

Emulate an Analog Nonlinear Audio Device, is it Possible ?

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Section 1

Why nonlinear models are important ?

Nonlinear Devices

A system is nonlinear if :

it does not respect the principles of superposition (additivity) and homogeneity (scaling)

Almost all audio devices exhibit a nonlinear behavior

- Loudspeakers.
- Amplifiers.
- Compressors.
- Guitar and Keyboard sound effects.
- Microphones.

Acoustic field :

More generally, the system equations governing fluid dynamics (for sound waves in liquid or gases) and elasticity (for sound waves in solid) are nonlinear.

Why Try to Emulate Audio Devices



FIGURE: Home studio ?



FIGURE: Home studio !

Advantages of the simulation :

- Wide variety of sounds and timbres.
- Weight and overcrowding.
- Cheaper.



Section 2

Non-linear modelling



Nonlinear Systems Identification Techniques

Autonomous models

- Physical model (non black box).
- NARMAX model (difficult to identify).
- MISO model (difficult to identify).
- **Volterra** model (difficult to identify).
- Neural network (too many parameters).
- ...

Non autonomous models

- Extended Kalman filter.
- Particle filtering.
- ...

Nonlinear Emulation : Volterra Series

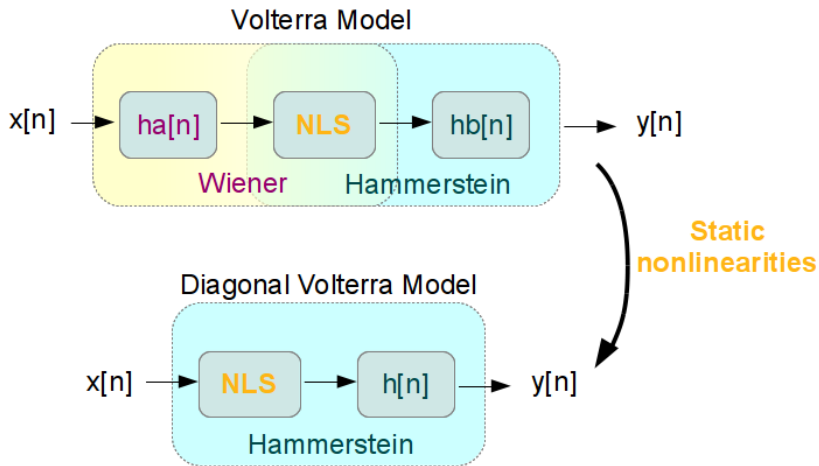


FIGURE: Volterra decomposition in subclass models

Miso to Hammerstein model

Power series model

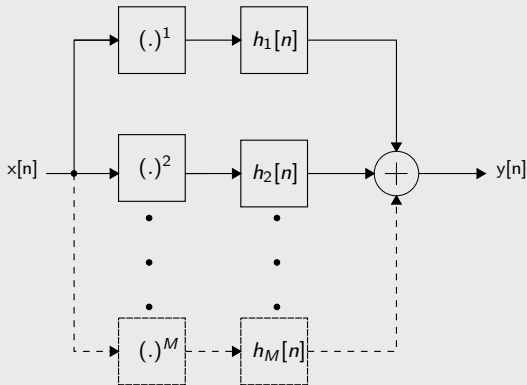
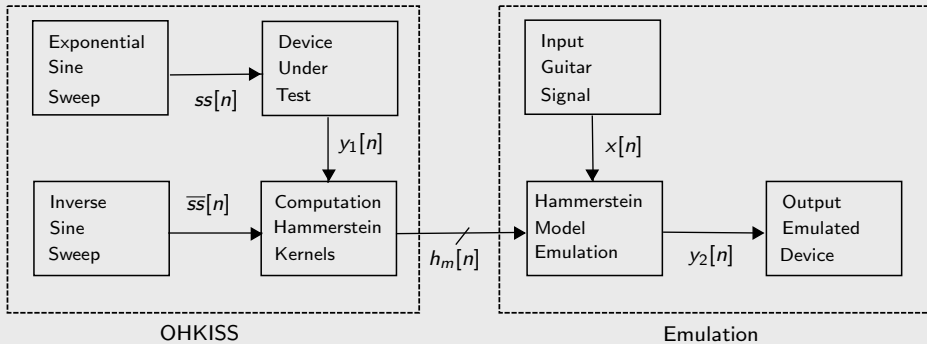


