INDICIAL PREDICTION SYSTEM
- QUICK TOUR -

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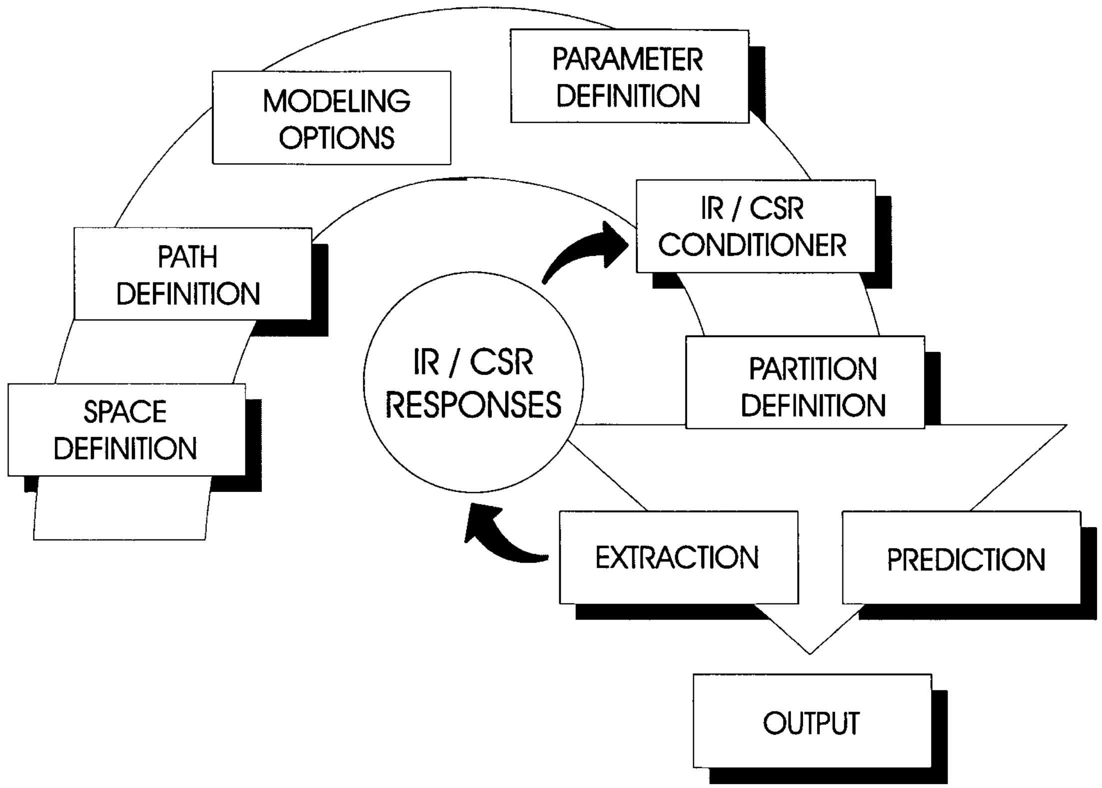
Mountain View, CA

IPS Overview



The IE and IP Programs Share Common Module Components.

Hardware / Software Requirements

- **The code compiles on the following systems**

HARDWARE	Operating System	F90 Compiler	C Compiler	Current Version
SUN	Solaris 2.x	Craysoft	gcc	✓
SUN	Solaris 2.x	SunPro	SunPro	✓
SGI	Irix 6.2	MIPSpro	Mipspro	✓
HP	HPUX 10.2	HP	HP	-
INTEL	Linux	NagWare	gcc	✓

- **Additional software required to compile**
  - gmake: GNU version of make †
  - perl: practical extraction and report language, version 5
  - gcc: GNU version of C-compiler (needed if system does not already have a C-compiler)†
  - pgplot: free device-independent plotting library

† Software is freeware, protected under GPL

Indicial Theory

If $$\delta\mu(t) = \mu_{\epsilon}(t,\tau)\frac{d\epsilon(\tau)}{d\tau}\delta\tau + O(\delta\tau)^2$$

and $$\mu_{\epsilon}(t,\tau) = \mu_{\epsilon}(t-\tau,0) \equiv \mu_{\epsilon}(t-\tau)$$

Then: $$\mu(t) = \mu_{\epsilon}(t)\epsilon(0) + \int_0^t \mu_{\epsilon}(t-\tau)\frac{d\epsilon(\tau)}{d\tau}\delta\tau$$

