Surgical Robotics

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“A Mathematical Model of Hysteresis”

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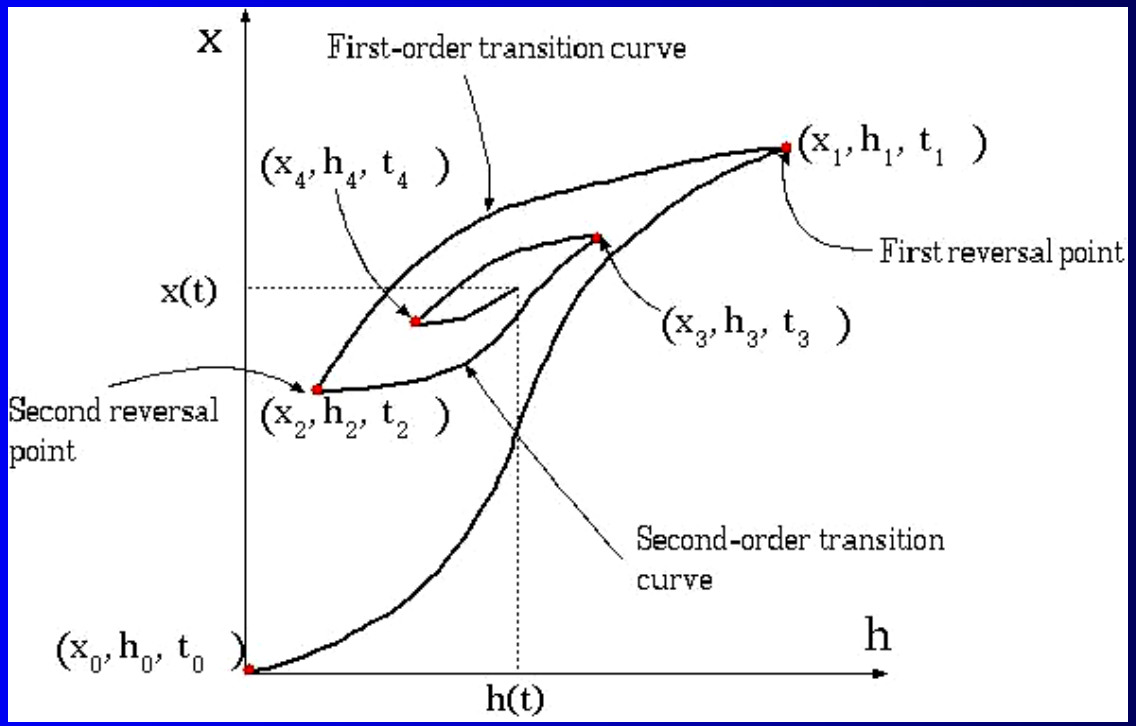
Outline

- **Hysteresis?....Where?...Why?**
- **Previous Models**
- **The Proposed Model**
- **Conclusions**
- **Future Works**

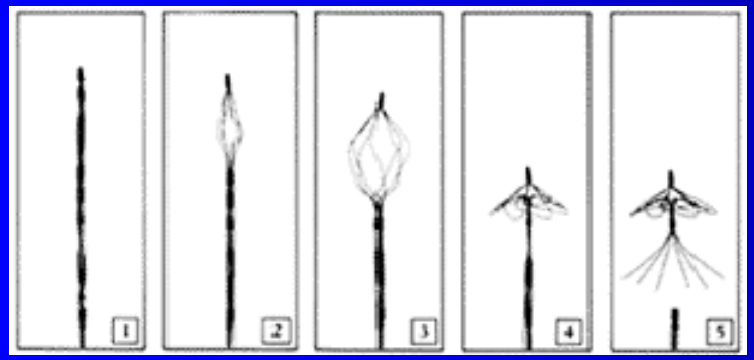
Hysteresis?...

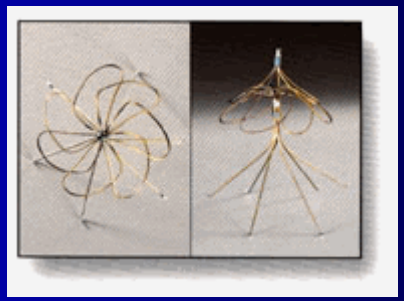
Hysteresis is a strongly nonlinear phenomenon. The state/output of the hysteretic system depends by past input history (memory effect). The free energy function has many local minima and saddles points.



…Where?

