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Multi-Linear State Space Model Identification for Large Scale Building Systems

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1. Introduction

Many Control Design approaches presuppose the knowledge of a state space description of the system. As in many real and large scale systems the construction of a state space model using analytical equations and rough assumptions is a time consuming process leading most of the times to questionable precision. A simple and efficient approach of approximating a **dynamic SSM,** of a given system, using measurement data is presented. The main problem is trying to minimize the approximation error of the state space realization matrices, using a simple and convenient way. A black-box system identification process is **applicable to any measurable system** and can be proven as a very efficient scheme for System State Space Model (SSM) realization.

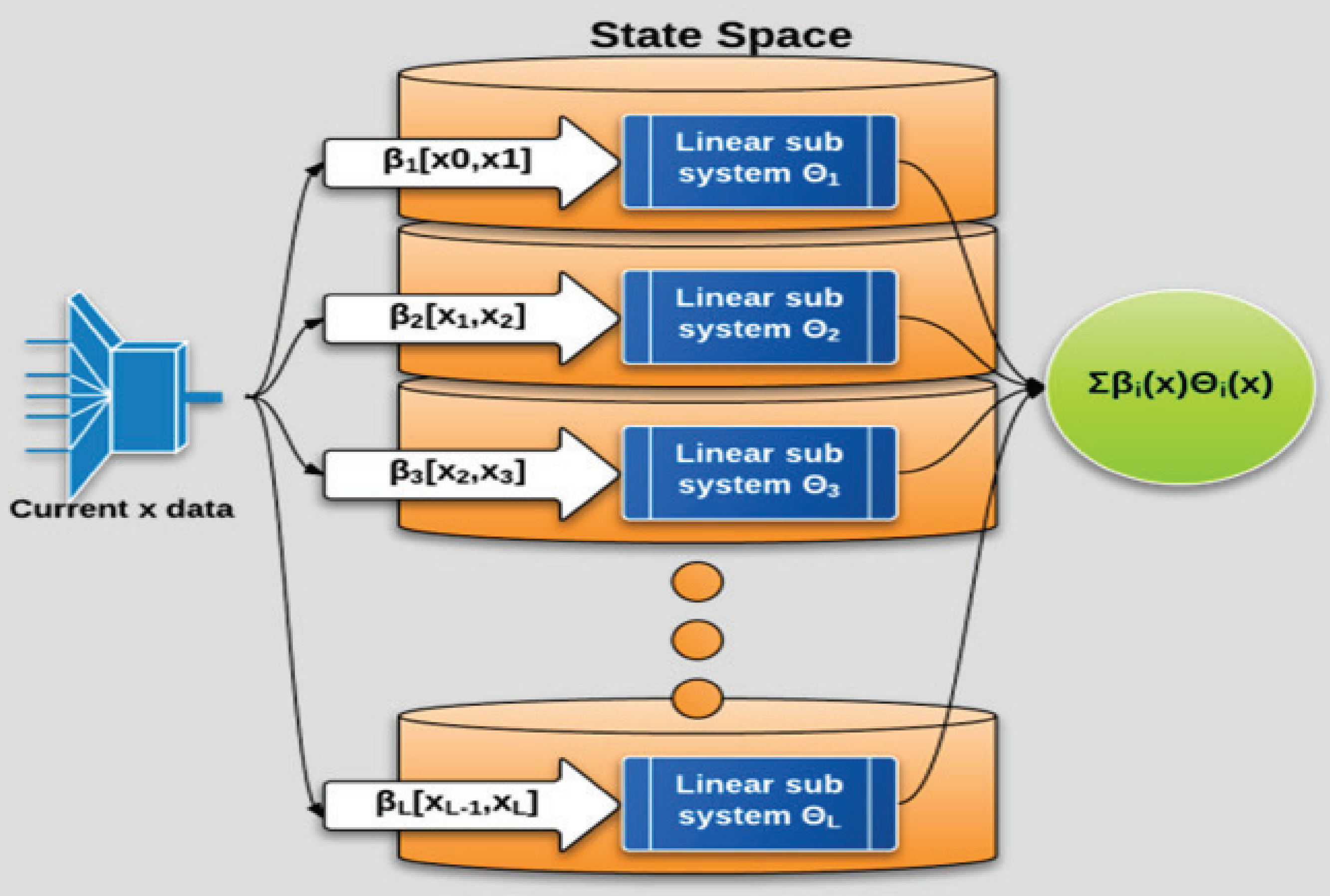

Fig.1: Linear subsystems state space division.

2. Methodology

The proposed strategy introduces **state space linear subdivision and local linearization according to the current system working point – state.** Locally referring but globally representative weight functions decide the contribution of each linear subsystem to the final model total dynamic behavior. Consider a general non-linear system:

$$\dot{\chi} = F(\chi, u, w)$$

Let β_i where i=1,2,…,L denote a set of smooth mixing signals (Fig. 1). The total system behavior can be approximated by the following equation:

$$\dot{\chi} \approx \sum_{i=1}^{L} \beta_i(y)(\bar{A}_i\chi + \bar{B}_i u + \bar{G}_i w + \bar{F}_i)$$

Or: $\chi_{[next]} \approx \chi_{[old]} + \Theta\Lambda$, where Θ to be found.