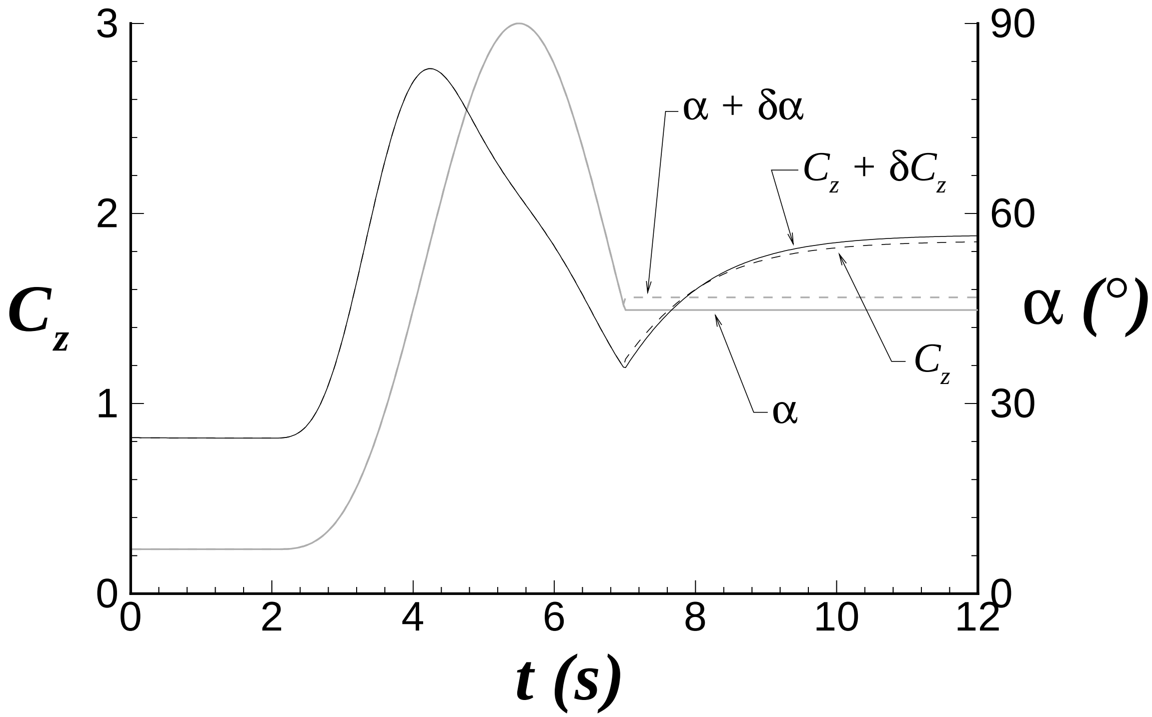
Nonlinear Indicial Theory

$$\Delta\mu(t) = \int_0^{\tau_c^-} \mu_\epsilon(\epsilon(\xi); t, \tau) \frac{d\epsilon}{d\tau}\, d\tau$$

$$+ \quad \Delta\mu^{CS}(\epsilon(\xi); t, \tau_c)$$

$$+ \int_{\tau_c^+}^{t} \mu_\epsilon(\epsilon(\xi); t, \tau) \frac{d\epsilon}{d\tau}\, d\tau$$