- Shape Memory Alloy (SMA). NiTiNol: muscle wire, aortic stents, Simon filter, knotting wire…
- Piezoelectric/Piezoceramics Actuators: MIS devices…
- Mechanic Friction: robot motor and joints, tissue modeling…
- Magnetic Materials
- Semiconductors, Biology, Laser Beam, Nanotechnology…

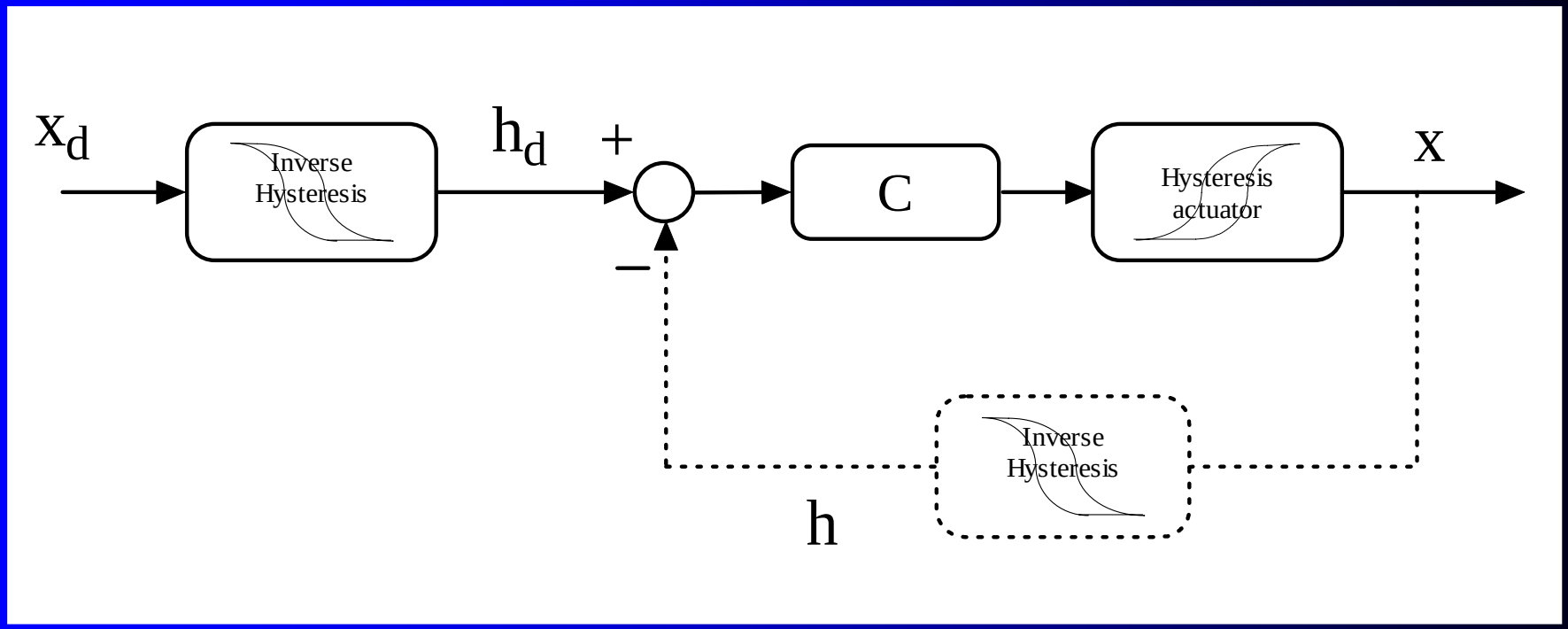




Simon Filter

…Why?

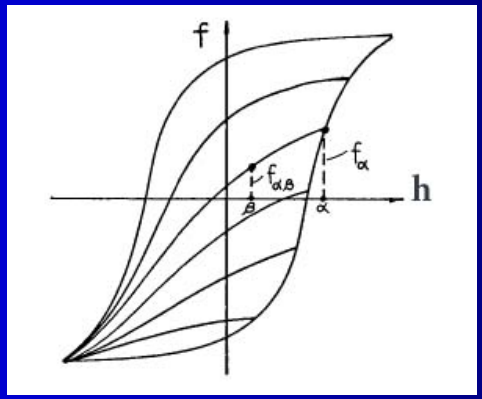
If we came up with the inverted model of hysteresis the fdt between x_d and x their cascade becomes the identity…



