Summary of paper #1

Learning nonlinear state-space model using auto encoders

In this paper, authors proposed a new SSM algorithm to identify nonlinear systems using Deep AEs.

AEs are a particular ANN that are usually used for dimensionality reduction and denoising. The main problem is to find the smallest dimension n_x that provides an acceptable mismatch between predictions $\hat{y}_k$ and the measured outputs $\tilde{y}_k$. A technique like feature extraction is applied on the input output data to reduce the state set to n_x. In this technique there are four factors to be determined.

1. The topology of the network.
2. Activation functions
3. learning algorithm
4. tuning parameters

In this technique, four functions including e (encoder), f (bridge), d (decoder), and s (observer), should be find. ANNs are used to tackle the tasks sure to their universal approximation properties and efficient numerical packages for training them such as Tensorflow. The fitting criterion is defined as

$$\min_{f,d,e,s} \sum_{k=k_0}^{N-1} L_1\left(\hat{O}_k, O_k\right) + L_1\left(\hat{O}_{k+1}, O_{k+1}\right) + \beta L_2({x^*}_{k+1}, x_{k+1}) + \beta L_4(\hat{x}_{k+1} + x_{k+1}) + \gamma L_3({\hat{O}^*}_{k+1}, \hat{O}_{k+1})$$

$$\text{S.t. } x_k = e(I_{k-1}), \quad k = k_0, \dots, N$$

$${x^*}_{k+1} = f(x_k, u_k), \quad k = k_0, \dots, N-1$$

$$\hat{O}_k = d(x_k), \quad k = k_0, \dots, N$$

$${O^*}_k = d({x^*}_k), \quad k = k_0 + 1, \dots, N$$

$$\hat{x}_{k+1} = s(x_k, u_k, y_k)$$

$${\hat{O}^*}_k = d(\hat{x}_k), \qquad k = 0,1, \dots, N$$

After finding the model, there is a comparison between NlRX model and the proposed approach, showing the better performance of the new technique. Also, they used n MPC controller to control the found model.

Limitations:

1. The robustness is not considered in this technique.
2. They restricted the activation functions to be differentiable. If such an assumption relaxed, better open-loop fit figures can be obtained.
3. They also have not tested non-smooth models extensively, as they are interested by EKF and MPC controller.