Indicial Response

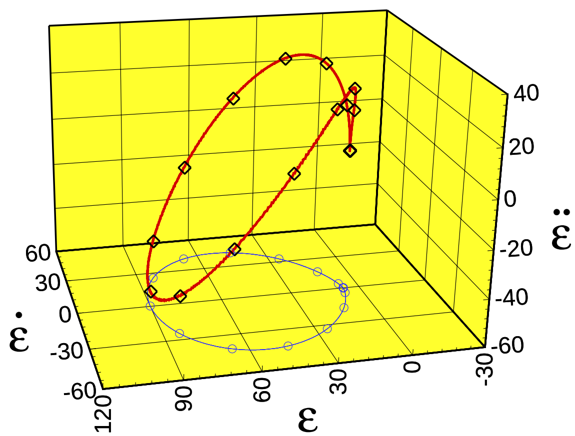


$$IR = \lim_{\delta\alpha \to 0} \frac{\delta C_z}{\delta \alpha}$$

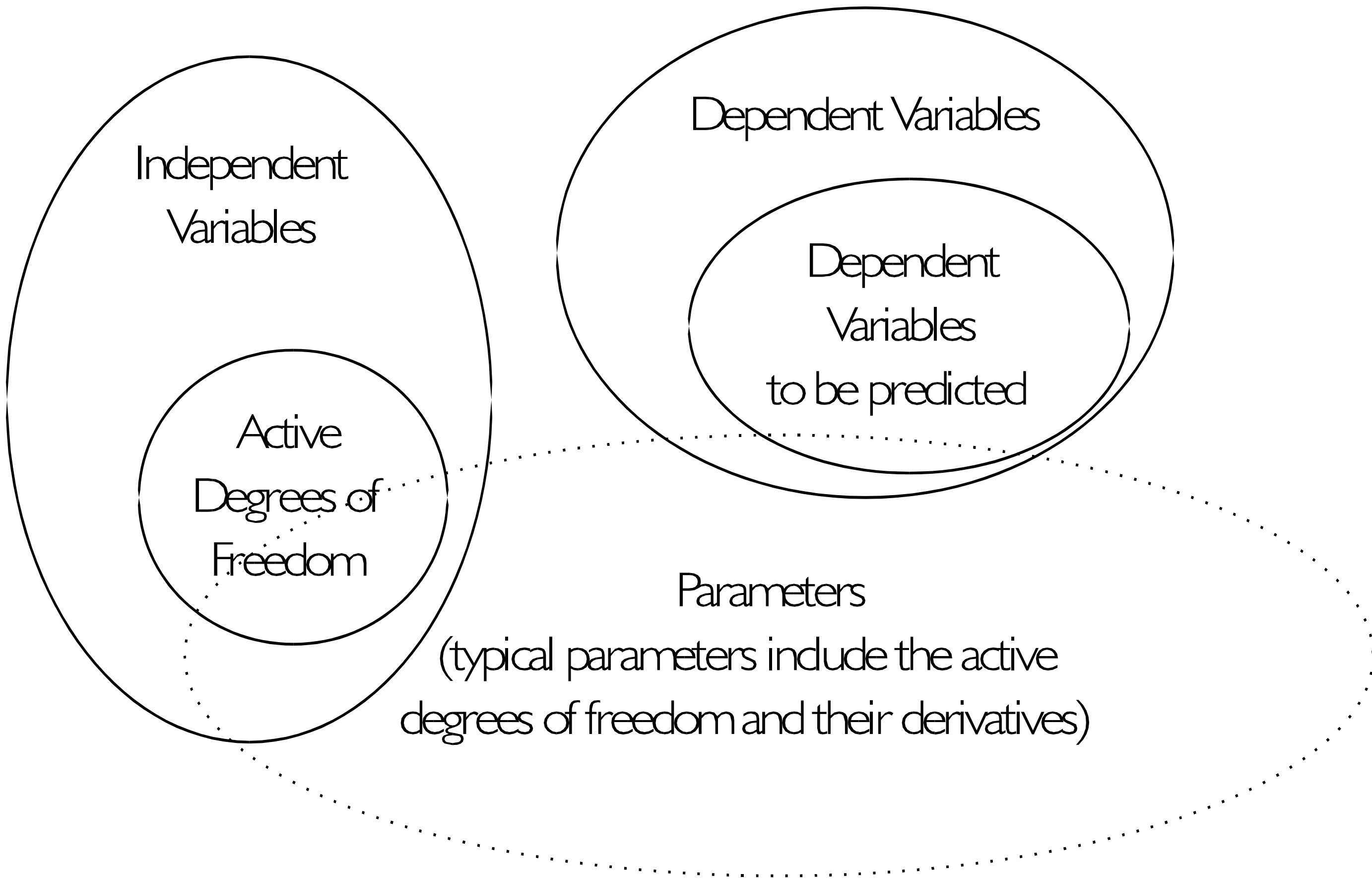
Nonlinear Indicial Model

$$\Delta\mu(t) = \int_0^t \mu_\epsilon(\epsilon(\xi);t,\tau)\,\frac{d\epsilon}{d\tau}\,d\tau$$

$$\approx \int_0^t \mu_\epsilon(t-\tau)\Big|_{\epsilon(\tau),\dot{\epsilon}(\tau),\ldots}\,\frac{d\epsilon}{d\tau}\,d\tau$$

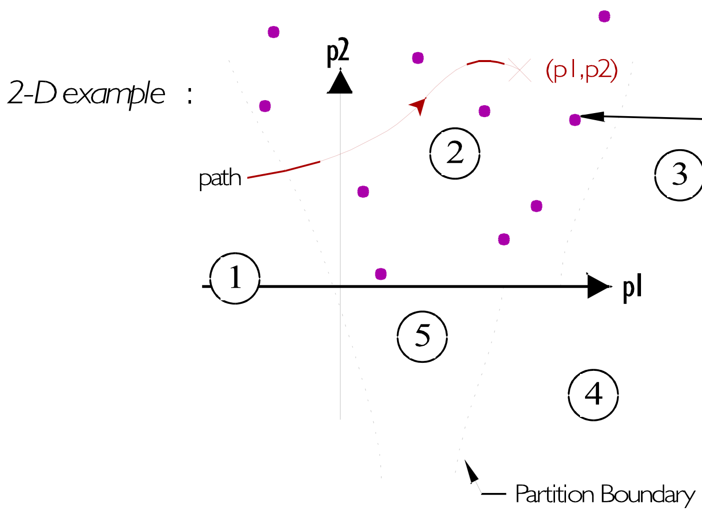


Terminology



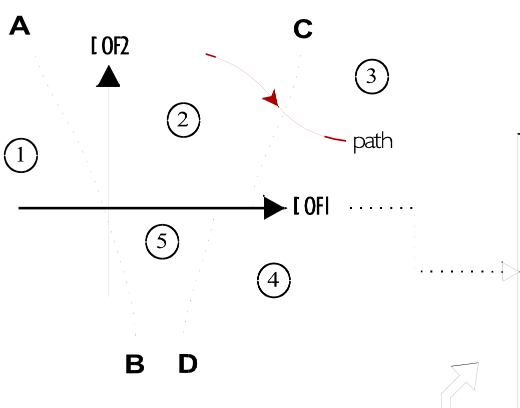
IR/CSR Space Partition

Illustration of IR Interpolation



To participate as nodes in the interpolation process at (p1,p2), only those indicial responses which belong to partition zone #2 are considered

