the IEEE*, v. 85, n. 1, p. 6–23, 1997. Nenhuma citação no texto.
- JING, Z.; PAN, H.; QIN, Y. Current progress of information fusion in China. *Chinese Science Bulletin*, v. 58, n. 36, p. 4533–4540, dec 2013. Nenhuma citação no texto.
- JULIER, S. J.; UHLMANN, J. K. Fusion of time delayed measurements with uncertain time delays. In: *Proceedings of the 2005 American Control Conference*. [S.l.: s.n.], 2005. p. 4028–4033. Nenhuma citação no texto.
- KAWAGUCHI, T.; INOUE, M.; ADACHI, S. State Estimation under Lebesgue Sampling and an Approach to Event-Triggered Control. *SICE Journal of Control, Measurement, and System Integration*, v. 10, n. 3, p. 259–265, 2017. Nenhuma citação no texto.
- KHALEGHI, B. et al. Multisensor data fusion: A review of the state-of-the-art. *Information Fusion*, Elsevier B.V., v. 14, n. 1, p. 28–44, 2013. Nenhuma citação no texto.
- LI, W.; SHAH, S. L.; XIAO, D. Kalman Filters for Non-Uniformly Sampled Multirate Systems. In: *IFAC Proceedings Volumes*. [S.l.]: IFAC, 2005. v. 38, n. 1, p. 99–104. Nenhuma citação no texto.
- LIANG, Y.; CHEN, T.; PAN, Q. Multi-rate optimal state estimation. *International Journal of Control*, v. 82, n. 11, p. 2059–2076, 2009. Nenhuma citação no texto.
- LIU, Q. et al. A survey of event-based strategies on control and estimation. *Systems Science and Control Engineering*, v. 2, n. 1, p. 90–97, dec 2014. Nenhuma citação no texto.
- MICHELI, M.; JORDAN, M. I. Random sampling of a continuous-time stochastic dynamical system. In: *Proc. of the 15th International Symposium on the Mathematical Theory of Networks and Systems*. [S.l.: s.n.], 2002. p. 1–15. Nenhuma citação no texto.

MOAYEDI, M.; FOO, Y. K.; SOH, Y. C. Filtering for networked control systems with single/multiple measurement packets subject to multiple-step measurement delays and multiple packet dropouts. *International Journal of Systems Science*, v. 42, n. 3, p. 335–348, 2011. Nenhuma citação no texto.

PEÑARROCHA, I.; SANCHIS, R.; ROMERO, J. A. State estimator for multisensor systems with irregular sampling and time-varying delays. *International Journal of Systems Science*, v. 43, n. 8, p. 1441–1453, 2012. Nenhuma citação no texto.

SCHENATO, L. et al. Foundations of Control and Estimation Over Lossy Networks. *Proceedings of the IEEE*, v. 95, n. 1, p. 163–187, jan 2007. Nenhuma citação no texto.

SHENG, J.; CHEN, T.; SHAH, S. L. Generalized predictive control for non-uniformly sampled systems. *Journal of Process Control*, v. 12, p. 875–885, 2002. Nenhuma citação no texto.

TEIXEIRA, B. O. S. *Constrained state estimation for linear and nonlinear dynamic systems*. Tese (Doutorado) — Universidade Federal de Minas Gerais, 2008. Nenhuma citação no texto.

WILLNER, D.; CHANG, C. B.; DUNN, K. P. Kalman filter algorithms for a multi-sensor system. In: *IEEE Conference on Decision and Control including the 15th Symposium on Adaptive Processes*. [S.l.: s.n.], 1976. v. 15, p. 570–574. Nenhuma citação no texto.

XUE-BO, J.; JING-JING, D.; JIA, B. Target Tracking of a Linear Time Invariant System Under Irregular Sampling. *International Journal of Advanced Robotic Systems*, v. 9, 2012. Disponível em: <http://journals.sagepub.com/doi/pdf/10.5772/54471>. Nenhuma citação no texto.

YAN, L. et al. State estimation for a kind of non-uniform sampling dynamic system. *International Journal of Systems Science*, v. 44, n. 10, p. 1913–1924, oct 2013. Nenhuma citação no texto.

ZOU, L.; WANG, Z.-D.; ZHOU, D.-H. Event-based Control and Filtering of Networked Systems: A Survey. *International Journal of Automation and Computing*, v. 14, n. 3, p. 239–253, 2017. Nenhuma citação no texto.