Prediction Augmentation Through Reinforcing Interactions Amongst Modeling, Sensing and Learning

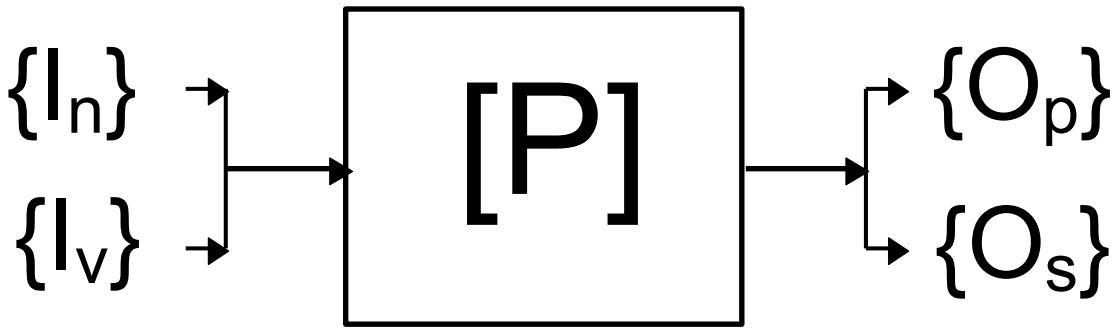
Patri K. Venuvinod

City University of Hong Kong

At the last meeting, the Working Group opined that “we need to give a nudge or push in a specific direction to suit our engineering purposes as we perceive them in the short as well as the long term”

This paper describes and argues for some specific ‘nudges’ which the author believes would be particularly useful at this point in the history of machining research.

The Process



$\{I_n\}$ = Nominal Input

$\{I_v\}$ = Unanticipated Input Variations

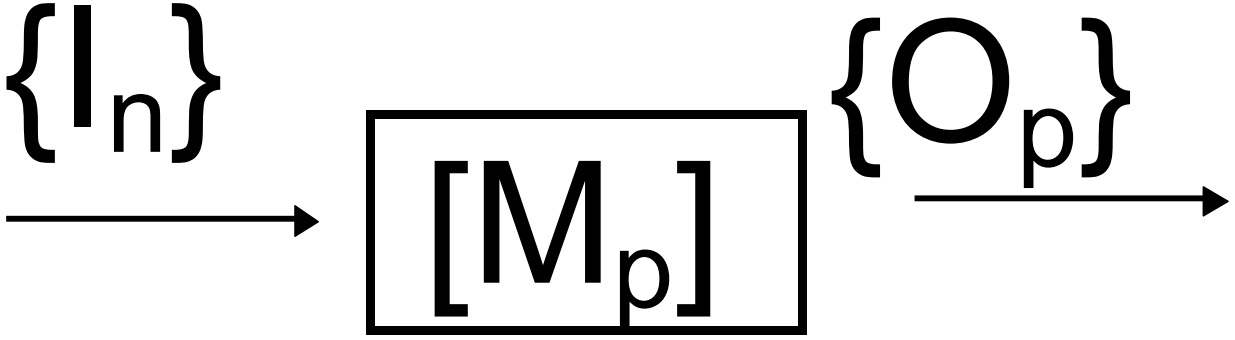
P = The Process

$\{O_p\}$ = Perfromance Measure (Output)

$\{O_s\}$ = Output capabele of being sensed

Aim of WG:

Quantitatively Predict $\{O_p\}$ from $\{I_n\}$



M_p = The process model aimed at predicting $\{O_p\}$ from given nominal inputs $\{I_n\}$

News Brief: May 1997 "Manufacturing Eng.", SME.

"A metal cutting ☞☜ modeling software called 💣✳♋♍♒📄👎

to be released by Third Wave

to be realized in 1997.

Capable of modeling *forces, temperatures, material removal rate, chip growth, chip breaking, chatter, and vibration*."