In conclusion the problem becomes a **LS minimization problem** of the approximation error:

$$e_{zj} = (\chi_{[z+1]} - \chi_{[z]})^{(j)} - \Theta^{(j)}_{row}\Lambda_{[z]}$$

3. Results

ZUB building, built in 2001, located at the campus of the University of Kassel, Germany is an exemplary low-energy building. The ZUB has three floors, a basement and an atrium in contact with a nearby building. For testing the proposed system identification procedure a **reduced 3 zoned model the so called Tower is used**. This Tower preserves all relevant characteristics from the whole model. TRNSYS v.17 simulation output data for system identification and weather data from 2003, are used. The results presented refer only to **one thermal zone of the building (Zone R_107)** due to lack of space. Please also note that the first day of every simulation is used as settling time so as the building reaches a reasonable state – working point. A summary for the identified model is incorporated in Tab. 1. The respective transients for the validation period are shown in Fig. 2.

Prediction (Optimization) Horizon	(1 Step) 15 min	(25 Steps) 6.25 h	(96 Steps) 24 h
L	2	3	2
Training Error	0.9%	4.7%	6.6%
Validation Error	1.1%	4.5%	14.7%

Tab.1: Approximation error for various prediction horizons.

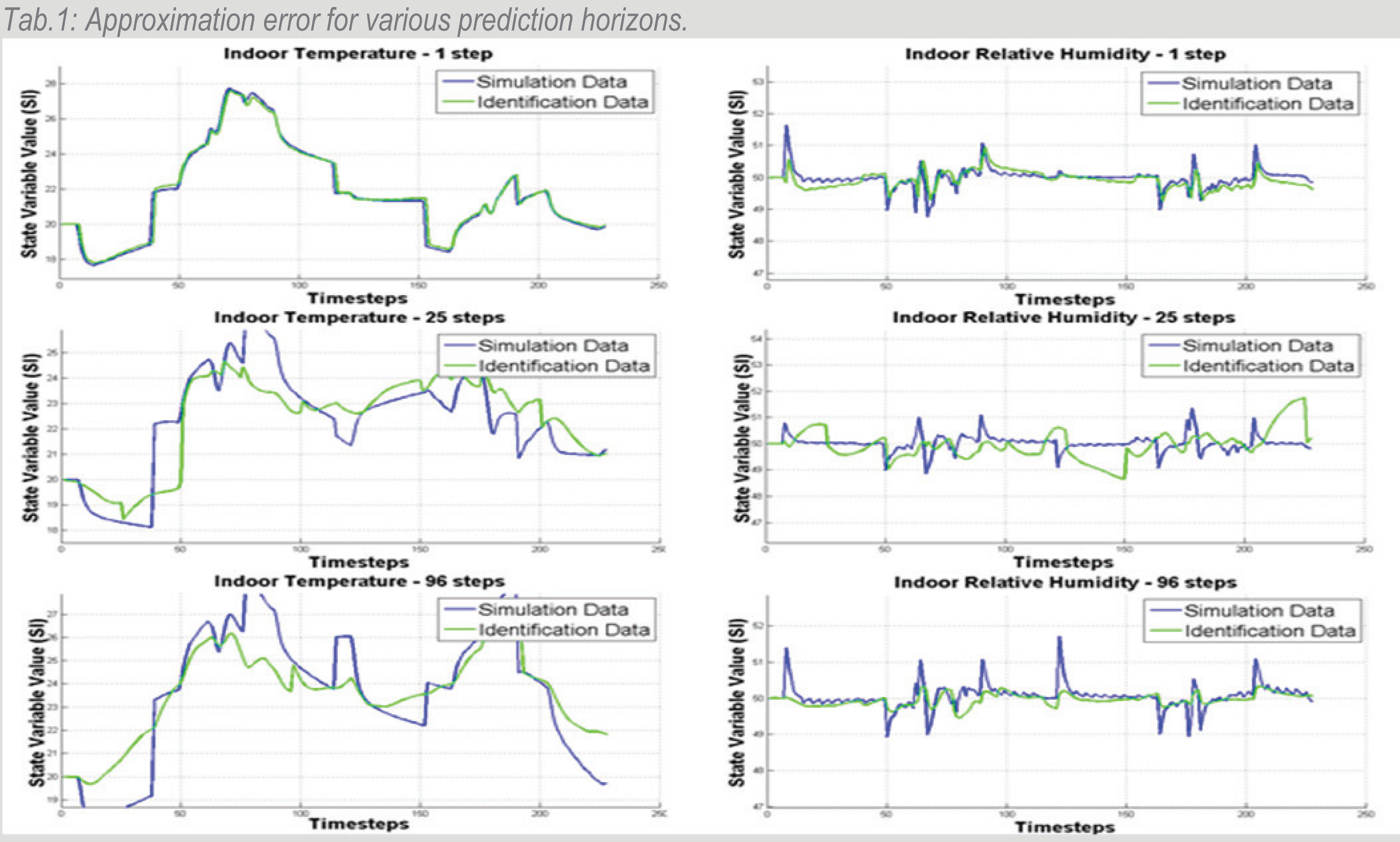

Fig.2: Building Tower model identification approximation results.

4. Conclusion

Simulation data from a validated TRNSYS model of an office building were used for demonstration, but practically these data may stem from measurement data of a real building. The idea of mixing signals as weighted factors for the linear sub-models to form the multi-linear state space model proved to work very well if the current state is updated frequently.

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