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Dedication

In the name of love, obedience, and respect, I dedicate this work:

To my dear first teachers: my parents,

To my mother, a friend who gave me life, a symbol of kindness always ready to assure me that everything will be alright. To this mother, who wholeheartedly shares joys and sorrows with us,

To my father, this great man, always ready to lend a hand when I need it, this constant beacon guiding my steps, this wonderful father who never hesitated to sacrifice everything for his children,

Today, from the bottom of my heart, I say 'THANKYOU, my parents', the wellspring of courage,

To my dear brothers,

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To my bright beautiful aunt,

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- Mimoune, K., Hammoudi, M. Y., Saadi, R., Benbouzid, M., & Boukhrouf, A. (2023). Real-Time Implementation of Non Linear Observer Based State Feedback Controller for Induction Motor Using Mean Value Theorem. *Journal of Electrical Engineering & Technology*, 18(1), 615-628.
- Mimoune, K., Hammoudi, M. Y., Hamdi, W., & Mimoune, S. M. (2023). Observer design for Takagi-Sugeno fuzzy systems with unmeasured premise variables: Conservatism reduction using line integral Lyapunov function. *ISA transactions*.
- Meredef, I. E., Hammoudi, M. Y., Betka, A., Hamiane, M., & Mimoune, K. (2022). Stability and Stabilization of TS Fuzzy Systems via Line Integral Lyapunov Fuzzy Function. *Electronics*, 11(19), 3136.

International Conferences

- Mimoune, K., Hammoudi, M. Y., Betka, A., & Benbouzid, M. (2022, May). Observer-based state feedback controller of PMSM using convex optimization via Feedforward Technique. In *2022 19th International Multi-Conference on Systems, Signals & Devices (SSD)* (pp. 982-989). IEEE.
- Boukhrouf, A., Hammoudi, M.Y., Saadi R. , Mimoune, K., & Ayad, M. Y. State and unknown inputs estimation of polytopic system by convex optimization. In *2020 International Conference on Emerging and Renewable Energy Generation and Automation (ICEREGA20)*

Abstract

Exploring the observation and estimation of non-linear systems, particularly those represented by Takagi-Sugeno fuzzy multi-systems, this research addresses the significant challenges in modeling and creating an observer for such systems. It adopts a multi-model approach and employs non-linear sector decomposition to transform these systems into a polytope form, facilitating the development of a robust observer that can accurately reconstruct both the system's states and its unknown inputs under various conditions. The study contrasts traditional quadratic approaches with an innovative non-quadratic method that uses a line-integral Lyapunov function for the estimation of both state and unknown inputs. This method, in conjunction with a specially designed observer, results in linear matrix inequality conditions, providing a more straightforward solution compared to the complex bilinear matrix inequality commonly associated with TS fuzzy systems. Notably, this approach demonstrates reduced conservatism, thereby enhancing its effectiveness and reliability. Additionally, the research investigates state and unknown input estimation for non-linear systems using TS fuzzy systems in scenarios where premise variables are unmeasurable, and it includes practical examples to illustrate the effectiveness of the proposed methods.

Key words: Takagi-Sugeno fuzzy model, State estimation, Fault estimation, Linear Matrix Inequality, Unknown inputs, Line integral lyapunov function.

Résumé

En explorant l'observation et l'estimation des systèmes non linéaires, en particulier ceux représentés par des systèmes flous multi-modèles de Takagi-Sugeno, cette recherche aborde les défis importants dans la modélisation et la création d'un observateur pour de tels systèmes. Elle adopte une approche multi-modèles et utilise une décomposition sectorielle non linéaire pour transformer ces systèmes en une forme polytopique, facilitant ainsi le développement d'un observateur robuste capable de reconstruire avec précision à la fois les états du système et ses entrées inconnues dans diverses conditions. L'étude met en contraste les approches quadratiques traditionnelles avec une méthode non quadratique innovante qui utilise une fonction de Lyapunov intégrale de ligne pour l'estimation à la fois de l'état et des entrées inconnues. Cette méthode, conjointement avec un observateur spécialement conçu, aboutit à des conditions d'inégalité matricielle linéaire, offrant une solution plus simple par rapport à l'inégalité matricielle bilinéaire complexe communément associée aux systèmes flous TS. Notamment, cette approche démontre un conservatisme réduit, améliorant ainsi son efficacité et sa fiabilité. De plus, la recherche enquête sur l'estimation de l'état et des entrées inconnues pour les systèmes non linéaires utilisant des systèmes flous TS dans des scénarios où les variables de prémisses sont non mesurables, et elle inclut des exemples pratiques pour illustrer l'efficacité des méthodes proposées.

Mots-Clés: Modèle flou de Takagi-Sugeno, estimation d'état, estimation de défauts, inégalité matricielle linéaire, entrées inconnues, fonction Lyapunov intégrale de ligne.

ملخص

في استكشاف المراقبة وتقدير الأنظمة غير الخطية، وخاصة تلك الممثلة بأنظمة تاكاغي-سوجينو الضبابية متعددة النماذج، تتناول هذه الدراسة التحديات الكبيرة في نمذجة وإنشاء مراقب لمثل هذه الأنظمة. تعتمد البحث على نهج متعدد النماذج وتستخدم تحليل القطاعات غير الخطية لتحويل هذه الأنظمة إلى شكل متعدد السطوح، مما يسهل تطوير مراقب قوي قادر على إعادة بناء حالات النظام ومدخلاته المجهولة بدقة تحت ظروف متنوعة. تقارن الدراسة بين النهج التقليدية الرباعية وطريقة غير رباعية مبتكرة تستخدم وظيفة لياونوف التكاملية الخطية لتقدير كل من الحالة والمدخلات المجهولة. تؤدي هذه الطريقة، بالتزامن مع مراقب مصمم خصيصاً، إلى ظروف عدم المساواة المصفوفة الخطية، مما يوفر حلاً أبسط مقارنة بعدم المساواة المصفوفة الثنائية المعقدة المرتبطة عادةً بأنظمة تاكاغي-سوجينو الضبابية. تبرز هذه الطريقة تقليلاً في التحفظ، مما يعزز فعاليتها وموثوقيتها. بالإضافة إلى ذلك، تحقق البحث في تقدير الحالة والمدخلات المجهولة للأنظمة غير الخطية باستخدام أنظمة تاكاغي-سوجينو الضبابية في سيناريوهات حيث لا يمكن قياس المتغيرات الأساسية، وتشمل أمثلة عملية لإظهار فعالية الأساليب المقترحة.

الكلمات المفتاحية: النظام غير الخطي، نموذج تاكاغي-سوجينو الغامض، تقدير الحالة، تقدير الخطأ، عدم مساواة المصفوفة الخطية، دالة لياونوف المتكاملة الخطية.

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Nomenclature

Abbreviations

BMI	Bilinear Matrix Inequality
LMI	Linear Matrix Inequality
MVT	Mean Value Theorem
MM	Multi-models
TS	Takagi-Sugeno
UI	Unknown inputs
PIO	Proportional integral observer
PMIO	Proportional multi integral observer
HIL	Hardware-in-the-loop
MPV	Measurable Premise variables
NMPV	Non-measurable premise variables
MF	Membership Function
QLF	Quadratic Lyapunov Function
PLF	Piecewise Lyapunov Function
NQLF	Non-Quadratic Lyapunov Function
LILF	Line Integral Lyapunov Function
FLF	Fuzzy Lyapunov Function
LPV	Linear Parameter Varying