Modeling of Machining Operations: Literature Database

Patri K. Venuvinod

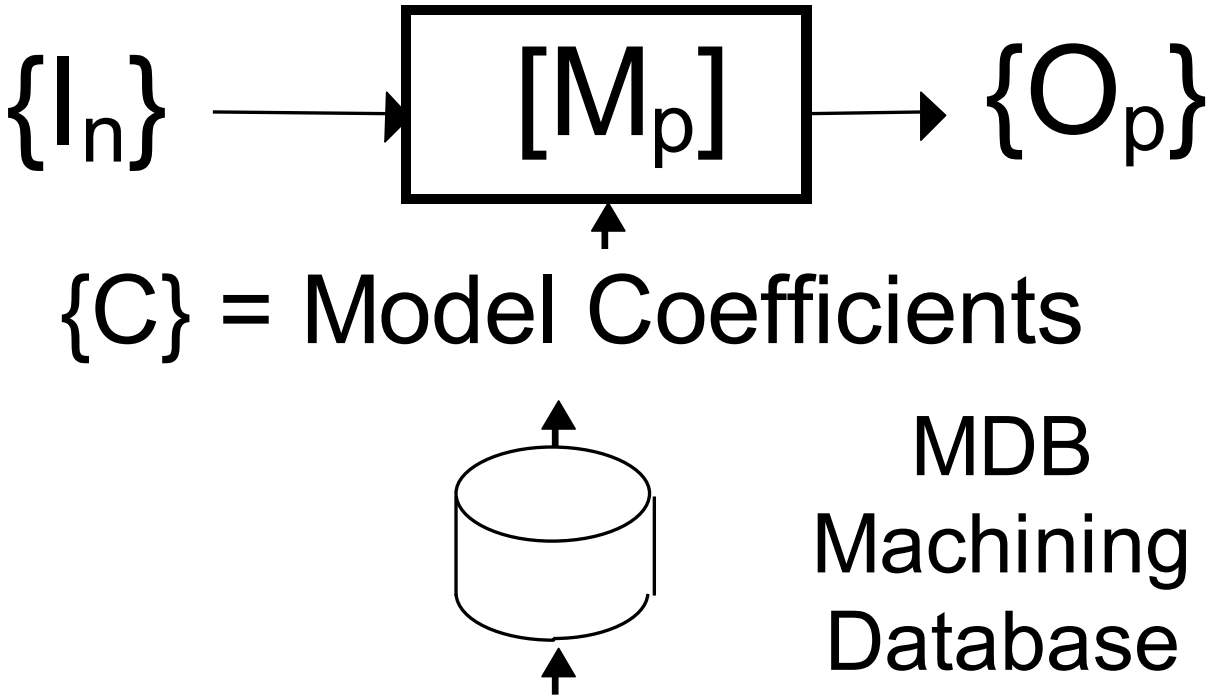
2801 articles, Labelled

Much insight into current status of modeling of machining operations

Current Status of Modeling

- **Still grappling with single edge cutting**
- **Still dominated by plane rake face**
- **Dominated by Analytical Modeling**
- **Some FEM recently (mostly 2D)**
- **Need expensive and, often, unreliable Machining Databases**
- **Good at qualitative prediction and developing understanding**
- **Quantitative prediction : Limited success**