Definition of Critical States Based on Partition Transitions

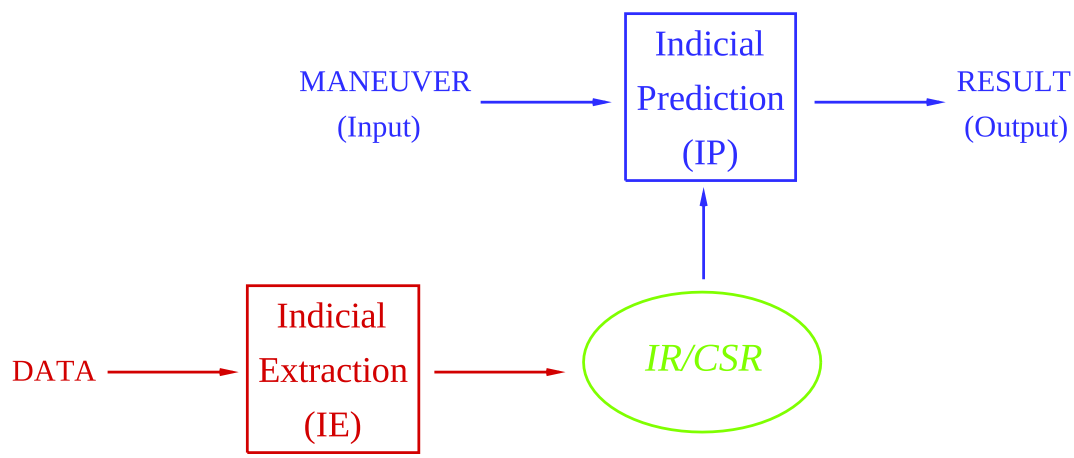


Transition between	**1**	and	**2**	:	**Critical State**	**[ID: A]**
Transition between	**1**	and	**5**	:	**Critical State**	**[ID: B]**
Transition between	**2**	and	**3**	:	**Critical State**	**[ID: C]**
Transition between	**2**	and	**4**	:	No critical state	
Transition between	**2**	and	**5**	:	No critical state	
Transition between	**3**	and	**4**	:	No critical state	
Transition between	**4**	and	**5**	:	**Critical State**	**[ID: D]**

Classify partition transitions

Direct/Inverse Problems

$$\int_{\Omega} input \times system \, d\Omega = output$$



Algorithm

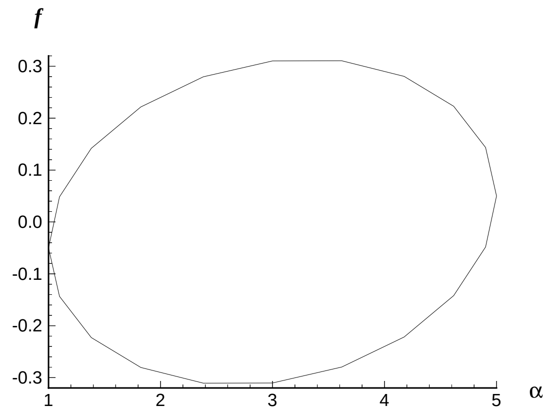
- $$IR(t) = IR_{QS} + DR(t)$$

  $$DEP \leftarrow \int_0^t IR_{QS}\, \dot{DOF}\, d\tau + \int_0^t DR(t-\tau)\, \dot{DOF}(\tau)\, d\tau$$

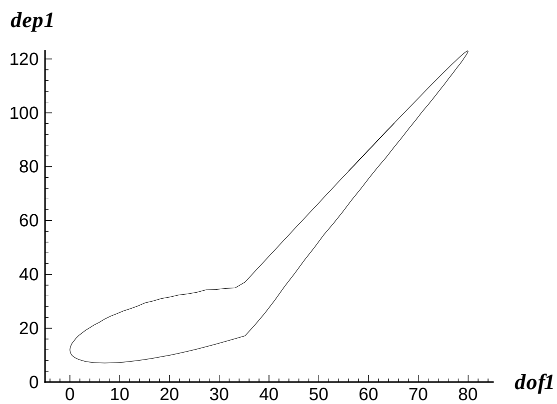
  $$DEP \leftarrow DEP + \sum_{CS} CSR_{QS} + \sum_{CS} CSR_{DR}(t-t_c)$$

- **Multiple DOF capability**
- **Arbitrary dimensional parameterization** (discrete or continuous)
- **Computational engines:**
  - Quadrature operations
  - Interpolation operations