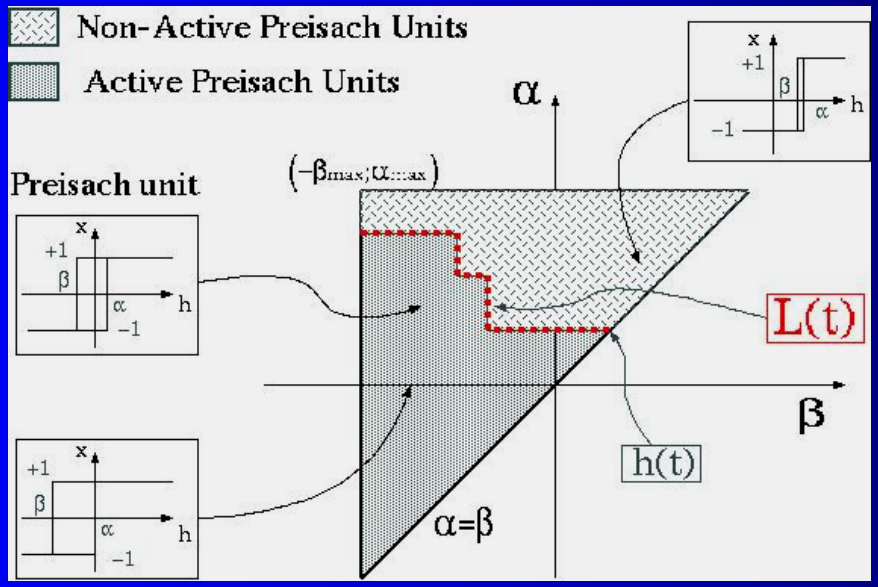
Previous Models

Preisach model has been introduced in 1935. The system has been seen as a collection of bistable units (relays).

- Identification phase



- Run time

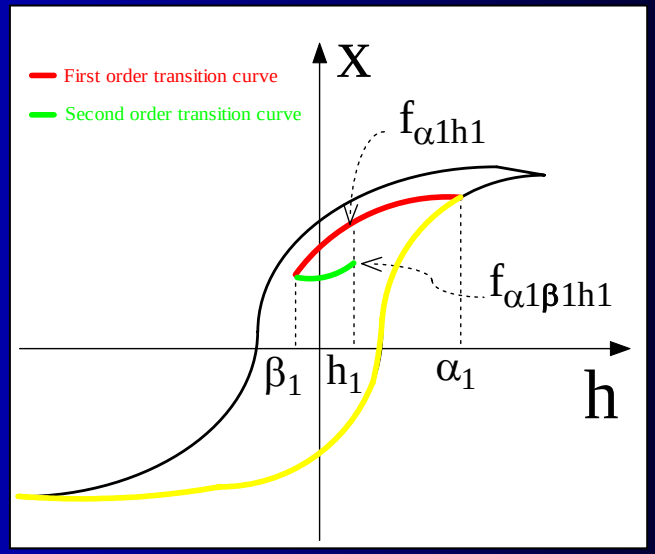


$$x(t) = \iint_{P_{\alpha\beta}} \mu(\alpha,\beta)h(t)d\alpha d\beta$$

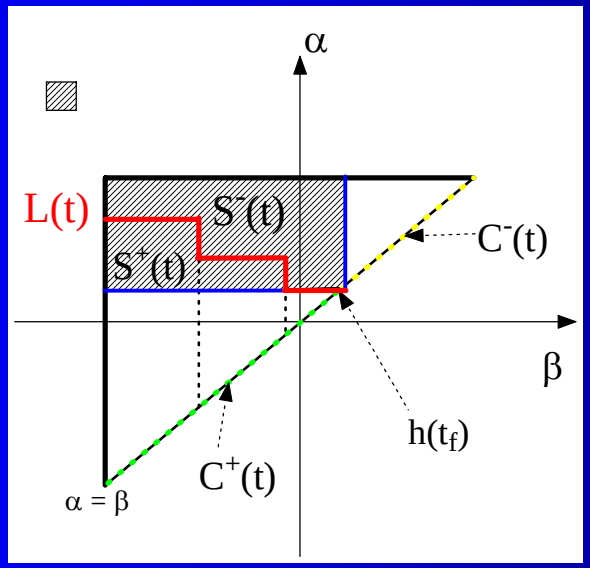
Previous Models

Generalized model has been introduced by I.D. Mayergoyz.