• The Current Ethos of Modeling

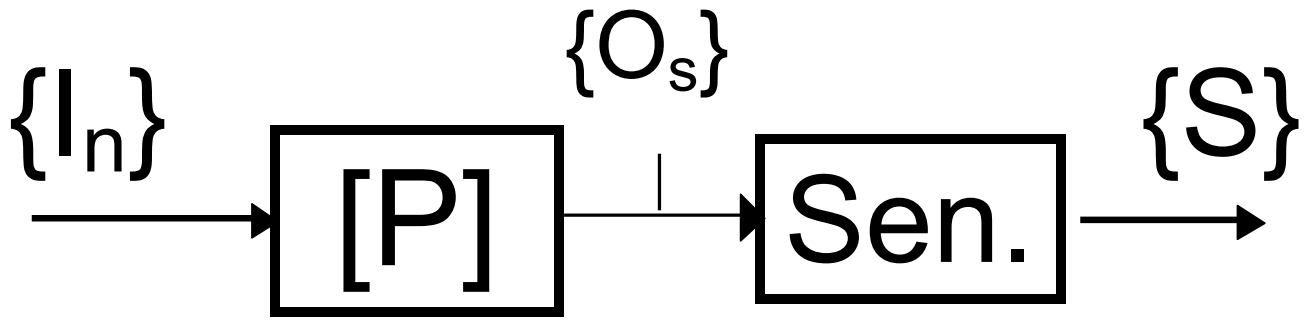


Persisting Problems

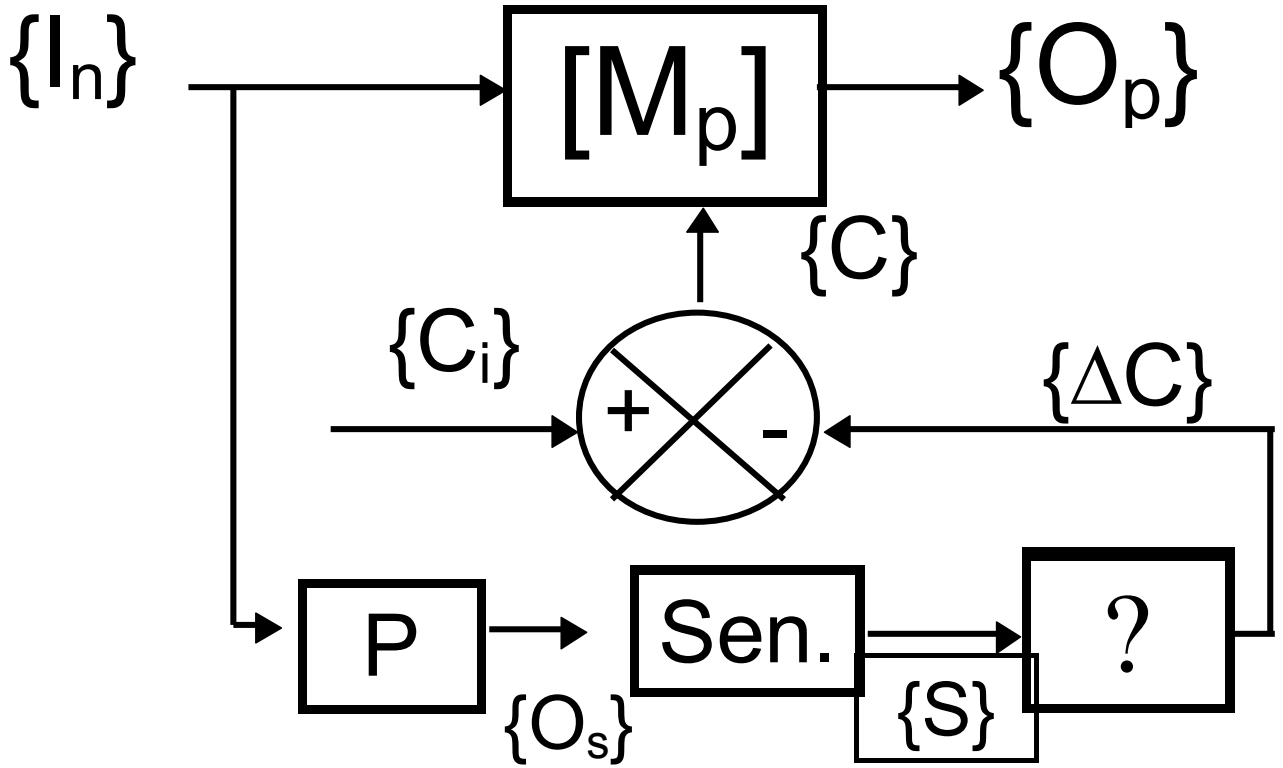
- Very few practical operations adequately modeled
- Limited success with quantitative prediction
- Models must change when chip forms change. Need to anticipate chip form change.
- Expensive and static Machining Data Base

Can we find an alternative to MDB?

