

Are model and predictor filters equivalent?

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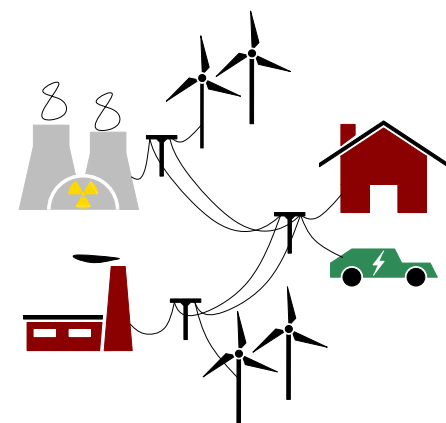
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Are model and predictor filters equivalent?

Studying identifiability in a dynamic network identification setting

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Main question

In open- and closed-loop identification there is a one-to-one relationship between (parameterized) predictor filters and model¹, is that the case for dynamic networks?

Approach of the problem

Predictor filters have a one-to-one relation to the filter

$$T(q, \theta) = (I - G(q, \theta))^{-1} \begin{bmatrix} H(q, \theta) & R(q, \theta) \end{bmatrix}$$

which is under conditions has a one-to-one relation to the filters in $\mathcal{M}(q, \theta)$.

Example: Can we distinguish the two networks below on the basis of their transfers $r \rightarrow w$?

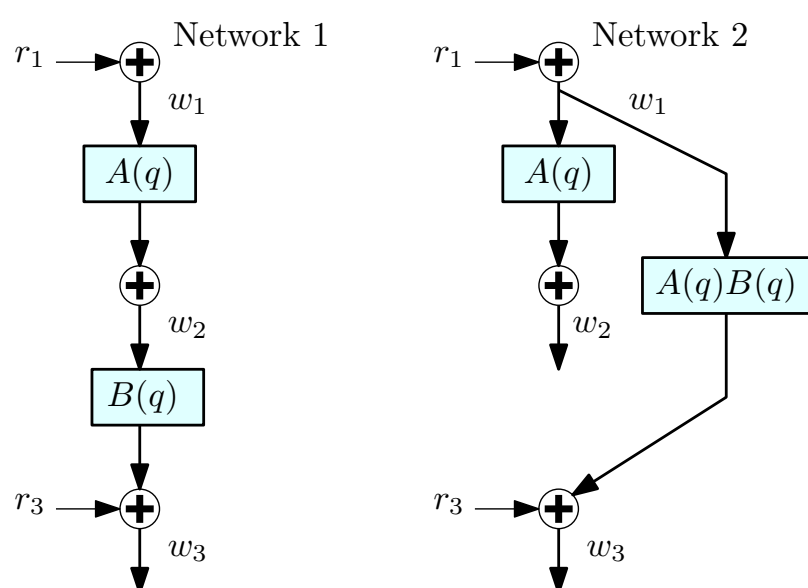


Figure 1: OH NO!! Two models generate the same mapping from external variables r to internal variables w .

Network, predictor, model structure

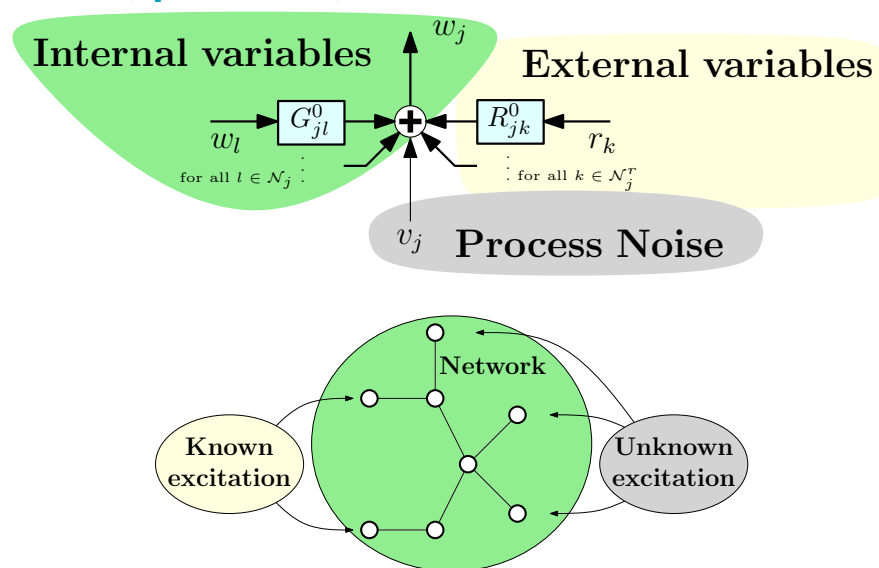


Figure 2: The network (top) is constructed by connecting all the building blocks (bottom).

All nodes w_j are stacked into columnvector w . Then we have

$$\begin{aligned} \text{Network:} & \quad w = G^0 w + R^0 r + H^0 e \\ \text{Predictor:} & \quad \hat{w}(t|t-1, \theta) = W_w(q, \theta)w(t) + W_r(q, \theta)r(t) \\ \text{Predictor filters:} & \quad W_w = I - H^{-1}(I - G), \quad W_r = H^{-1}R \\ \text{Model structure:} & \quad \mathcal{M} = \{G(q, \theta), H(q, \theta), R(q, \theta)\}. \end{aligned}$$

Note that G and G^0 have zeros on the diagonal.

$\hat{w}(\theta_1) = \hat{w}(\theta_2)$	Predictor equality
① \Updownarrow	Conditional: Data must be informative .
$W_w(\theta_1) = W_w(\theta_2)$ $W_r(\theta_1) = W_r(\theta_2)$	Predictor filter equality
② \Updownarrow	Unconditional ²
$T(\theta_1) = T(\theta_2)$	Mapping equality
③ \Updownarrow	Conditional ² : see conditions below,
$\mathcal{M}(\theta_1) = \mathcal{M}(\theta_2)$	Model equality
④ \Updownarrow	Conditional: classical identifiability .
$\theta_1 = \theta_2$	Parameter equality

Results

Definition: \mathcal{M} is called a **globally network identifiable** model structure when ③ holds.

Theorem: When G is as flexible as possible then ③ holds when $\begin{bmatrix} H(q, \theta) & R(q, \theta) \end{bmatrix} P(q)$ has a leading diagonal for some $P(q)$ ².

example: Choose $H(q, \theta)$ diagonal. Plugging it into predictor filter W_w shows that \mathcal{M} is globally network identifiable. Diagonal H corresponds to having uncorrelated noise on every node.

Conclusion

The one-to-one relation between (parameterized) predictor filters and model is conditional in case of dynamic networks. Combinations of H and R can lead to a network identifiable \mathcal{M} , it is not necessary that H is diagonal. When H is not diagonal networks where noises are correlated can be considered.

References

- ¹L. Ljung. *System Identification: Theory for the User*. Prentice-Hall, 1999.
- ²H.H.M. Weerts, A.G. Dankers, and P.M.J. Van den Hof. Identifiability in dynamic network identification. In *17th IFAC Symposium on System Identification*, 2015.