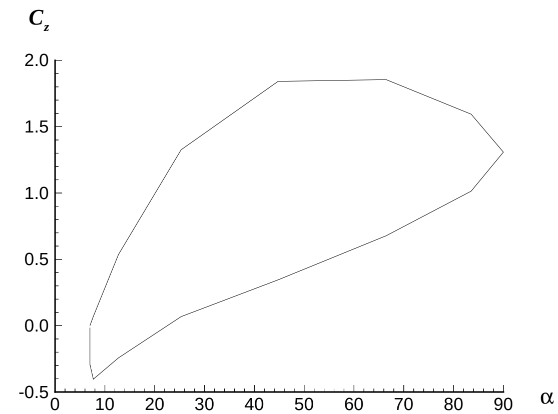
Sample Outputs



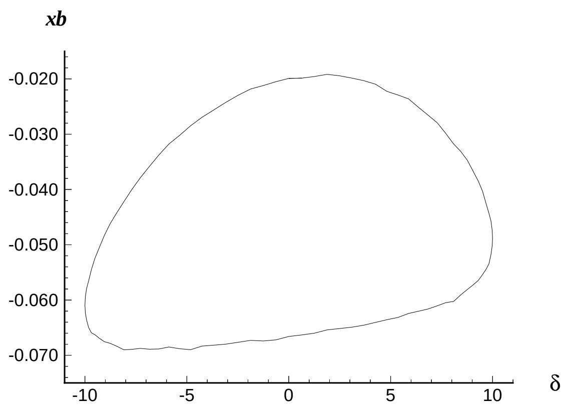
Case ‘linear’



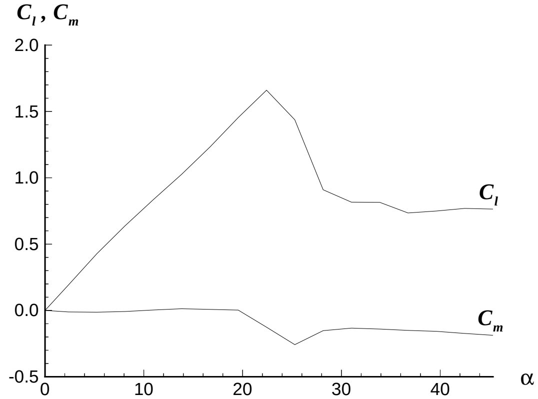
Case ‘nlir’



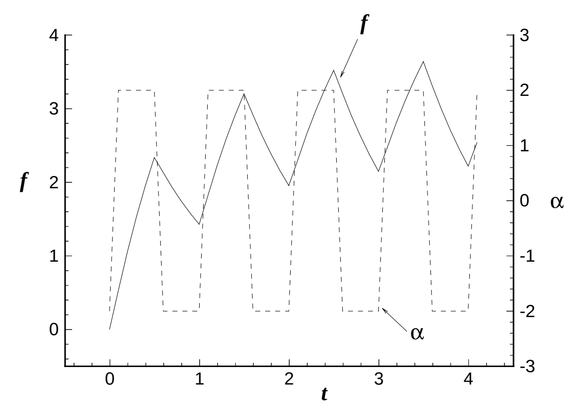
Case ‘GK’



Case ‘gursul’

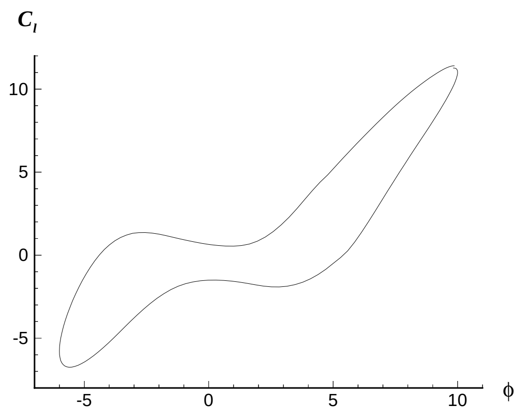


Case ‘NN’

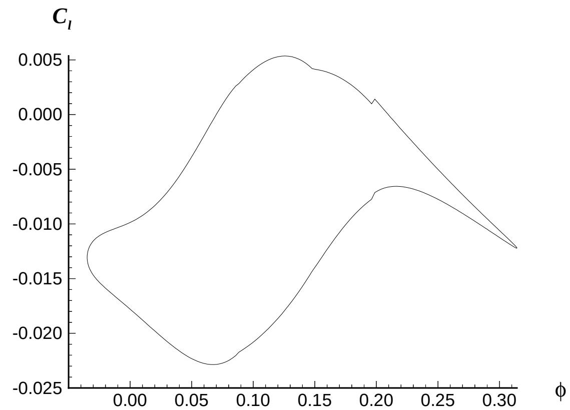


Case ‘xlin2'

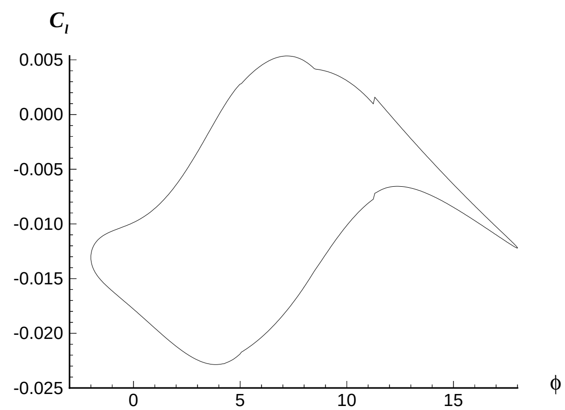
Sample Outputs (Cont'd)