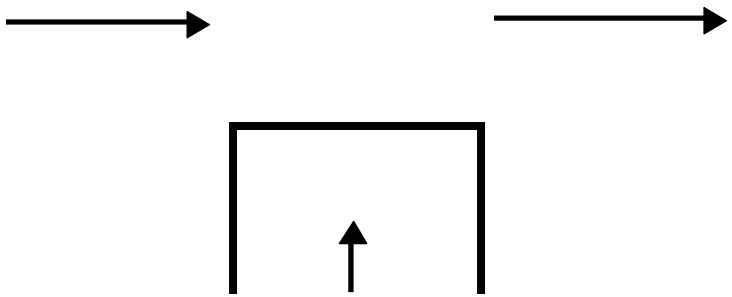
- **Sensing**



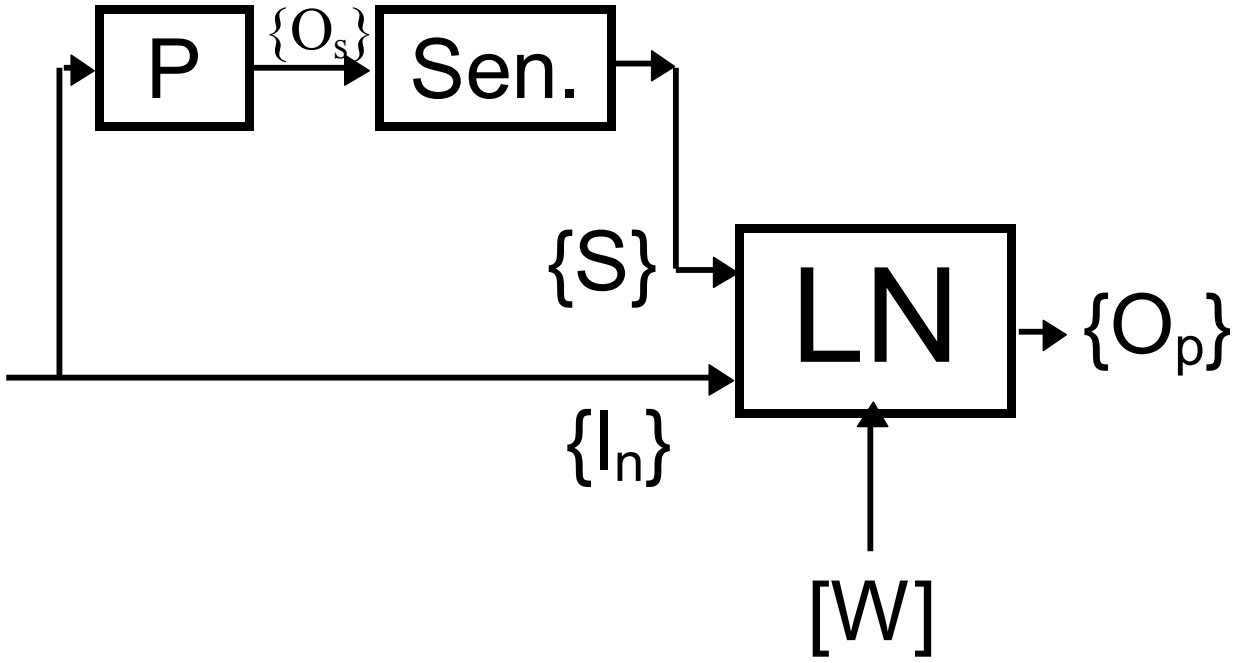
- **Calibrating A Predictive Model Using Sensed Output**



