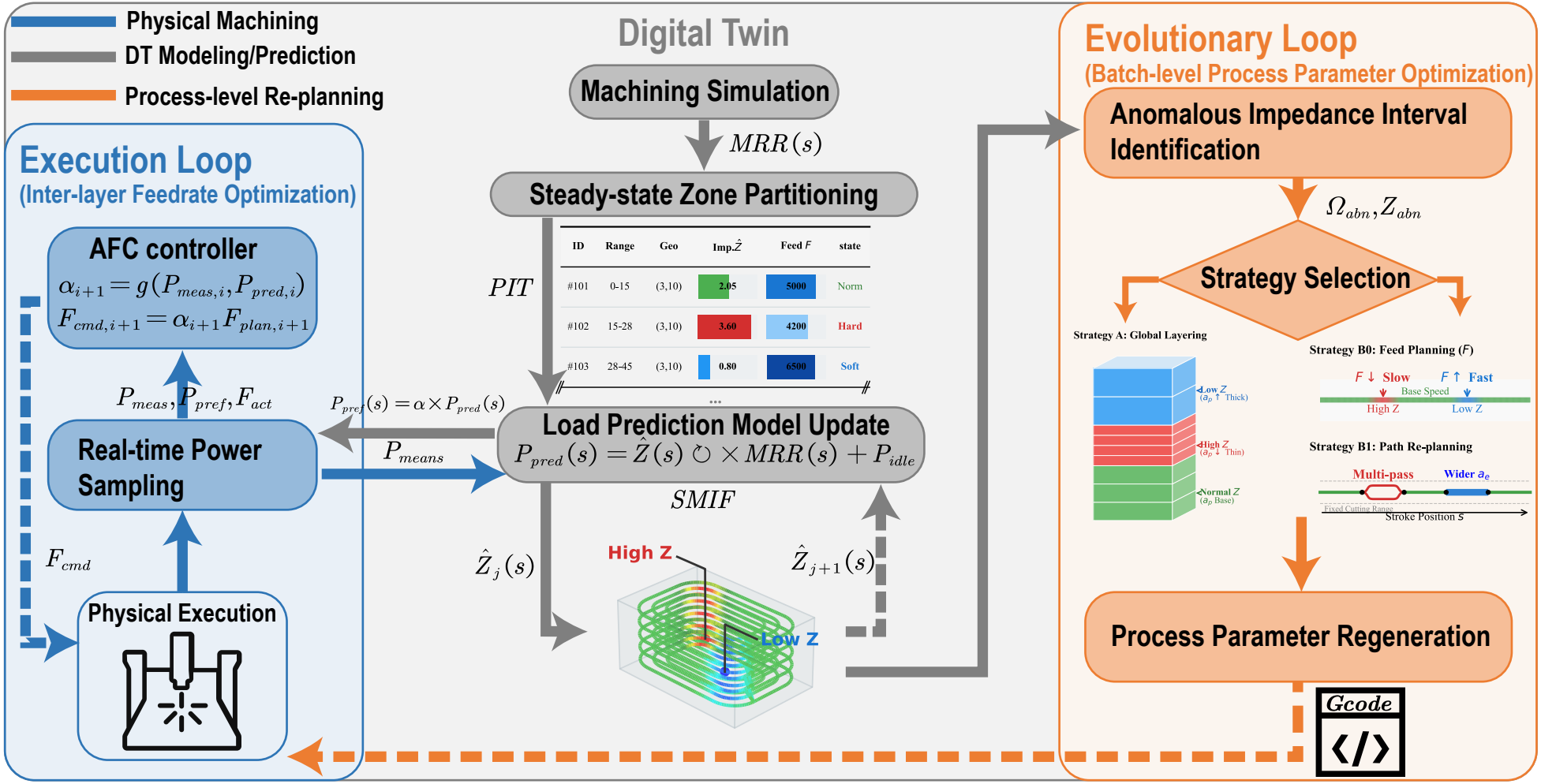
Physical Machining
DT Modeling/Prediction
Process-level Re-planning
Digital Twin
Machining Simulation
$MRR(s)$
Steady-state Zone Partitioning
PIT
ID
Range
Geo
Imp.$\hat{Z}$
Feed F
state
#101
0-15
(3,10)
2.05
5000
Norm
#102
15-28
(3,10)
3.60
4200
Hard
#103
28-45
(3,10)
0.80
6500
Soft
Load Prediction Model Update
$P_{pred}(s) = \hat{Z}(s) \circlearrowleft \times MRR(s) + P_{idle}$
SMIF
$P_{pref}(s) = \alpha \times P_{pred}(s)$
P_{means}
$\hat{Z}_j(s)$
$\hat{Z}_{j+1}(s)$
High Z
Low Z
Execution Loop
(Inter-layer Feedrate Optimization)
AFC controller
$\alpha_{i+1} = g(P_{meas,i}, P_{pred,i})$
$F_{cmd,i+1} = \alpha_{i+1} F_{plan,i+1}$
$P_{meas}, P_{pref}, F_{act}$
Real-time Power Sampling
F_{cmd}
Physical Execution
Evolutionary Loop
(Batch-level Process Parameter Optimization)
Anomalous Impedance Interval Identification
Ω_{abn}, Z_{abn}
Strategy Selection
Strategy A: Global Layering
Low Z (a_p ↑ Thick)
High Z (a_p ↓ Thin)
Normal Z (a_p Base)
Strategy B0: Feed Planning (F)
F ↓ Slow
F ↑ Fast
Base Speed
High Z
Low Z
Strategy B1: Path Re-planning
Multi-pass
Wider a_e
Fixed Cutting Range
Stroke Position s
Process Parameter Regeneration
Gcode