A knowledge-embedded end-to-end intelligent reasoning method for processing quality of shaft parts

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Outline

- **Paper Related**
- **Related work of our teams**

Background

0	毛坯	195	扩孔	320	磨齿
10	车工	200	数车	330	磨螺纹
20	标印	210	标印	340	数车
30	车工	220	数车	345	抛光
40	磨工	225	校正	350	扭矩标定
45	车工	228	车工	355	磨工
50	钻孔	230	外磨	356	扭矩标定
100	稳定处理	240	数控	358	钳工
120	车工	250	数控	370	检验
130	外磨	260	钳工	380	动平衡
140	扩孔	280	校正	390	高速动平衡
160	磨工	290	中心孔磨	391	磨工
170	磨工	292	外磨	393	动平衡
173	车工	293	外磨	394	高速动平衡
175	珩磨	294	数车	395	扭矩标定
185	校正	296	珩磨	396	超声波清洗
186	中心孔磨	297	校正	400	荧光检验
187	磨工	299	中心孔磨	405	镀银
190	标印	300	外磨	410	检验

Multi-stage manufacturing processes（MMPs）

Original process	57
Processing-related	33
Long-end related	**15**

Inner hole	4
External round	**11**

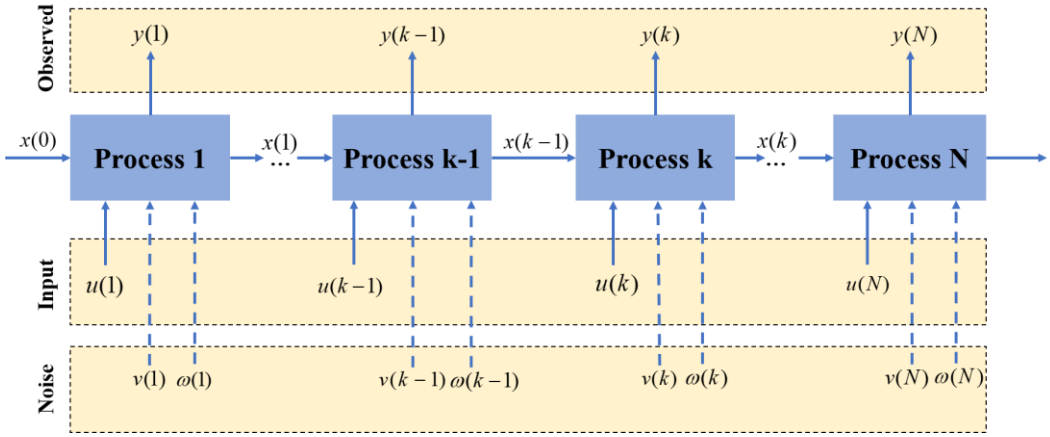
External circular surface	**5**

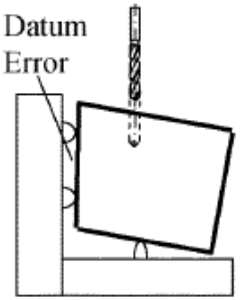
MMPs involved in the processing of parts

Challenge 1：

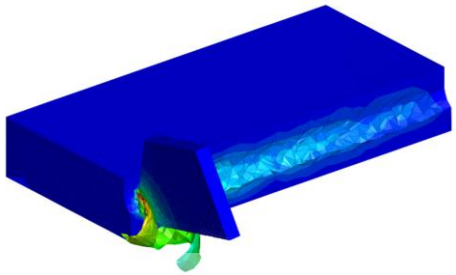
Complex intermediate factors affecting final quality

Background

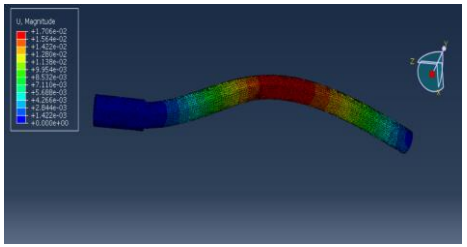




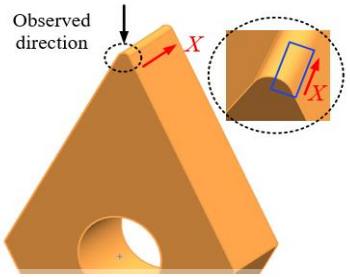
Clamping



Force & Heat



Deformation



Wear

The propagation pattern is complex and difficult to model accurately

Challenge 2:

Constrains the perceived accuracy of part machining quality

Methodology

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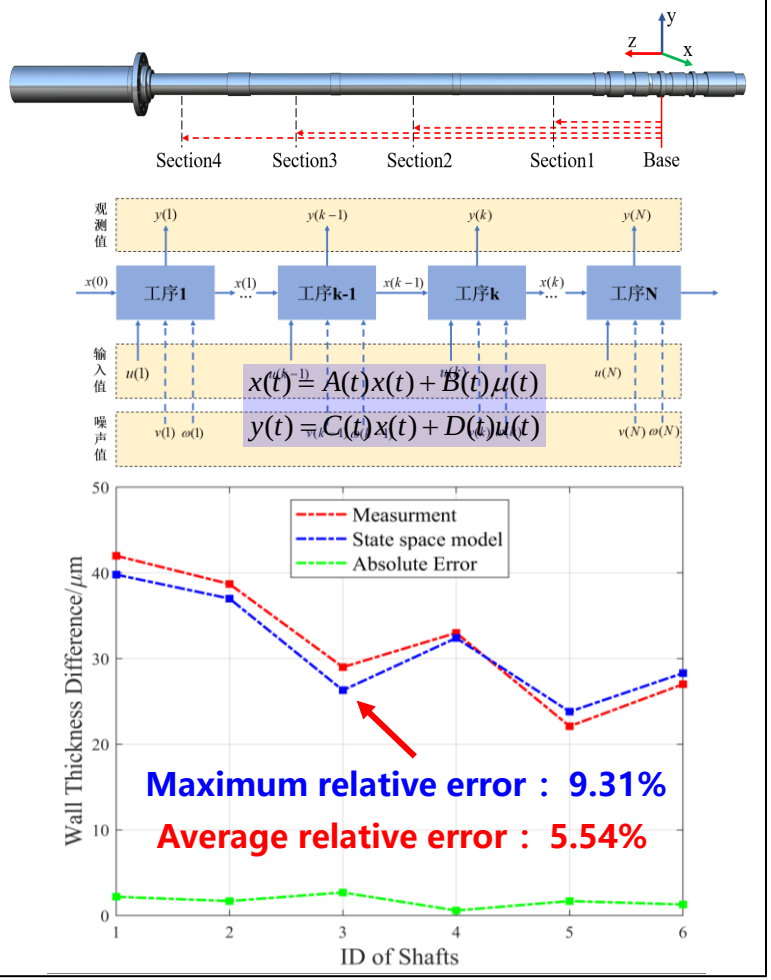
Overall Model