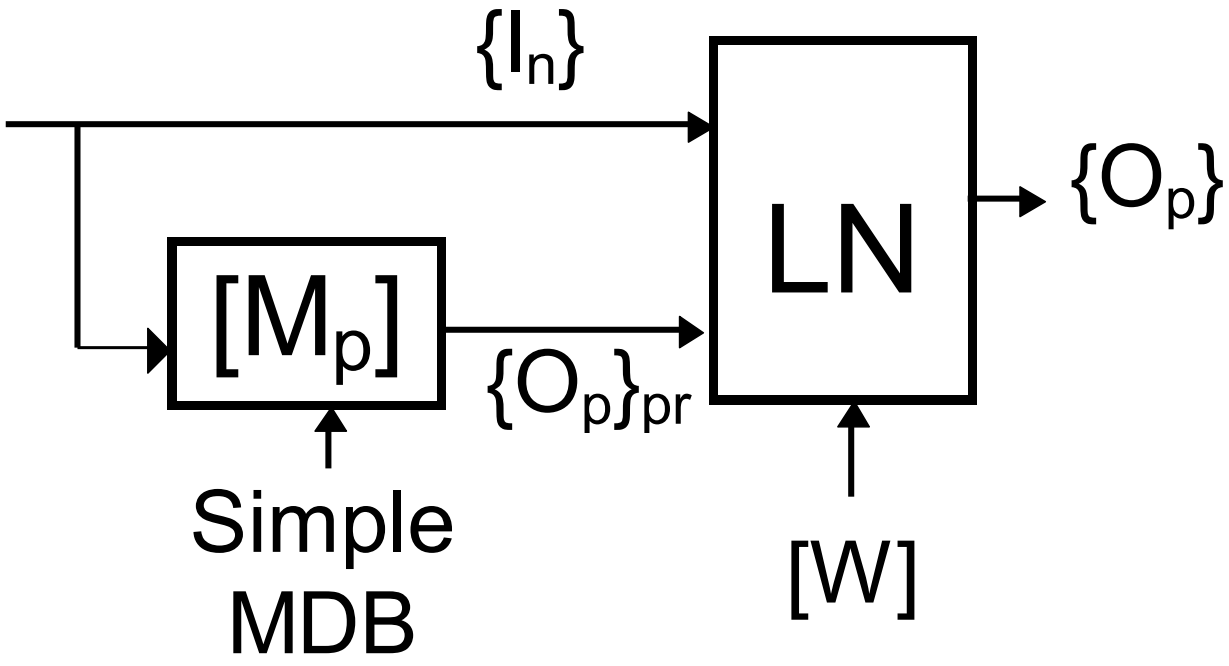
- **Learning**



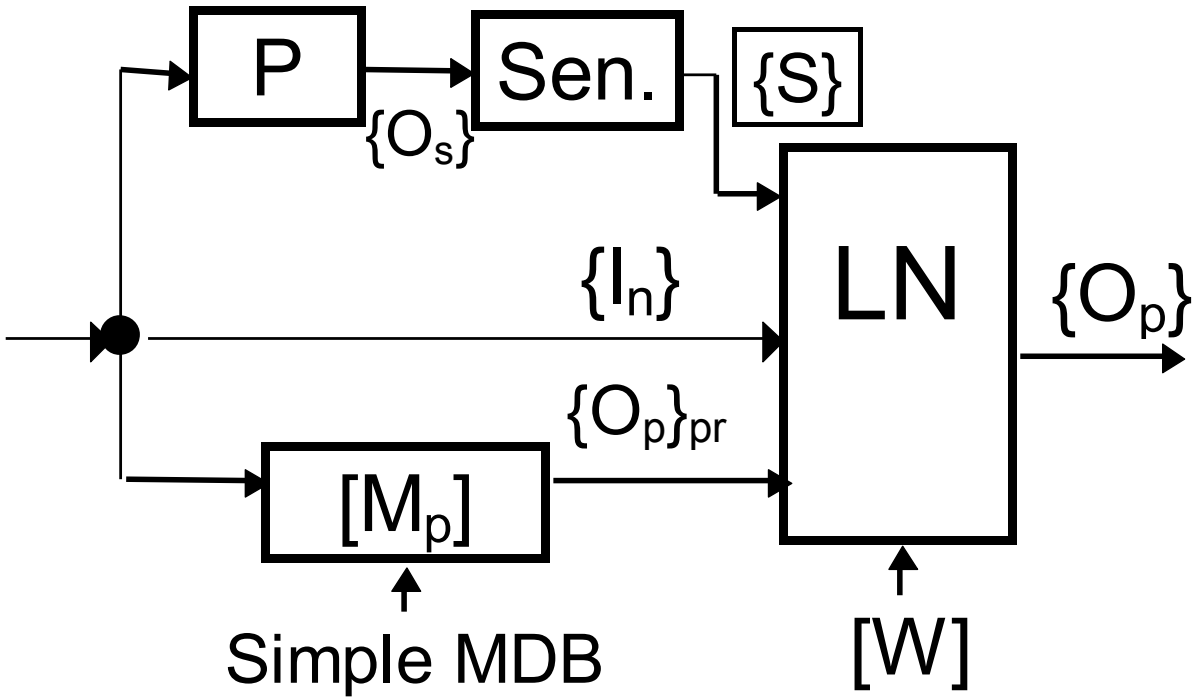
- **Augmenting a Learning System Through $\{O_s\}$**