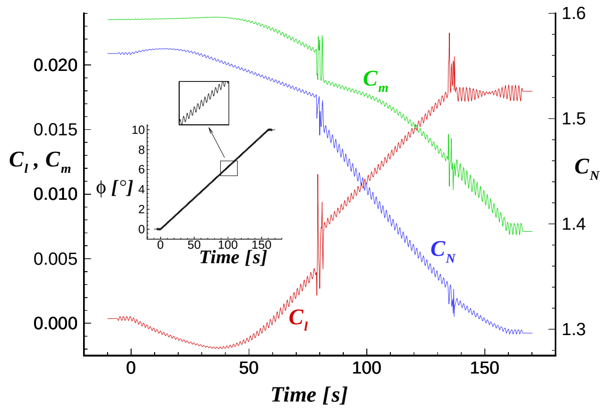
Case 'reno97'



Case 'myatt'



Case 'myattdeg'



Case 'delta_all'

Extraction: Theory

$$DEP^{dyn}(t_j) = \int_0^{t_j} DR(t_j - \tau)\, D\dot{O}F(\tau)\, d\tau$$

⇓

- **Linear interpolation:** $DR(t-\tau) = \sum_k w_k(\tau)\, DR_k(t-\tau)$
- **Basis function expansion:** $DR_k(t) = \sum_i x_{i,k}\, f_{i,k}(t)$

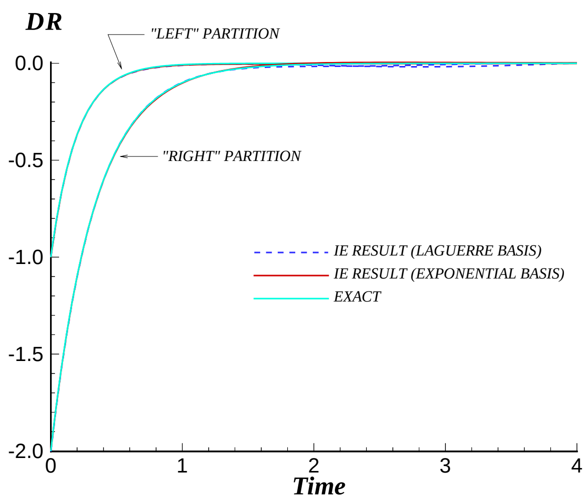
⇓

$$[A][x] = [b]$$

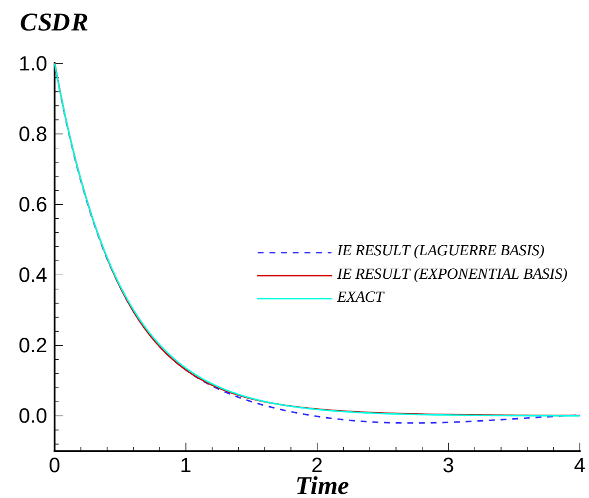
Solution by singular value decomposition

Extraction: Sample Results

- **Linear system, complete set of basis functions**
  → 4-digit accuracy
- **Linear system, incomplete basis functions**
  20% time constant error → 5% accuracy on extraction
  → 1% accuracy on prediction
- **Nonlinear system, incomplete basis functions:**