SSM-based SOV model



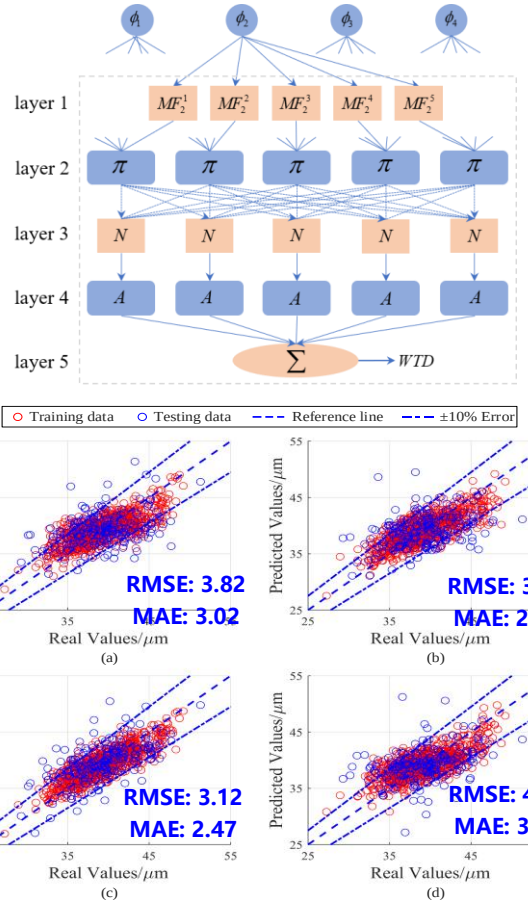
Knowledge of error propagation of MMPs

Mechanism knowledge

Data Knowledge

Quality reasoning model with knowledge embedded

End-to-end part quality inference based on ANFIS



Methodology

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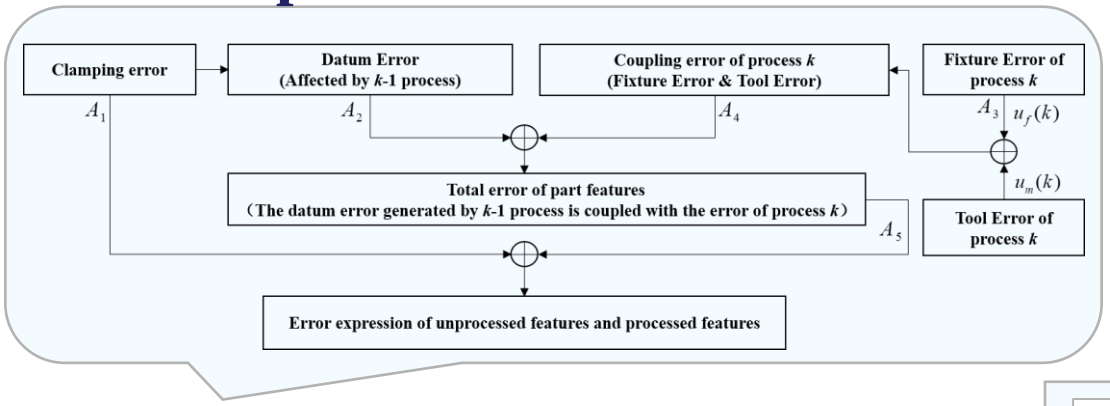
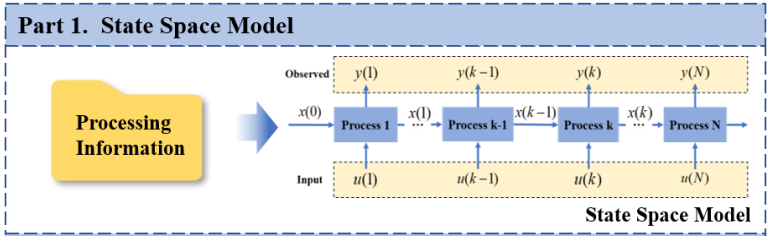
State Space Model



