Model reduction based on limited-time interval impulse response Gramians

Kumar, D. a, b, Jazlan, A. c, Sreeram, V. a

a School of Electrical, Electronic and Computer Engineering, The University of Western Australia, 35 Stirling Highway, Crawley, Australia
b Electrical Engineering Department, Motilal Nehru National Institute of Technology, Allahabad, UP, India
c Department of Mechatronics Engineering, Faculty of Engineering, International Islamic University Malaysia, Jalan Gombak, Selangor, Malaysia

Abstract

In this paper, three new Gramians are introduced namely - limited-time interval impulse response Gramians (LTIRG), generalized limited-time Gramians (GLTG) and generalized limited-time impulse response Gramians (GLTIRG). GLTG and GLTIRG are applicable to both unstable systems and also to systems which have eigenvalues of opposite polarities and equal magnitude. The concept of these Gramians is utilized to develop model reduction algorithms for linear time-invariant continuous-time single-input single-output (SISO) systems. In the cases of GLTIRG and GLTG based model reduction, the standard time-limited Gramians are generalized to be applied to unstable systems by transforming the original system into a new system which requires the solution of two Riccati equations. Two numerical examples are included to illustrate the proposed methods. The results are also compared with standard techniques. © 2019 Chinese Automatic Control Society and John Wiley & Sons Australia, Ltd

Author keywords

balanced truncation, impulse response Gramian, model reduction, time interval, unstable systems

Indexed keywords

Engineering controlled terms: Eigenvalues and eigenfunctions, Impulse response, Numerical methods, Riccati equations

Engineering uncontrolled terms: Balanced truncation, Impulse response Gramian, Model reduction, Time interval, Unstable system

Engineering main heading: Continuous time systems

Asian Journal of Control

2019

Model reduction based on limited-time interval impulse response Gramians

Kumar, D. a, b, Jazlan, A. c, Sreeram, V. a

a School of Electrical, Electronic and Computer Engineering, The University of Western Australia, 35 Stirling Highway, Crawley, Australia
b Electrical Engineering Department, Motilal Nehru National Institute of Technology, Allahabad, UP, India
c Department of Mechatronics Engineering, Faculty of Engineering, International Islamic University Malaysia, Jalan Gombak, Selangor, Malaysia

Abstract

In this paper, three new Gramians are introduced namely - limited-time interval impulse response Gramians (LTIRG), generalized limited-time Gramians (GLTG) and generalized limited-time impulse response Gramians (GLTIRG). GLTG and GLTIRG are applicable to both unstable systems and also to systems which have eigenvalues of opposite polarities and equal magnitude. The concept of these Gramians is utilized to develop model reduction algorithms for linear time-invariant continuous-time single-input single-output (SISO) systems. In the cases of GLTIRG and GLTG based model reduction, the standard time-limited Gramians are generalized to be applied to unstable systems by transforming the original system into a new system which requires the solution of two Riccati equations. Two numerical examples are included to illustrate the proposed methods. The results are also compared with standard techniques. © 2019 Chinese Automatic Control Society and John Wiley & Sons Australia, Ltd

Author keywords

balanced truncation, impulse response Gramian, model reduction, time interval, unstable systems

Indexed keywords

Engineering controlled terms: Eigenvalues and eigenfunctions, Impulse response, Numerical methods, Riccati equations

Engineering uncontrolled terms: Balanced truncation, Impulse response Gramian, Model reduction, Time interval, Unstable system

Engineering main heading: Continuous time systems
Principal Component Analysis in Linear Systems: Controllability, Observability, and Model Reduction

doi: 10.1109/TAC.1981.1102568

MODEL REDUCTION WITH BALANCED REALIZATIONS: AN ERROR BOUND AND A FREQUENCY WEIGHTED GENERALIZATION.

doi: 10.1109/cdc.1984.272286

Model reduction via frequency weighted balanced realization

doi: 10.23919/acc.1990.4791093

A new frequency-weighted balanced truncation method and an error bound

doi: 10.1109/9.788542

Accuracy-enhancing methods for balancing-related frequency-weighted model and controller reduction

doi: 10.1016/S0005-1098(03)00030-X

Improved results on frequency-weighted balanced truncation and error bounds

doi: 10.1002/rcn.1745

A generalised partial-fraction-expansion based frequency weighted balanced truncation technique

doi: 10.1080/00207179.2013.764017
8. Gugercin, S., and Antoulas, A.C.
   A survey of model reduction by balanced truncation and some new results
   doi: 10.1080/00207170410001713448
   View at Publisher

9. Gawronski, W., and Juang, J.N.
   Model reduction in limited time and frequency intervals
   doi: 10.1080/00207729008910366
   View at Publisher