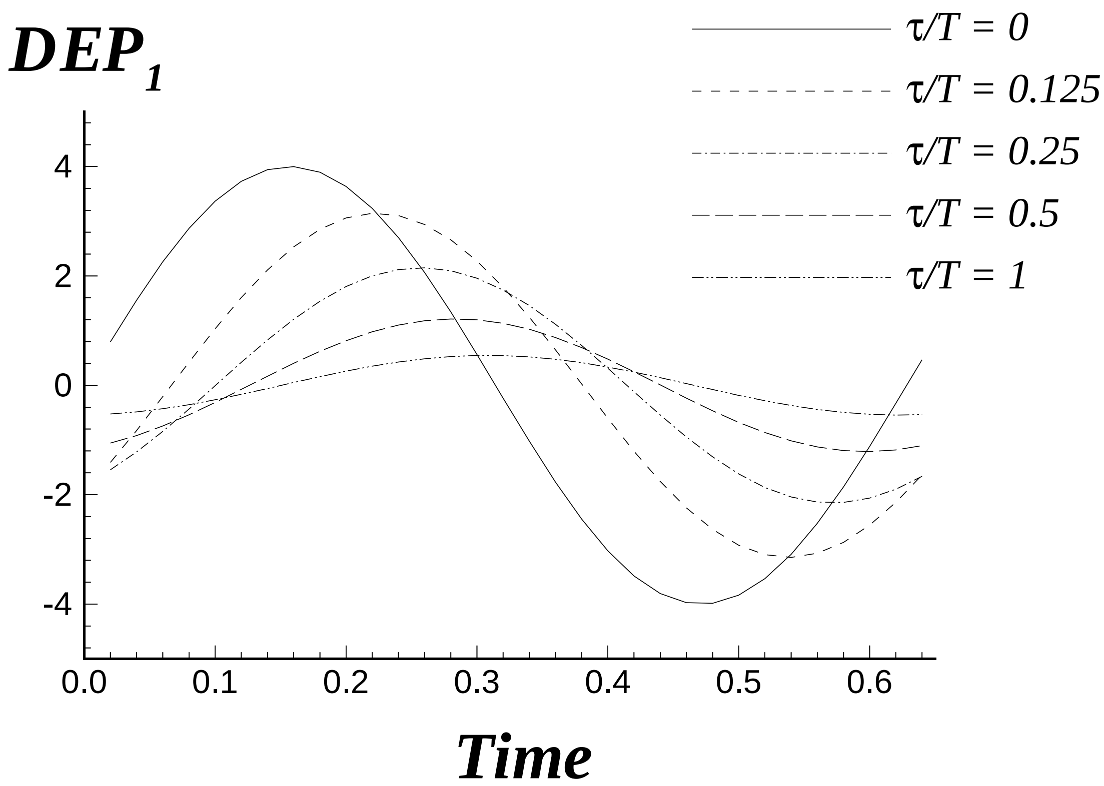
Extracted IR Nodes



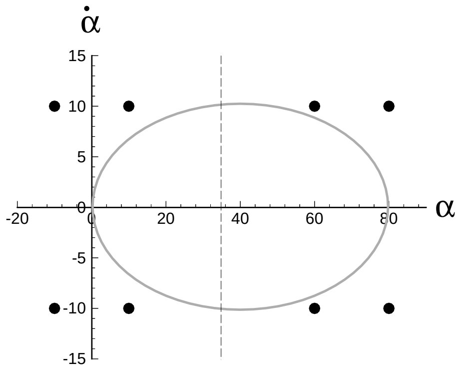
Extracted CSR Node

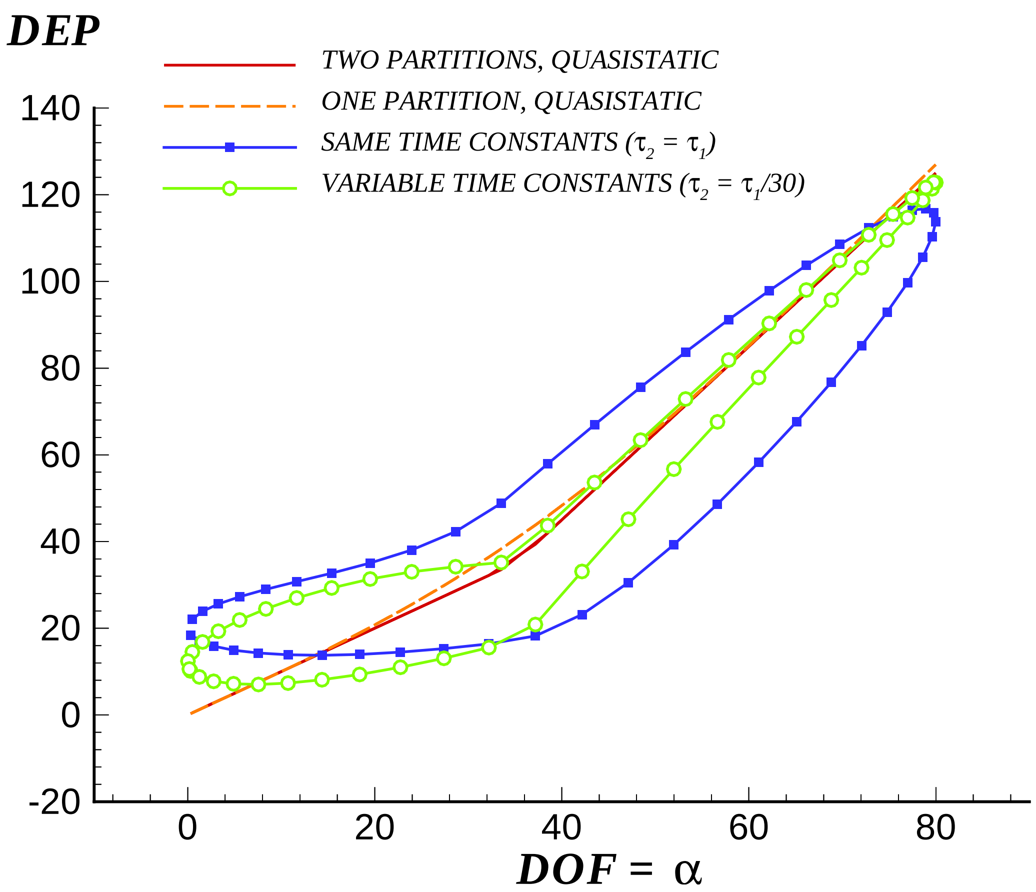
Linear Indicial Response

Ratio τ/T	Amplitude	Phase
0	4	0°
0.125	3.146	-38.1°