- Identification phase



- Run time

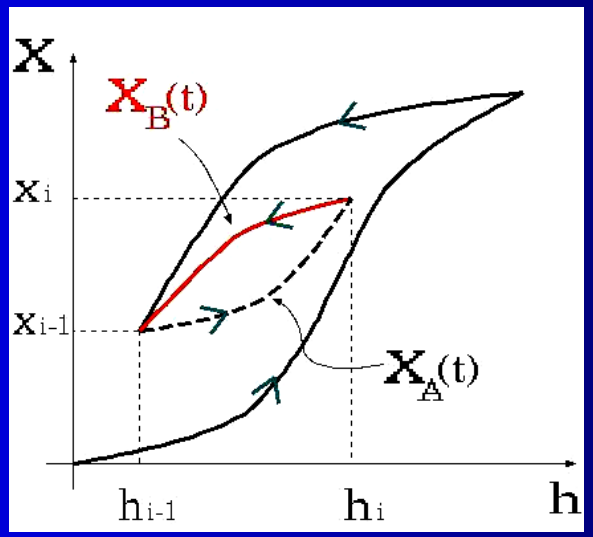


$$x(t) = \iint_{P_{\alpha\beta u}} \mu(\alpha, \beta, h) h(t) d\alpha d\beta$$

Proposed Model

A time varying function **W** is used in order to maintain the system “memory”.

- Identification phase

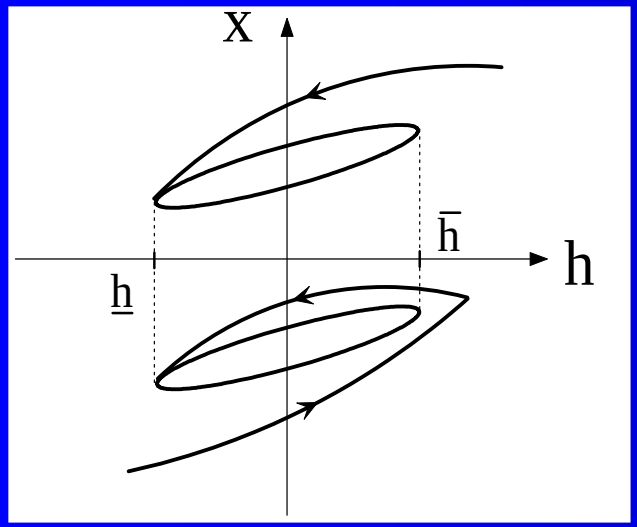


- Run time : $$x(t) = x(t_{k-1}) + \int_{h(t_{k-1})}^{h(t)} W_h(\zeta)\, d\zeta, \quad \forall t \in \varepsilon_k.$$

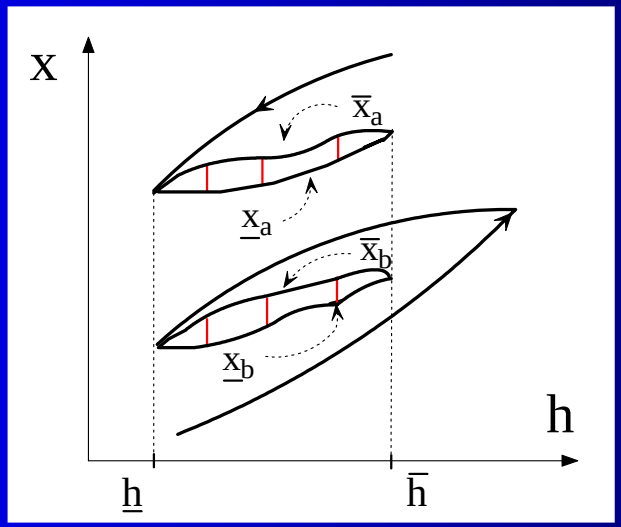
$$W_h(k,\zeta) = w_{h0}(\zeta) + \sum_{i \in \mathcal{A}_k} w_h(h_{i-1}, x_i, h_i)(\zeta)$$

