Optimal Intermediate Time Allocation of Point-to-Point Iterative Learning Control on a Gantry Robot

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Iterative Learning Control

- Iterative learning control (ILC) :
  - **High performance**
  - A **repeated** task
- Benefits:
  - Tracking error converges to **zero**
- Point-to-point ILC:
  - **A subset of time instants, Λ**
  - Significant **freedom**

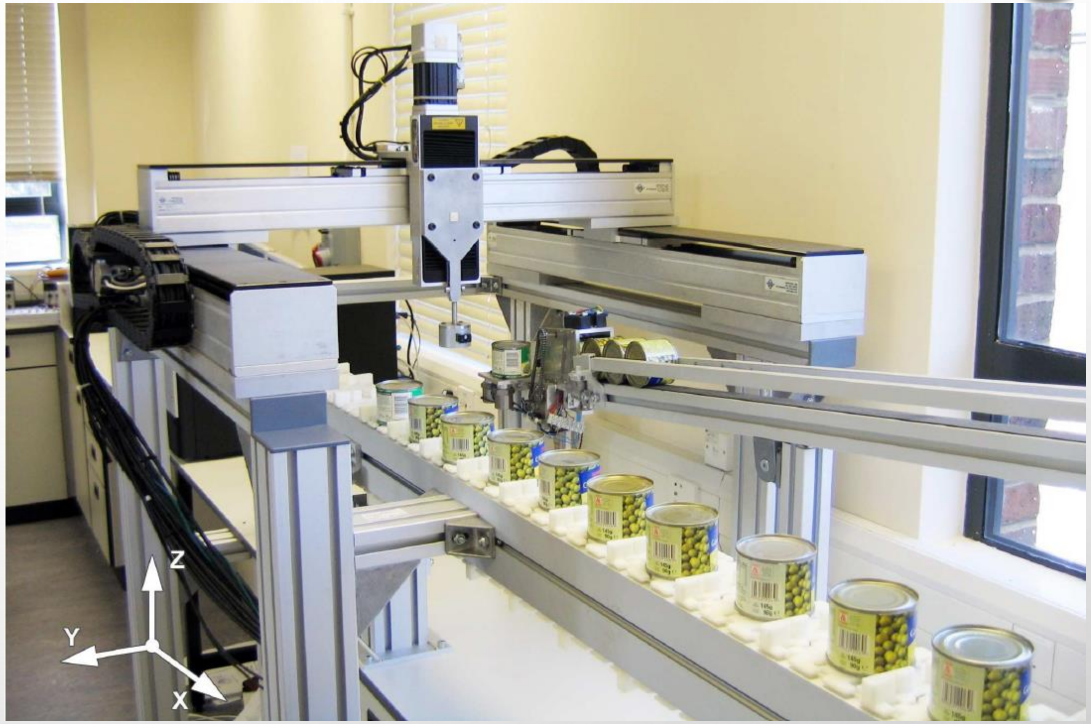
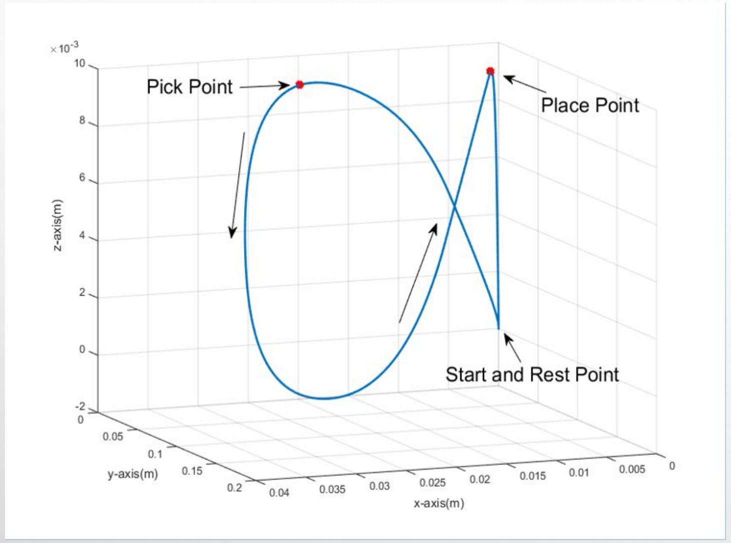