0.25	2.149	-57.5°
0.5	1.214	-72.3°
1	0.629	-81.0°



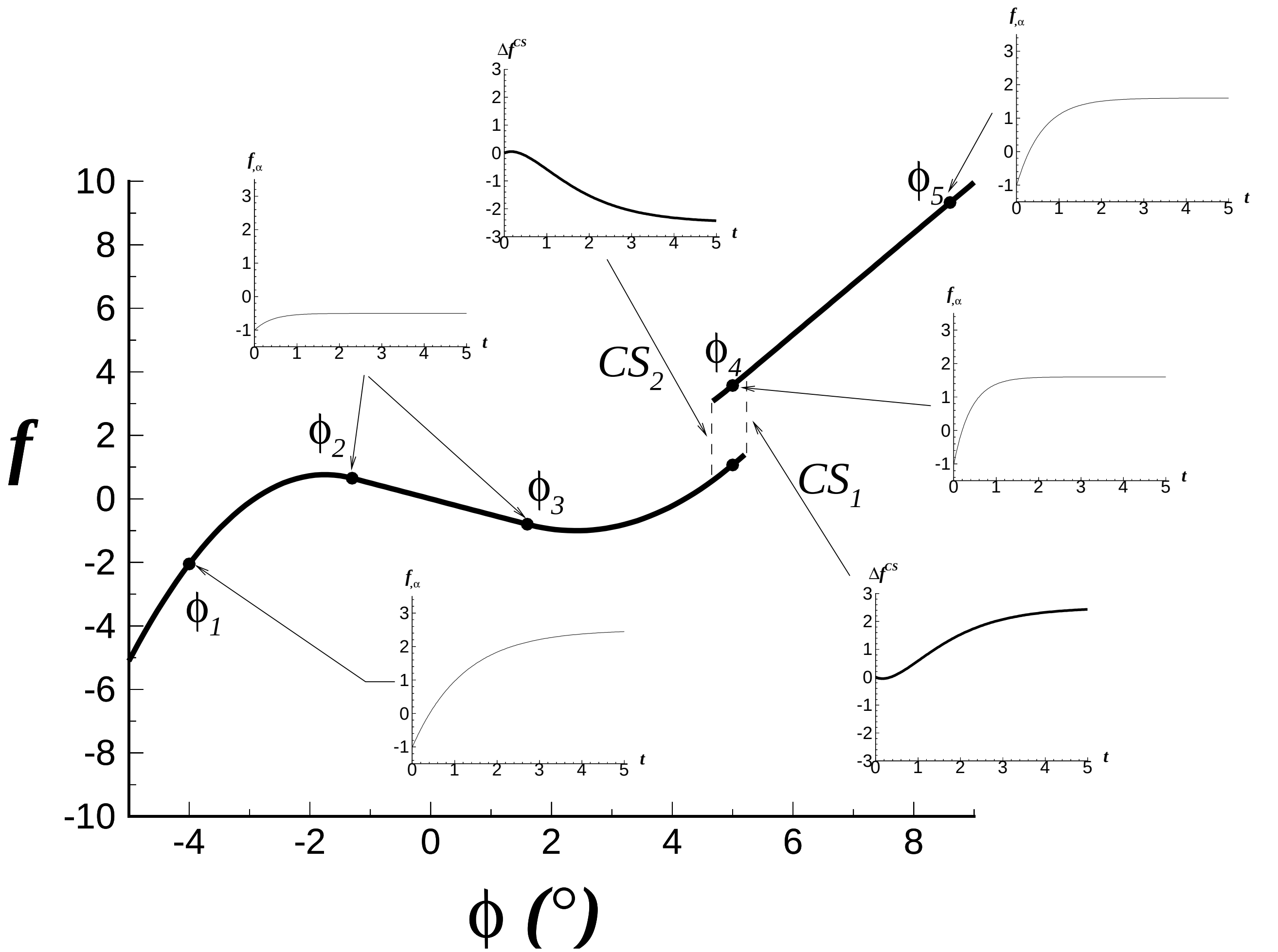
IR Space Partitioning





‘reno97’ synthetic data example

- **Static hysteresis case, with 5 IRs and 2 CSRs**



Critical State Hysteresis