التحكم المكين بالعكس الديناميكي المعمم
عزير الأنصاري
مشرف: د. عبد الرحمن بن حسن باجودة

المستخلص

يهدف هذا العمل البحثي إلى تصميم وتطبيق عدة قوانين تحكم في الأنظمة الديناميكية بطريقة العكس الديناميكي المعمم. يبدأ تصميم نظام التحكم بالعكس الديناميكي المعمم بتعريف معادلات قيدية تفاضلية ديناميكية مستقرة تقاربياً تمثل الأهداف المطلوبة من عملية التحكم. ومن ثم تجري عملية تحويل المعادلات التفاضلية إلى معادلات جبرية بتعويض معادلات الحالة للنظام الديناميكي فيها، ومن ثم تقلب المعادلات بواسطة معكوس مور- بنروز المعمم وقانون جريفيل لحل المعادلات الجبرية الخطية لاستخلاص قانون التحكم ذي التغذية العكسية. وتمنع وضعية الشذوذ الرقمي لمعكوس مور- بنروز من التحقق فإن معكوس مور- بنروز يعد بواسطة معامل تدريج ديناميكي يحافظ على عملية القلب الديناميكي مستقرة.

ويتكون أحد قوانين التحكم الجديدة بطريقة العكس الديناميكي التي يقدمها البحث من حد جديد من نوع النمط الانزلاقي يضاف إلى قانون التحكم التقليدي الأصلي. وتهدف إضافة الجد الجديد إلى دعم عملية التحكم يجعل أداء النظام المغلق مكيناً في وجه الدينيمات غير المنمذجة والبaramرات المتغيرة وذات القيم غير المؤكدة في معادلات النموذج الرياضي. إضافةً إلى منع المؤثرات الخارجية من التأثير السلبي على أداء النظام الديناميكي ومنع التدهور في أداء نظام التحكم نتيجة التدريج.
The dynamic standard for inverted Mor- Benrouz. And the
anomalies that occurred normally resulting from
use of the primary sliding mode control. The new
control law for the dynamic standard inverted
system introduced by the study adopts the concept
of the primary sliding mode.

Also, the study introduces another control
law for dynamic inverted system, which is a common
between the direct and indirect control methods.
The direct control adaptive part uses the concept
of control without trying to estimate the system
parameters, while the indirect control adaptive
part estimates the unknown parameters
using the artificial neural network.

The control systems introduced by the study
are stable and practically semi-ideal, and
applied in this study on models of dynamic
models of various systems such as guided
missiles, bi-rotor and quad rotor, in addition
to the submarine, satellites, spacecrafts and some
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Robust Generalized Dynamic Inversion Control

Uzair Ansari
Supervisor: Dr. Abdulrahman H. Bajodah

1. ABSTRACT

The objective of this research work is to design, and implementation of new variants of the conventional Generalized Dynamic Inversion (GDI) control. The GDI control methodology is of the left inversion type, i.e., the control inputs are obtained by means of plant’s output’s error feedback and not based on actual plant’s outputs. Therefore, GDI control does not involve deriving inverse dynamical equations of motion for the controlled plant. Instead, prescribed servo (virtual) constraints that represent the control objectives are evaluated along the trajectories of the open loop dynamical system, and are imposed thereafter on its closed loop dynamics by means of the MPGI-based Greville formula. GDI allows for two cooperating controllers that act on two orthogonally complement control spaces: one is the particular controller that realizes the dynamic constraints, and the other is the auxiliary controller that is affine in the null control vector which provides an additional degree of design freedom.

The robust form of GDI control, which is referred as Robust Generalized Dynamic Inversion (RGDI) control, is proposed by augmenting the Sliding Mode Control (SMC) element in the form of switching (discontinuous) control. The RGDI control realizes the combination of the equivalent control and the switching control elements. The equivalent control (conventional GDI) is obtained through non-square inversion of the constraint dynamics, which are prescribed in the form of the controlled state variables deviation functions. On the other hand, the augmentation of the SMC loop in the form of switching control, is vital to enhance the robustness attributes of the design, against modeling uncertainties, exogenous disturbances, in addition to improve the tracking accuracy. The singularity problem that is associated with non-square matrix inversion is solved, by incorporating a controlled dynamic scaling factor within the MPGI expression, which ensures nonsingular tracking control. The overall stability of proposed control law will be established by using positive definite Lyapunov control function.

To introduce adaptive features in conventional GDI, another approach is proposed which is called Hybrid Direct-Indirect Adaptive Generalized Dynamic Inversion (HDI-AGDI) control. The presented approach realizes the combination of both direct and indirect forms of the adaptive control. The structure of the direct AGDI control is similar to the RGDI control approach, however, the switching control based on the concept of SMC, is equipped with the adaptive modulation gain instead of a fixed gain. This implies that the chattering associated with SMC is reduced, by performing the adjustment in the modulation gain. The indirect AGDI control
provides the online estimates of unknown plant parameters using Radial Basis Function Neural Networks (RBF-NN), whose weight vectors are updated online, with the aid of control Lyapunov function by employing the tracking error information. The designed HDI-AGDI approach will guarantee uniformly ultimately bounded tracking errors and semi-global practically stable tracking performance, by employing positive definite Lyapunov energy function.

Another modified version of conventional GDI is suggested, by combining it with Super-Twisting Sliding Mode Control (STSMC), and the hybrid approach is referred as GDI-STSMC. The proposed approach generalize the basic sliding mode idea acting on the higher order time derivatives, instead of influencing the first derivative like it happens in standard sliding modes. This will keep the main advantages of the conventional SMC, at the same time they totally remove the chattering effect and provide for even higher accuracy in realization. The error convergence of GDI-STSMC is demonstrated with the aid of a positive definite Lyapunov candidate function, such that it will guarantee semi-global practically stable tracking performance.

The performance evaluation and feasibility analysis of all the three proposed control strategies are investigated through numerical simulations on various nonlinear dynamical systems in Simulink/Matlab environment, considering parametric uncertainties, nonlinearities and exogenous disturbances. Apart from numerical simulations, the performance of RGDI control routine is also validated through experiments on numerous Quanser’s test benches that will provide hardware in loop experimental research platform for rapid prototyping of real-time control, and to visualize its tracking capabilities and stability aspects.