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.
4. Compared to our work, this model needs a large amount of data which we do not have access to.

Hypothetical Solutions:

1. Consider the **Robust Error Identification (REI)** in the definition of fitting criterion.
2. I have no idea. Still working.
3. I have no idea. Still working.
4. 1) Use **Data Augmentation** techniques to increase the amount of data.
   2) Use **existing fluid resuscitation models** to create a large data set.
   For the first solution I should dig more in the literature to see if there is any such thing as data augmentation in dataset in the form of time series.
   Also, for the second solution, we cannot consider the individuality in models. We can just implement the technique to get results, then generalize the technique when the acceptable amount of data is acceptable.