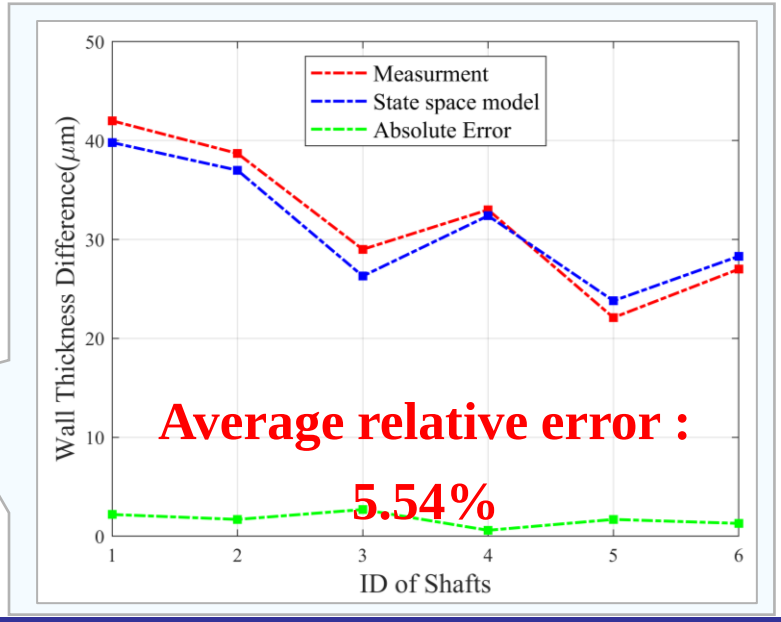


$$x(k) = A(k)x(k-1) + B(k)u(k) \quad k = 1, 2, \ldots, N$$

$$A(k) = [A_1(k) + A_5(k)A_4(k)A_2(k)A_1(k)]$$

$$B(k) = A_5(k)[A_4(k)A_3(k) \quad I_{6\times 6}]$$

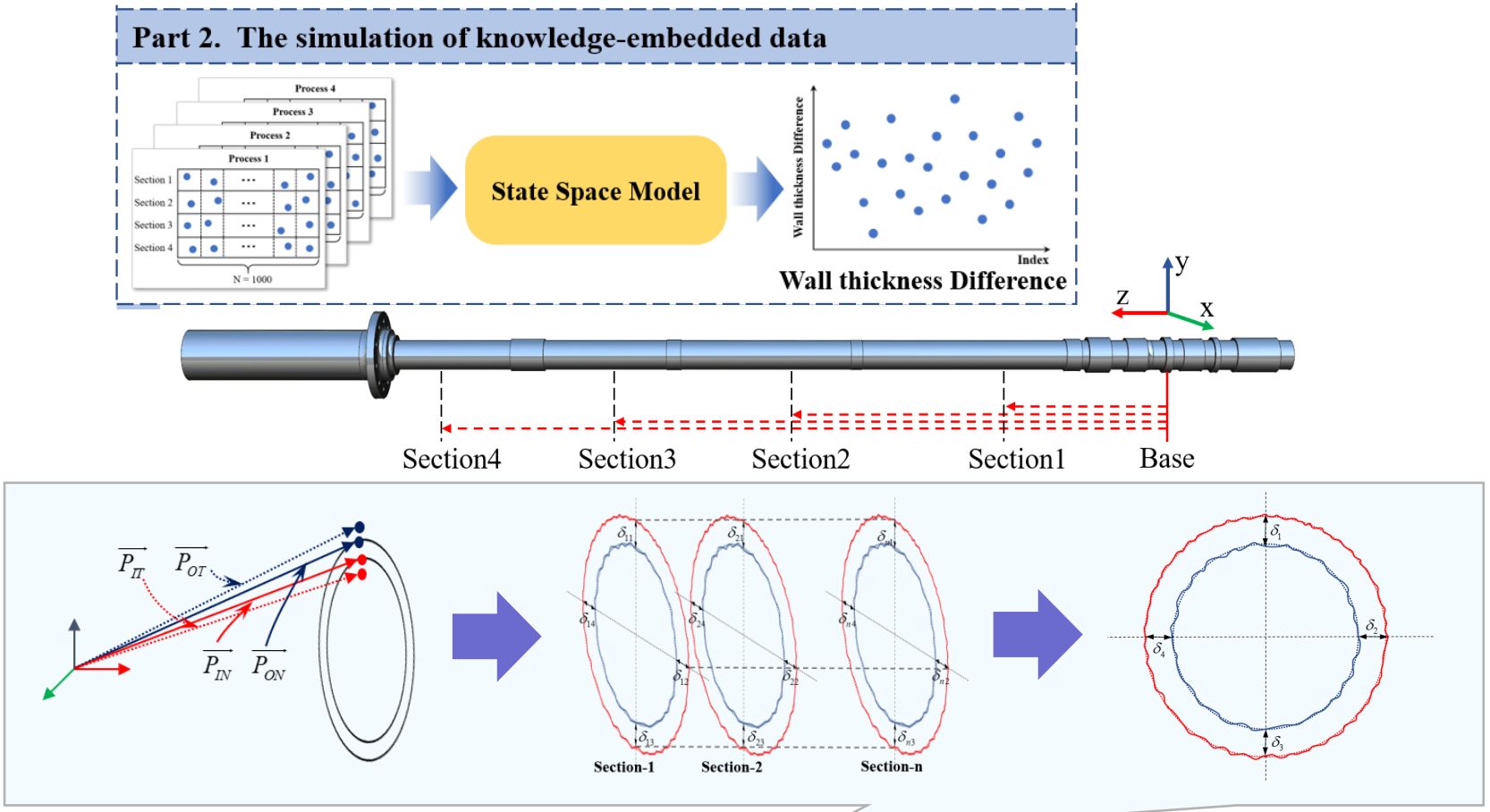
ID	Measurement/μm	State space model/μm	Absolute relative Error
1	42.0	39.8	5.24%
2	38.7	37.0	4.39%
3	29.0	26.3	9.31%
4	33.0	32.4	1.82%
5	22.1	23.8	7.69%
6	27.0	28.3	4.81%



The error propagation relationship between adjacent processes was constructed and extended to MMPs

Methodology

The simulation of knowledge-embedded data

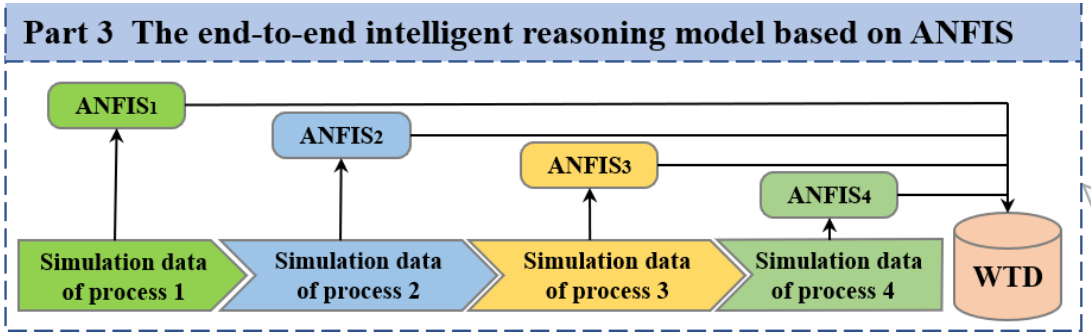


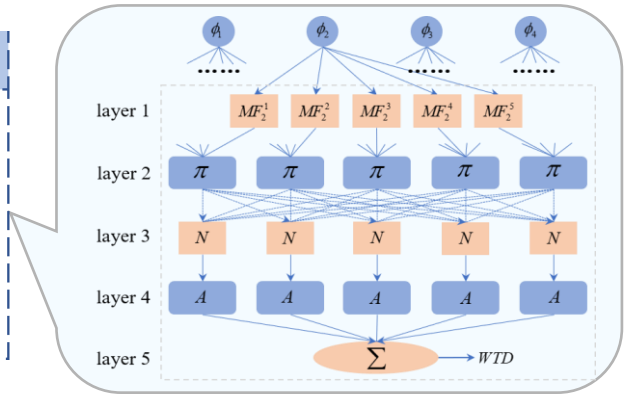
$$Wall\ thickness\ Difference = \max(\delta_1, \delta_2, \delta_3, \delta_4) - \min(\delta_1, \delta_2, \delta_3, \delta_4)$$