10. Tahavori, M., and Shaker, H.R.
    Model reduction via time-interval balanced stochastic truncation for linear time
    invariant systems
    doi: 10.1080/00207721.2011.604741
    View at Publisher

11. Shaker, H.R., and Tahavori, M.
    Generalized time-limited balanced reduction method
    ISBN: 978-147990177-7
doi: 10.1109/acc.2013.6580703
    View at Publisher

12. Shaker, H.R., and Tahavori, M.
    Time-interval model reduction of bilinear systems
    www.tandf.co.uk/journals/titles/00207179.asp
doi: 10.1080/00207179.2013.875628
    View at Publisher

13. Jazlan, A., Sreeram, V., and Togneri, R.
    Cross gramian based time interval model reduction

    Model Reduction of Large Scale Descriptor Systems Using Time Limited Gramians
doi: 10.1002/asjc.1444
    View at Publisher

15. Gugercin, S., and Antoulas, A.C.
    A time-limited balanced reduction method
    ISBN: 0780379241
doi: 10.1109/CDC.2003.1272471
    View at Publisher
16. Jazlan, A., Houlis, P., Sreeram, V., Togneri, R.  
An Improved Parameterized Controller Reduction Technique via New Frequency Weighted Model Reduction Formulation  
doi: 10.1002/asjc.1559  
View at Publisher

Frequency Interval Cross Gramians for Linear and Bilinear Systems  
doi: 10.1002/asjc.1330  
View at Publisher

Frequency interval model reduction of complex fir digital filters  (Open Access)  
doi: 10.3934/naco.2019021  
View at Publisher

19. Toor, H.I., Imran, M., Ghafoor, A., Kumar, D., Sreeram, V., Rauf, A.  
Frequency limited model reduction techniques for discrete-time systems  
http://www.ieee-cas.org  
doi: 10.1109/TCSII.2019.2909122  
View at Publisher

20. Kumar, D., Sreeram, V., Du, X.  
Model reduction using parameterized limited frequency interval gramians for 1-D and 2-D separable denominator discrete-time systems  
doi: 10.1109/TCSI.2017.2787768  
View at Publisher

21. Kumar, D., Sreeram, V.  
Factorization-based frequency-weighted optimal Hankel-norm model reduction  
doi: 10.1002/asjc.2096  
View at Publisher

22. Kumar, D., Zulfiqar, U., Sreeram, V.  
Frequency-weighted balanced truncation of 2-D separable denominator discrete-time systems  
http://ieeexplore.ieee.org/xpl/mostRecentIssue.jsp?punumber=8592610  
ISBN: 978-153866617-3  
doi: 10.1109/ANZCC.2018.8606618  
View at Publisher
Reduced order controller design for symmetric, non-symmetric and unstable systems using extended cross-gramian

(Azhar, M.R.F., Zulfiqar, U., Liaquat, M., Kumar, D. 
doi: 10.3390/MACHINES7030048

A new method for the model reduction technique via a limited frequency interval impulse response Gramian

(Sahlan, S., Ghafoor, A., Sreeram, V. 

Balanced realization and model reduction for unstable systems

(Zhou, K., Salomon, G., Wu, E. 
doi: 10.1002/(SICI)1099-1239(199903)9:3<183::AID-RNC399>3.0.CO;2-E

Generalized cross-gramian for linear systems

(Shaker, H.R. 
doi: 10.1109/ICIEA.2012.6360824

Generalized gramian based frequency interval model reduction for unstable systems

(Jazlan, A., Sreeram, V., Togneri, R., Minh, H.B. 
ISBN: 978-192210790-9 
doi: 10.1109/AUCC.2016.7868000

Model reduction of linear continuous systems using impulse-response grammmians

(Agathoklis, P., Sreeram, V. 
doi: 10.23919/acc.1990.4791125

Model reduction of linear continuous systems using weighted impulse response Gramians

(Sreeram, V., Agathoklis, P. 

Model reduction of linear continuous systems using impulse-response Gramians

(Kailath, T. 
Prentice-Hall Englewood Cliffs, NJ
Model Reduction via Balanced State Space Representations

doi: 10.1109/TAC.1982.1102945

View at Publisher

---

Input-output pairing based on cross-gramian matrix

doi: 10.1109/SICE.2006.314989

View at Publisher

Kumar, D.; School of Electrical, Electronic and Computer Engineering, The University of Western Australia, 35 Stirling Highway, Crawley, Australia; email: deepak_kumar@mnnit.ac.in
© Copyright 2019 Elsevier B.V., All rights reserved.