FIGURE: Polynomial Hammerstein model

$$y[n] = x[n] \circledast h_1[n] + x[n]^2 \circledast h_2[n] + \dots + x[n]^M \circledast h_M[n] \quad (1)$$

OHKISS method

From Identification to Emulation



Deconvolved ESS Through a NL Device

$$z[n] = y[n] \circledast x^{-1}[n] \quad (2)$$

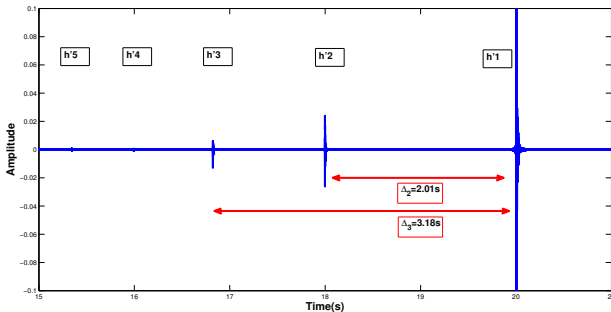


FIGURE: $z[n]$, the deconvolution of the ESS through a Nonlinear device

From measured kernels to Hammerstein kernels (see [5])

$$h'_m[n] \xrightarrow{\text{compute}} h_m[n] \quad (3)$$

Section 3

Real audio devices emulation

Real Output Device Signal vs Emulated Signal

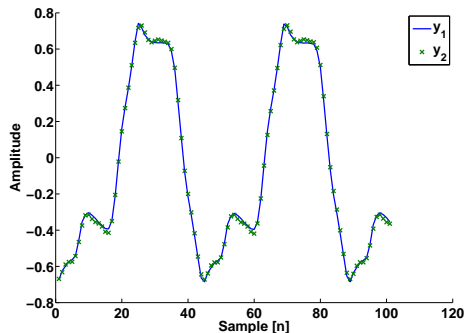
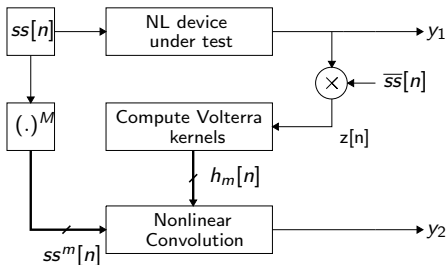


FIGURE: Output signal from TSA15 (y_1) and emulated signal (y_2) comparison.

So what ?



FIGURE: The Grail of emulation techniques ?

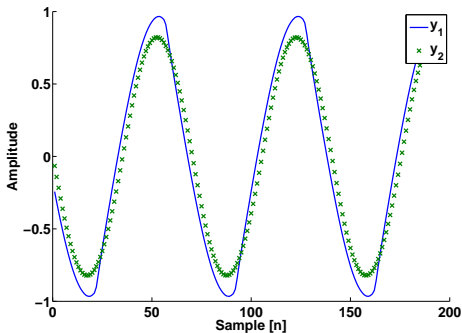


FIGURE: Comparison between the real output signal with an input amplitude of 0.5 (y_1) and the simulated signal where Hammerstein kernel where calculated for a input amplitude of 1 (y_2)

Principal limitation :

Input level dependency

Section 4

Conclusion

Questions ?

Hammerstein model do not fits for all input amplitude but works well for a given level.

- Can we measure several models at different levels and switching between them ?
- Do we have to try others models and identification methods ?

Thank you for your attention !

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