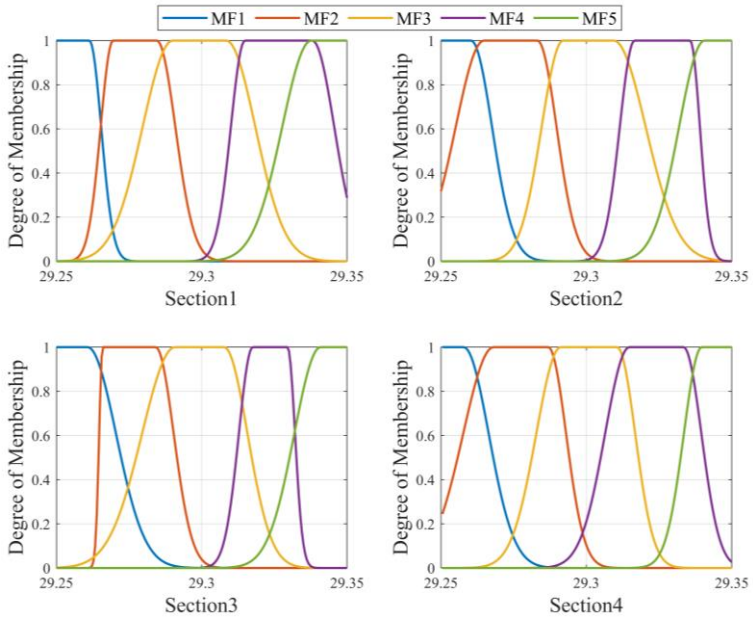
Enables the acquisition of knowledge-embedded datasets