Conclusions

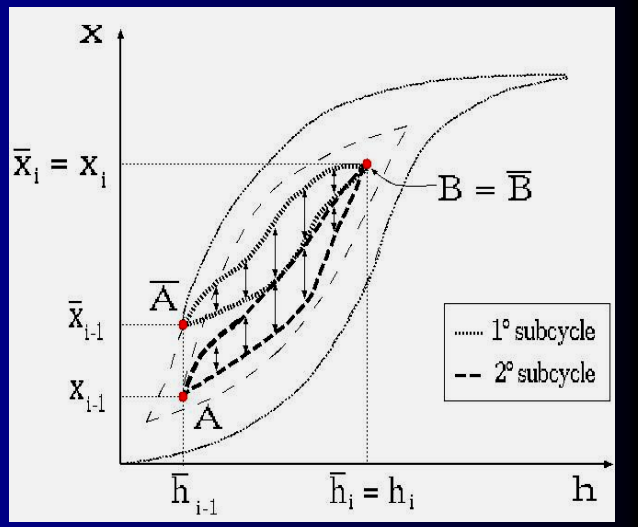
- Preisach Model ⇔ Wiping-out & Congruency properties, 1° rc.
- Generalized Model ⇔ Wiping-out & Equal chords properties, 2° rc.
- Proposed Model ⇔ Wiping-out & Same Vertex Equal Chords, **n**° rc.



