A unified low-cost framework for general bonding equipment through iterative learning

Abhishek Bareja[‡†]
Frank Boeren[‡]
Tom Kok[†]
Tom Oomen[‡]

[‡] Eindhoven University of Technology
[†] ITEC Department, NXP Semiconductors

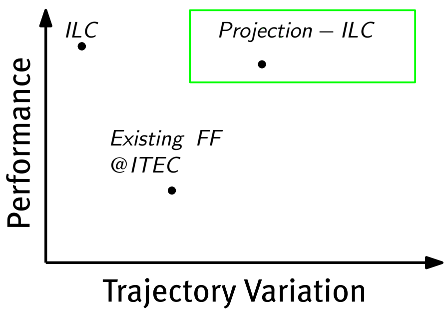
Introduction

Next-generation bonding equipment in the semiconductor assembly processes aim at very high throughput under stringent process requirements. An accurate feedforward methodology is the key to improving the servo performance of such systems.

Figure 1: Bonding systems: Die- and Wire-bonder.

Iterative Learning Control (ILC) is a superior feedforward methodology that exploits measured data to improve servo performance for perfectly repetitive motion tasks. Besides such tasks, bonding systems in semiconductor assembly processes also involve *almost* repeating tasks, which prohibit the direct application of ILC. In this research [1], a unified ILC design framework is proposed for bonding systems that:

- achieves high servo performance for repetitive tasks,
- is based on loop-shaping based design,
- allows for trajectory variations.



Projection-based ILC

After each iteration:

Step 1. determine ILC feedforward as:

$f_{j+1} = Q(f_j + Le_j)$,

using frequency-domain loop-shaping design for Q and L filters.

Step 2. Approximate f_{j+1} with a lower order feedforward $\hat{f}_{j+1}$ using basis functions [2], [3] that are dependent on the current reference. The approximation is done using 'Weighted-projection' method that retains ILC performance.

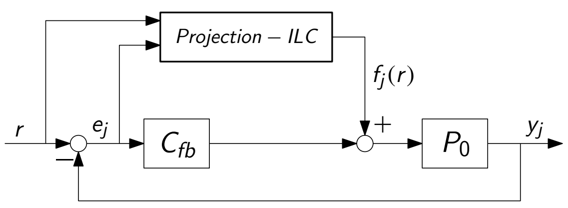


Figure 2: Projection-ILC block scheme.

Key features:

- added robustness against standard ILC,
- loop-shaping based Q and L filters,
- analytic solution (allowing update in each iteration)

Experimental Results

Experiments conducted on a high-speed axis of wire-bonder.

Figure 3: Z-axis of wire bonder.

The reference trajectory is varied in final position by 6 % after 10^{th} iteration.

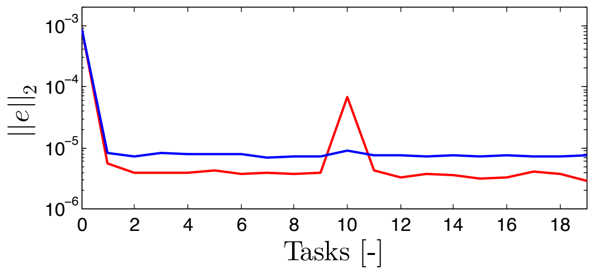


Figure 4: 2-norm of servo error for Standard ILC (red) and Projection-ILC (blue).

Figures 4 and 5 show deterioration in S-ILC performance for variations in the task, while P-ILC performance is hardly effected. This experiment confirms that proposed method offers both high performance and allows for trajectory variations.

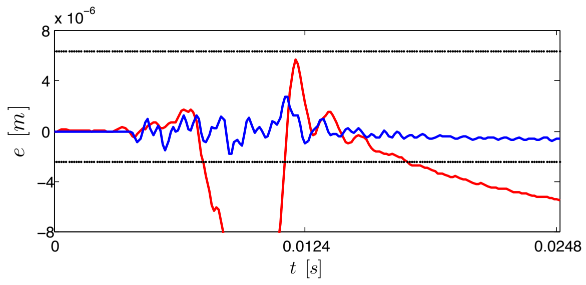


Figure 5: Error time plot after the change in the reference trajectory for S-ILC (red) and P-ILC (blue).

Ongoing Research

- Friction, cogging, position varying effects
- Input-shaping [3]

Conclusion

- standard design rules
- extension towards NXP tasks
- low cost: time, money and training

References

[1] A. Bareja, F. Boeren, T. Kok and T. Oomen, Unified ILC Design Framework for Repeating and Almost Repeating Tasks: With Application to Bonding Equipment in Semiconductor Assembly processes, Submitted for journal publication.
[2] J. Bolder, T. Oomen and M. Steinbuch, Rational Basis Functions in Iterative Learning Control - With Experimental Verification on a Motion System, IEEE Transactions on Control Systems Technology, 2014.
[3] F. Boeren, D. Bruijnen, N. van Dijk and T. Oomen, Joint Input Shaping and Feedforward for Point-to-Point Motion: Automated Tuning for an Industrial Nanopositioning System, IFAC Mechatronics, 2014.