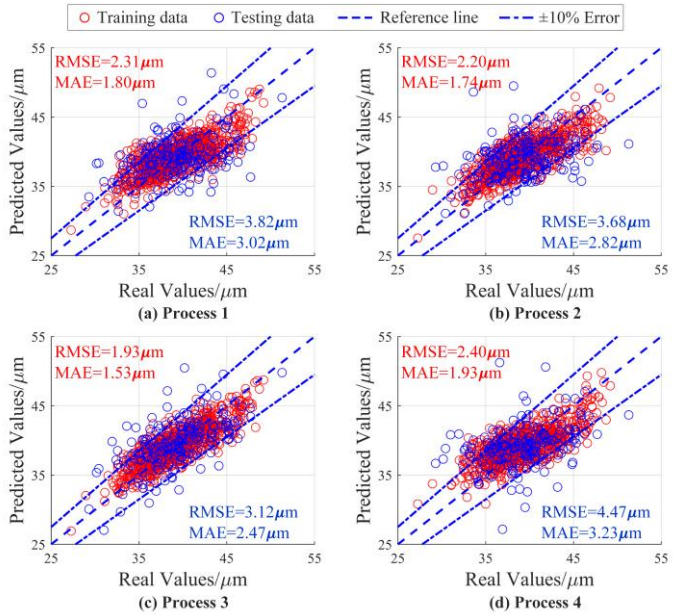
Methodology

The end-to-end intelligent reasoning model based on ANFIS









End-to-end part processing quality perception

Application

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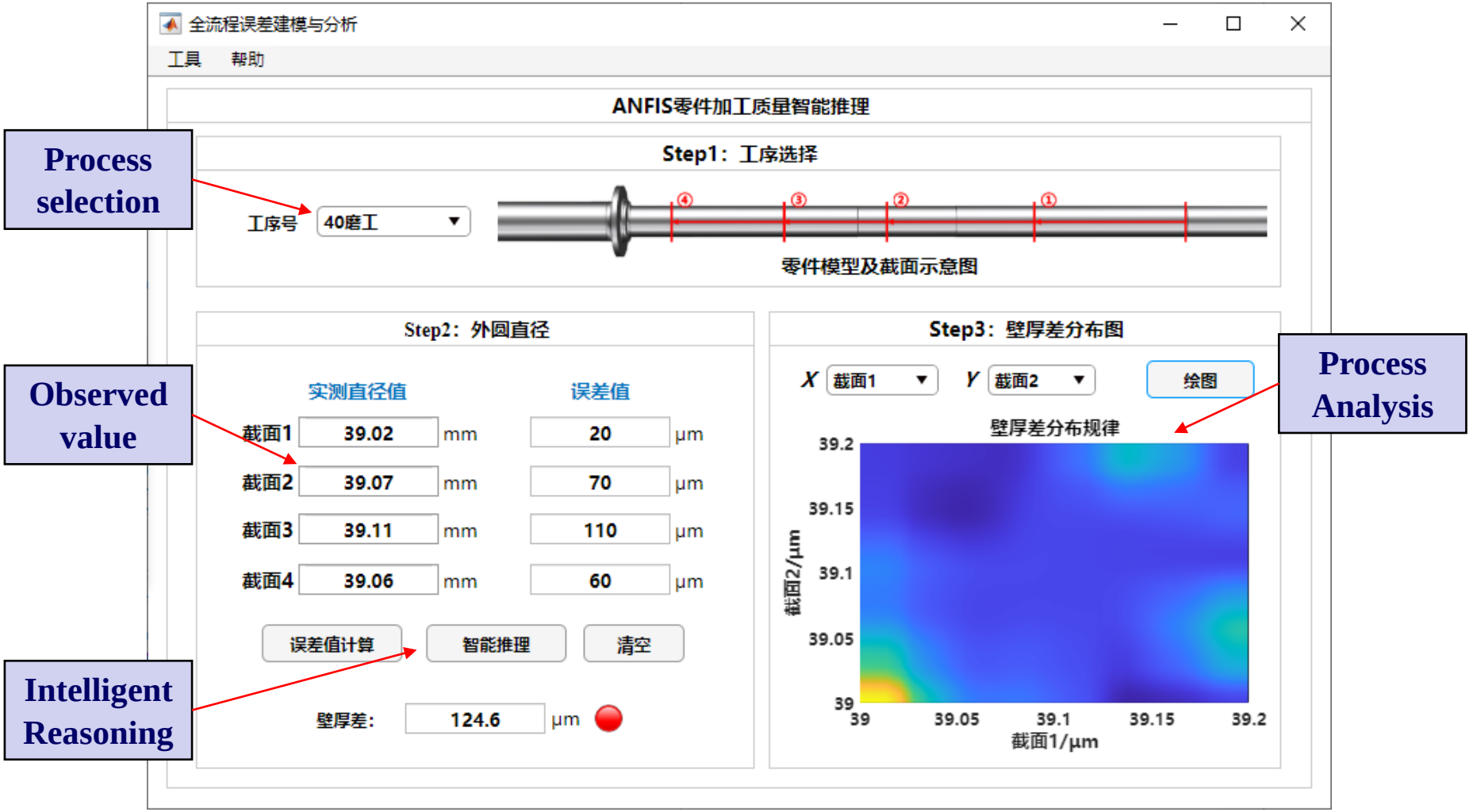


Developed integrated software

Conclusion

A knowledge-embedded end-to-end intelligent reasoning method for processing quality of shaft parts is proposed.

The final machining quality of the part (Wall Thickness Difference) can be pre-perceived by the measurement results of the current process.

By analyzing the membership functions, it is possible to specify the appropriate size range for each section, which ensuring that the WTD meets the requirements.