Congruency

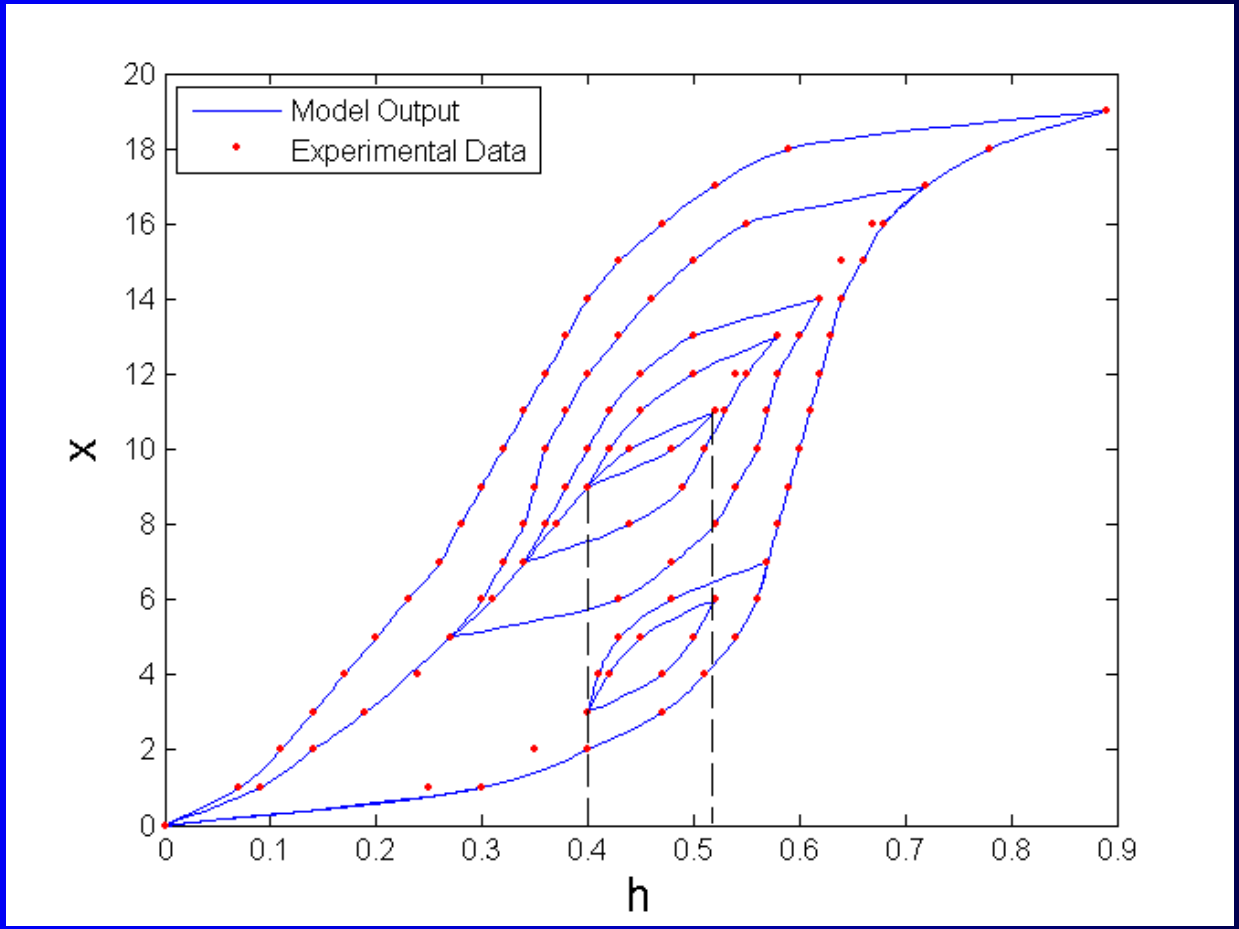


Equal chords



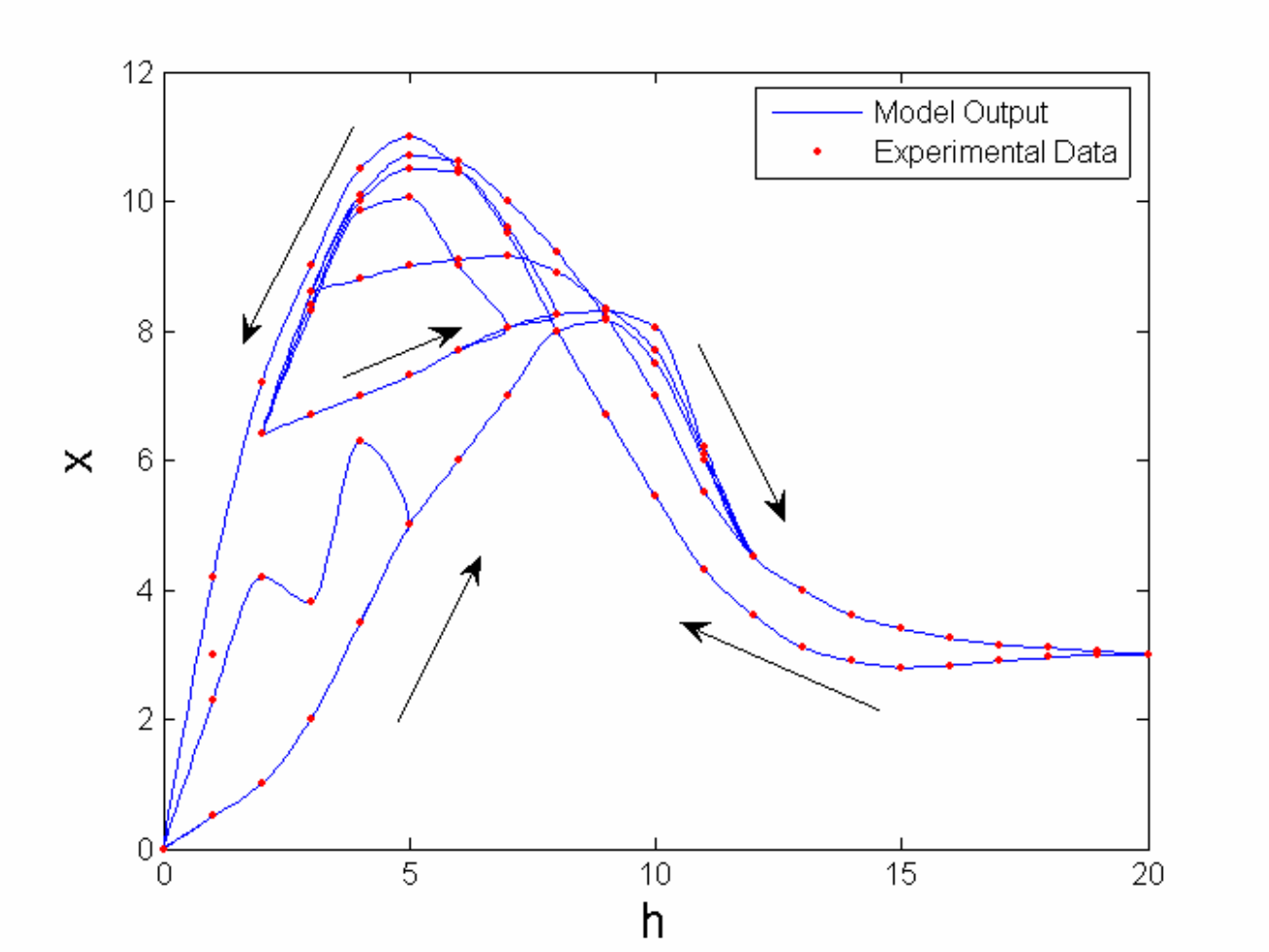
SVEC

...Conclusions



Example of minor loops and 6° order reversal curves reconstruction.

...Conclusions



Example of Resistivity VS Temperature in NiTiNol actuator wire.

Future Works

- Develop a dynamic version of the proposed model to take into account *rate dependence* hystereses and *accommodation* effect;
- Setup an hybrid framework for the model analysis when used in control loop;
- Generate an algorithm for the adaptive version;
- Vector version of the model.