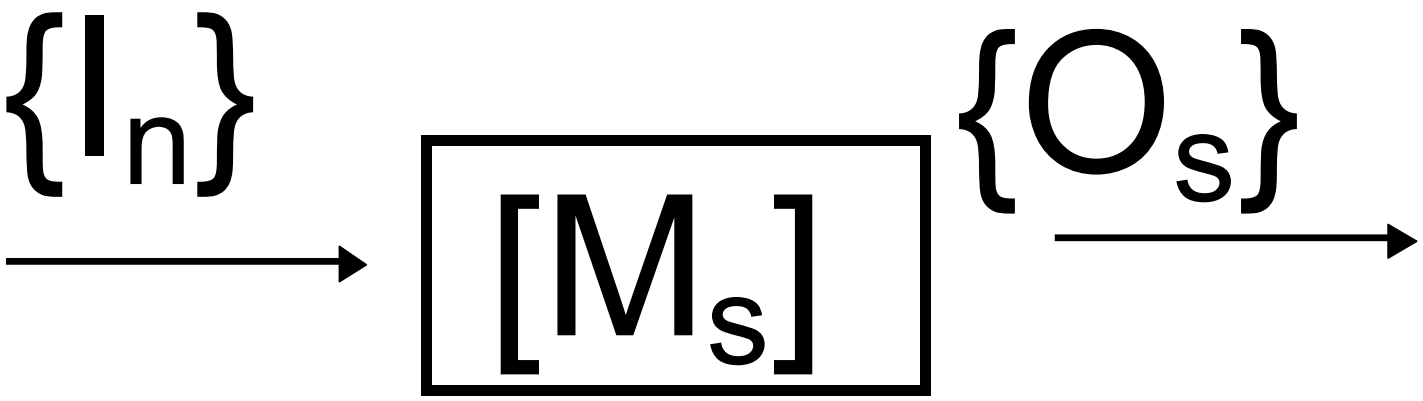
Augmenting Learning with Modeling



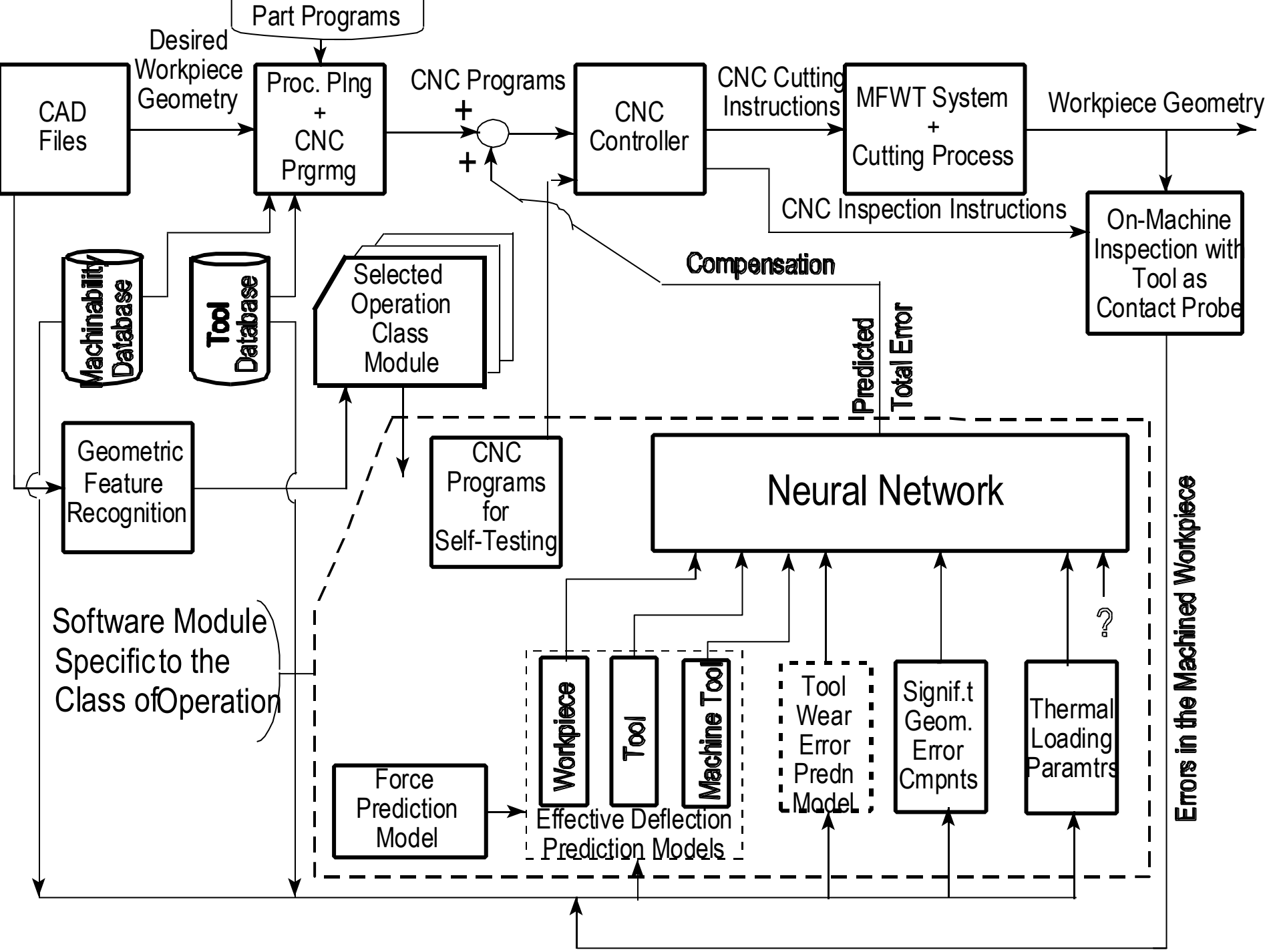
Augmenting Learning Through Modeling as well as Sensing



- **A Possible Nudge**



$[M_s]$ = The process model aimed at predicting $\{O_s\}$ — unlike $[M_p]$ which predicts $\{O_p\}$


Part Programs
Desired Workpiece Geometry
CAD Files
Proc. Plng + CNC Prgrmg
CNC Programs
+
+
CNC Controller
CNC Cutting Instructions
MFWT System + Cutting Process
Workpiece Geometry
CNC Inspection Instructions
On-Machine Inspection with Tool as Contact Probe
Machinability Database
Tool Database
Selected Operation Class Module
Compensation
Predicted Total Error
Geometric Feature Recognition
CNC Programs for Self-Testing
Neural Network
Software Module Specific to the Class of Operation
Workpiece
Tool
Machine Tool
Tool Wear Error Predn Model
Signif.t Geom. Error Cmpnts
Thermal Loading Paramtrs
?
Force Prediction Model
Effective Deflection Prediction Models
Errors in the Machined Workpiece