Outline

- Paper Related
- **Related work of our teams**

Theoretical Research

$$x_i = f(x_{i-1}) + s_i + w_i$$

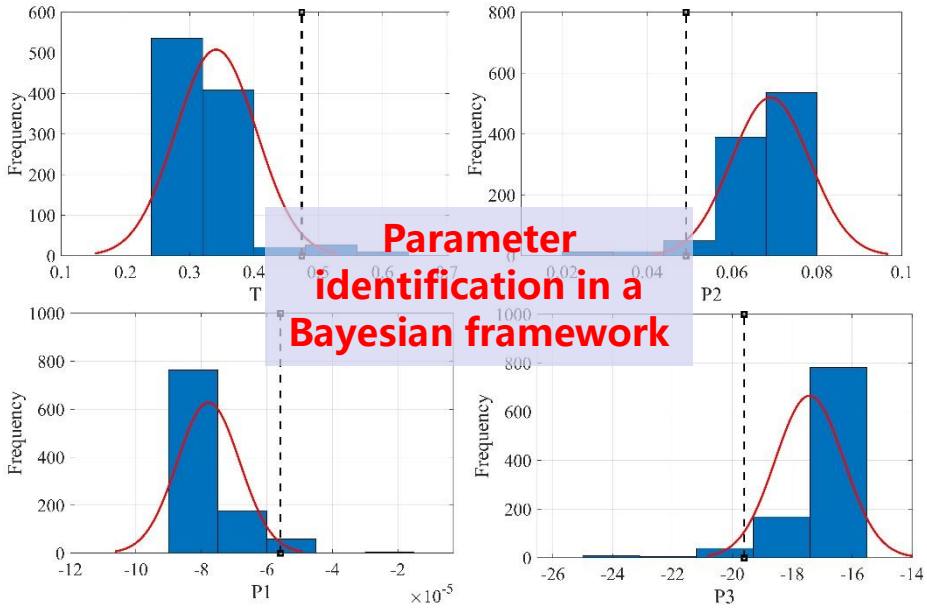
Process i　Process i-1　System　random

①Uncertainty of transmission coefficient→T_f

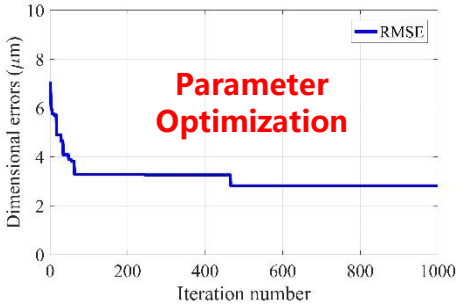
②Uncertainty of systematic errors→p

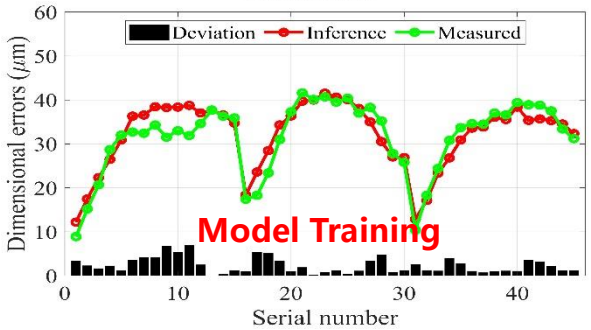
Improved semi-parametric model

$$E_{in} = \Delta \cdot T_f + [p_{1f}, p_{2f}, p_{3f}] \cdot [u^2, u, 1]^T + (E_u + E_d)/2$$



Parameter identification in a Bayesian framework





Improved semi-parametric regression model for mechanism knowledge fusion

Theoretical Research

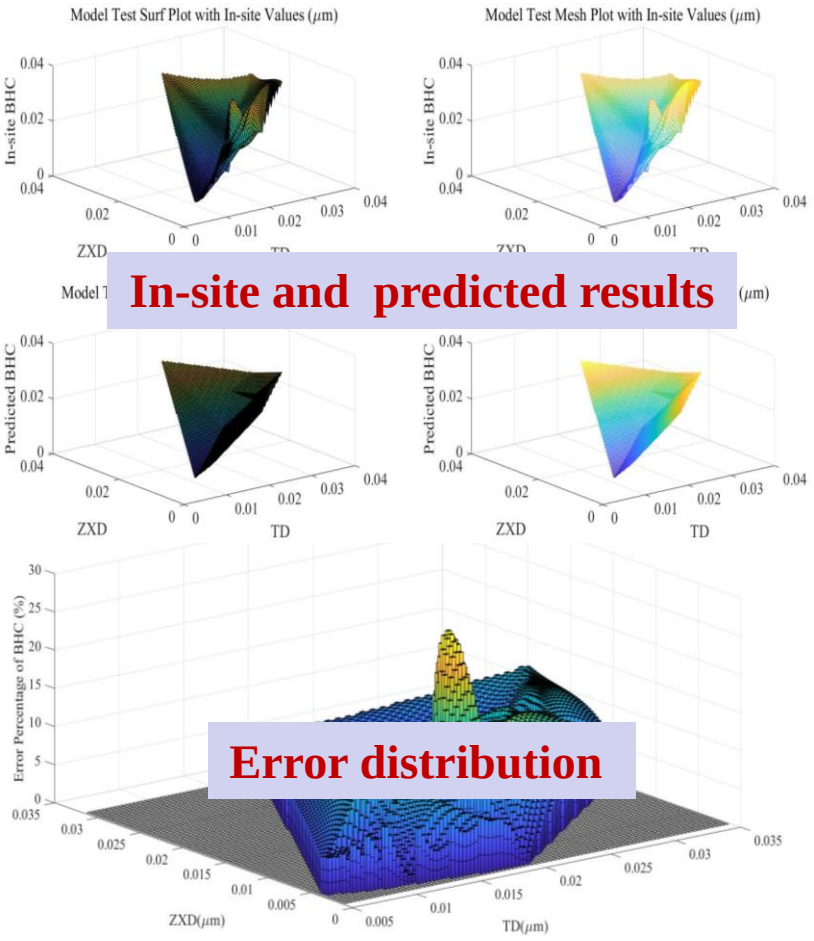
➢ Forward-backward algorithm

$$r_t(i,j)=\frac{\alpha_t(i)a_{ij}b_{j(t+1)}\beta_{t+1}(j)}{P_r(O\mid\lambda)}=\frac{\alpha_t(i)a_{ij}b_{j(t+1)}\beta_{t+1}(j)}{\sum_{i=1}^{N}\sum_{j=1}^{N}\alpha_t(i)a_{ij}b_{j(t+1)}\beta_{t+1}(j)}$$

$$r_t(i)=\sum_{j=1}^{N}r_t(i,j)=\frac{\alpha_t(i)\beta_t(j)}{P_r(O\mid\lambda)}$$

