Dynamic Neural Networks in Control Problems

(Redes Neuronales Dinámicas en Problemas de Control)

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(Alexander Pozniak Gorbatch)

Content of the 60-hours optional course

(contenido de 60 horas curso opcional)

September 12, 2023 – December 12, 2023

Each Tuesday (Martes) and Friday (Viernes) 13:00-15:00.

Presentation in English

1. **Introduction** . . . .
2. **ANN as computational artificial intelligence (AI) modeling instrument**. . . . . .
   2.1. General concept of ANNs . . . . . .
   2.2. Static (Feedforward) ANNs . . . . . .
   2.3. Dynamic Neural Networks (DNNs). . . . . .
   2.4. Some limitations of ANN. . . . . .
3. **Particularities of DNNs** . . . . . .
   3.1. Design of the learning procedures . . . . . .
   3.2. The justification of the DifNNs structure . . . . . .
4. **Neural observer as a universal software sensor**. . . . . .
   4.1. Uncertain system and the observer structures. . . . . .
   4.2 Main assumptions . . . . . .
   4.3 Quasi-linear format of models . . . . . .
   4.4 Neuro-observer (software-sensor) structure . . . . . .
   4.5 Learning law for weights adaptation . . . . . .
5. **Estimation quality of a DNN non-parametric modeling** . . . . . .
   5.1. Definition of an ellipsoid . . . . . .
   5.2. Zone convergence of state estimation error by DNNO based on the ellipsoid technique. . . . . .
6. **Adaptive controllers based on DNN estimates** . . . . . .

6.1 Separation principle . . . . . .
6.2 Average cost functions and locally-optimal control . . . . . .
6.3 Projectional Observers of Nonlinear Systems . . . . . .
6.4 Sliding Mode Control (SMC) . . . . . .
6.5 Backstepping control . . . . . .

7. **DNN control of mechanical systems** . . . . . .
7.1 DNN control for Lagrange systems given in the general format . . . . . .
7.2 2-link robot-manipulator with DNN controller . . . . . .
7.3 ASG-DNN controller of the robotic arm with a pilot's cabin on the end-effector (motion cueing control) . . . . . .
7.4 Dynamic Motion Backstepping DNN Control of Underwater Autonomous Vehicle . . . . . .
8. **Differential Neural Networks Prediction Using Slow and Fast Hybrid Learning** . . . . . .
8.1 Causal Approximation of prediction in dynamic models . . . .
8.2 DNN Predictor with Slow and Fast Components . . . . . .
8.3 Application to Prognosis of Infections and Deaths of COVID-19 Dynamics . . . . . .

9. **Application of Dynamic Neural Networks to Environment-Oriented biotechnological systems (a short excurse)** . . . . . .
9.1. Different types of bioreactors and fermentation regimes
9.1.1. Batch regimen . . . . . .
9.1.2. Semi-batch regimen . . . . . .
8.1.3. Continuous regimen . . . . . .
9.2. Microorganisms metabolism . . . . . .
9.2.1 Types of metabolic activities . . . . . .
9.4. Adaptive ANN control for biotechnological processes . . . . .
10. **Application of neural networks to environment-oriented chemical processes (a short excurse)**

10.1. Photolosys . . . . . .
10.2. Catalysis . . . . . .
10.3. Ozonation . . . . . .
10.4. Catalytic ozonation . . . . . .

Recommended bibliography

1. Poznyak A, Sanchez E, Yu W (2001), *Differential neural networks for robust nonlinear control: identification,state estimation, and trajectory tracking.* World Scientific, Singapore.
2. Poznyak T, Chairez I, Poznyak A (2019), *Ozonation and biodegradation in environmental engineering: dynamic neural network approach.* Elsevier, Amsterdam - NY.
3. Poznyak A, Chairez I, Poznyak T (2019), *A survey on artificial neural networks application for identification and control in environmental engineering: biological and chemical systems with uncertain models.* Annu Rev Control 48:250–272.
4. Alejandra Hernandez-Sanchez, Isaac Chairez, Alexander Poznyak, Olga Andrianova. *Dynamic Motion Backstepping Control of Underwater Autonomous Vehicle Based on Averaged Sub-gradient Integral Sliding Mode Method*, Journal of Intelligent & Robotic Systems, (2021) 103:48, https://doi.org/10.1007/s10846-021-01466-3.
5. A. Poznyak, I. Chairez, A. Anyutin. *Differential Neural Networks Prediction Using Slow and Fast Hybrid Learning: Application to Prognosis of Infections and Deaths of COVID-19 Dynamics*. Neural Processing Letters, March 2023, https://doi.org/10.1007/s11063-023-11216-1