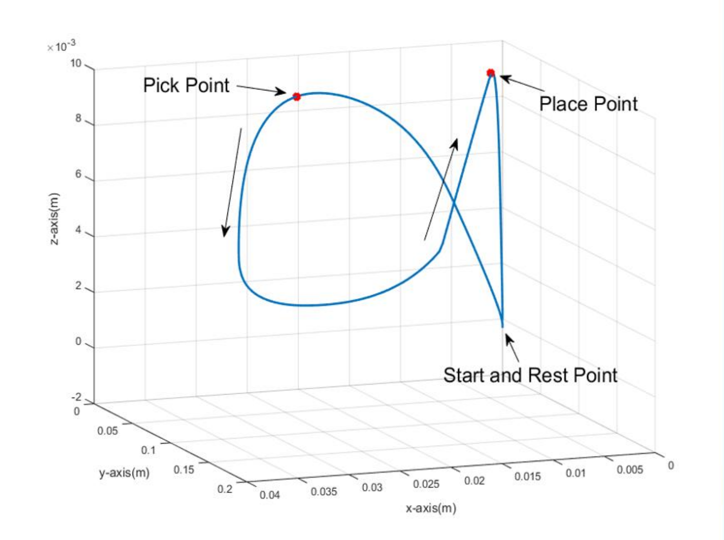
Fig.1 A Gantry Robot Test Platform

Motivation

- In current point-to-point ILC, $\boldsymbol{\Lambda}$ is known ***a priori***.
- The **input energy** $\|u\|^2$ depends on $\boldsymbol{\Lambda}$.



More than 30% input energy is reduced



(a) Original Allocation $[0.5,1.5]$ **(b) New Allocation** $[0.65,1.35]$

Fig.2 Reference Trajectory Before and after Changing Tracking Time Allocation

Question: Can we design a control law to choose $\boldsymbol{\Lambda}$ **automatically** to optimise $\|u\|^2$ subject to the tracking requirement $r_p = G^p(\boldsymbol{\Lambda})u$?

Two Stage Design Framework

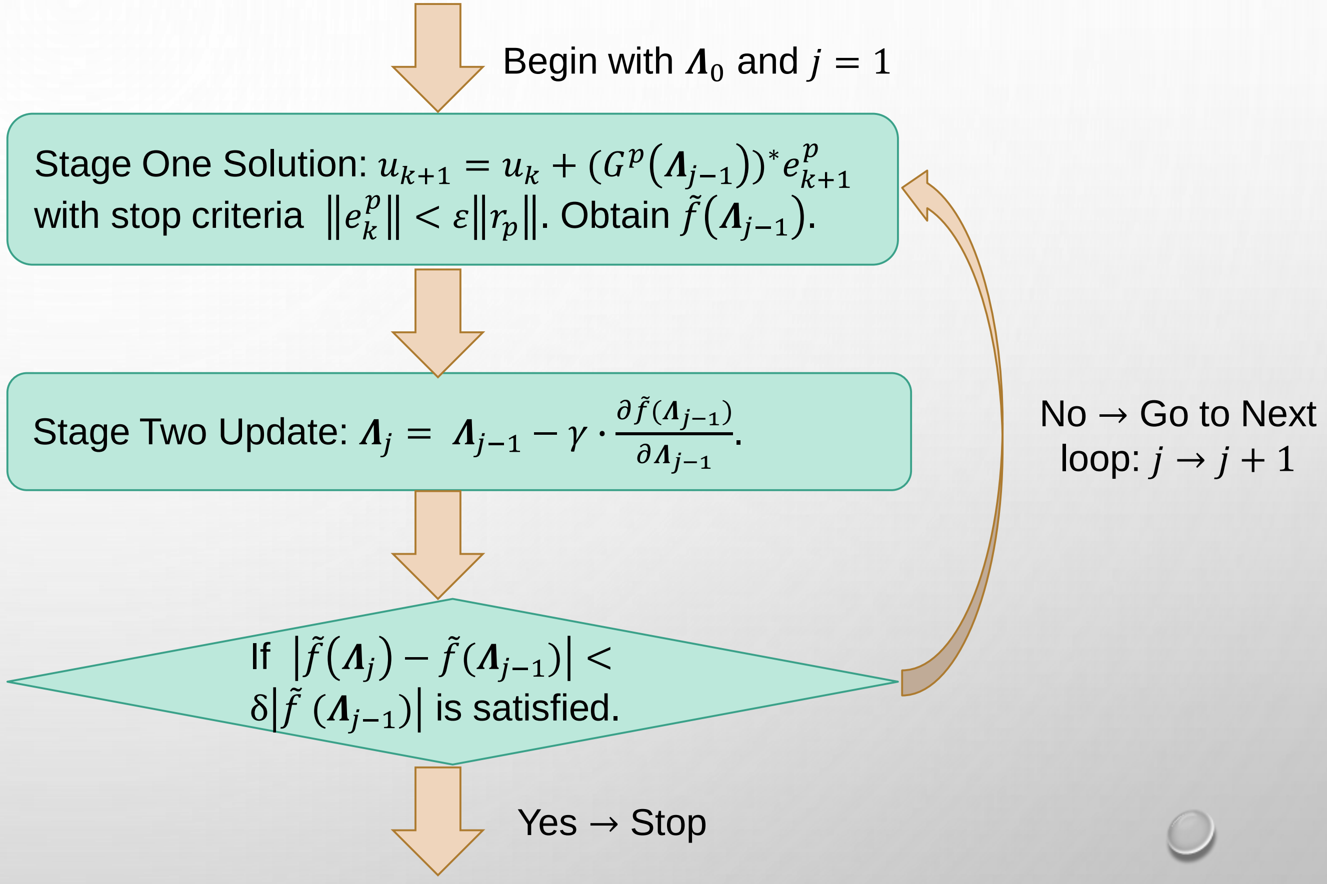
- **Stage one** : assume $\boldsymbol{\Lambda}$ is **fixed** and solve:

$$\min_{u}\{f(u) = \|u\|^2\}, \text{ s.t. } r_p = G^p(\boldsymbol{\Lambda})u$$

- **Stage two** : substitute $u_\infty(\boldsymbol{\Lambda})$ into the original problem:

$$\min_{\boldsymbol{\Lambda}}\{\tilde{f}(\boldsymbol{\Lambda}) = f(u_\infty(\boldsymbol{\Lambda}))\}$$

which cannot be solved **analytically.**



Experimental Verification

Conclusions:

- The proposed algorithm achieves **perfect tracking**.
- All time points converge to the **same time positions**.
- Around **35%** input energy is saved compared to the input energy at original allocation.

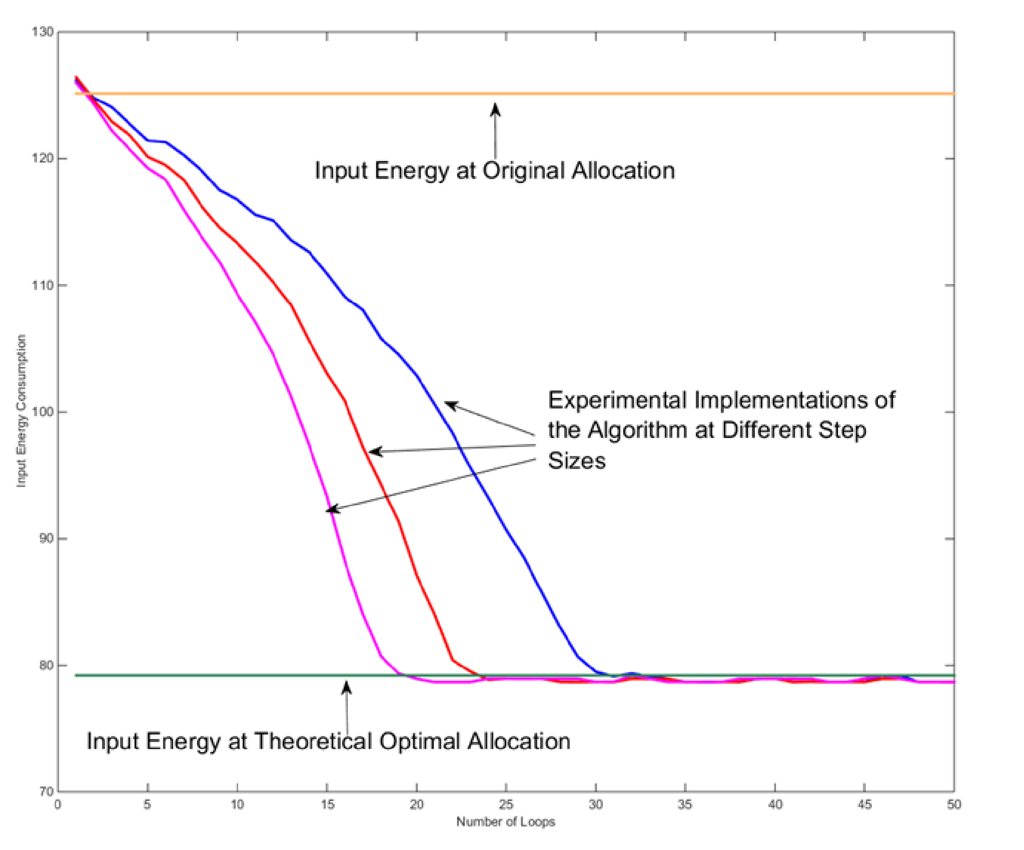


Fig.4 Experimental Results at Z-axis