➢ Baum-Welch algorithm

$$\overline{\pi}_i=\gamma_1(i)\qquad \overline{a}_{ij}=\frac{\sum_{t=1}^{T-1}r_t(i,j)}{\sum_{t=1}^{T-1}r_t(i)}\qquad \overline{b}_{ij}=\frac{\sum_{t=1,o_t=v_k}^{T-1}r_t(i)}{\sum_{t=1}^{T}r_t(j)}$$



HMM was used for qualification prediction with inspection data

Software Development

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Knowledge

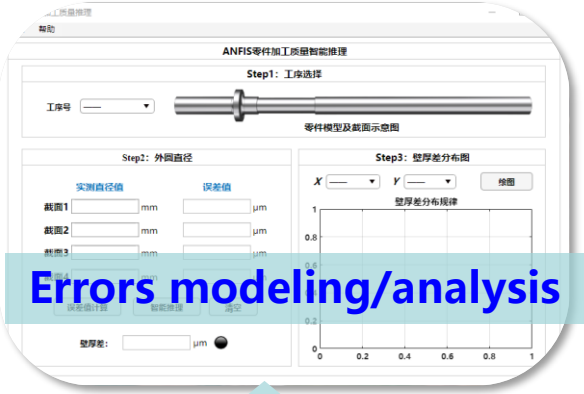
Data

Process Analysis

Information Mining

Error models

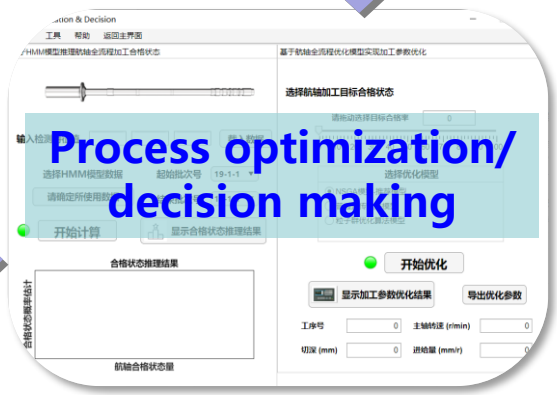
Optimization Strategies



Errors modeling/analysis

Database

Process Data Mining



Process optimization/ decision making

Decision-making solutions

Multi-process processing intelligent reasoning optimization software

Promotional Applications

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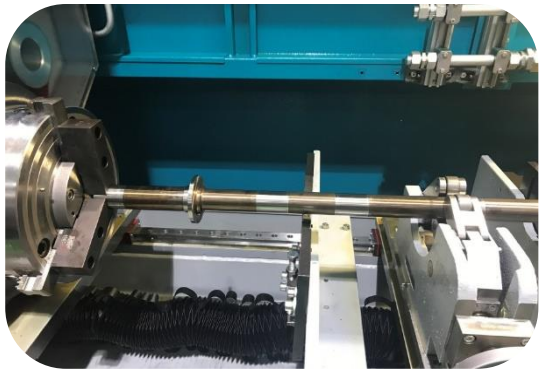
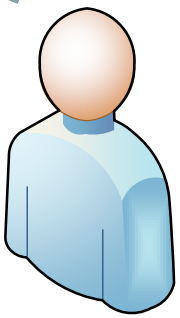
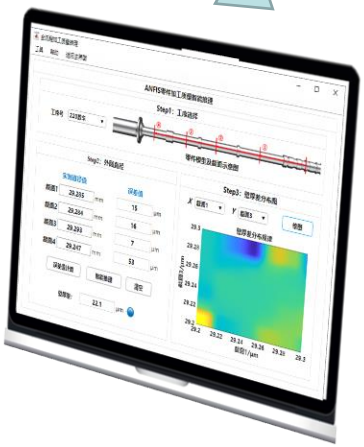
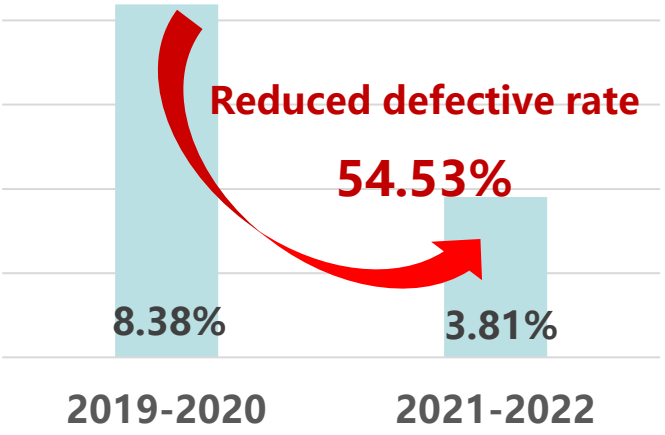


Shaft machining workshop

Workers—Production—Software







Provide support for the machining of a type of shaft for AVIC

Thanks for listening！

Email：zhang_teng@hust.edu.cn

Github：https://github.com/ZhangTeng-Hust

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