Optimal Active Control and Optimization of a Wave Energy Converter

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Motivation

Potential of Wave Energy

- Sustainable Energy for the Globe – distributed and diverse generation
  - 25% of UK energy (~10 GW),
  - ~2TW Globally

- A maturing Marine Technology

Our aim: Efficiency Enhancement via Advanced Control Methods
Optimal Control in a receding horizon scheme

- **Big devices with narrow bandwidth**

- **Maximize energy while satisfying constraints**
  - Nonconvex Cost + Bilinear Dynamics
  - Solution: Bang-Bang Control

- **Efficient Optimal control computations**
  - Projected gradient scheme within Indirect method – Cheaper Control Computations
  - general nonlinear program solvers -- computationally expensive
Results

Optimal Active Control

![Graph showing energy extraction over iterations for different time periods (Tp) with varying significant waves (Hs=1m). The graph plots energy extracted (MJ) against iteration number.]
Results

Optimal Active Control

![Graph showing average power (kW) vs. typical period (Tp) for different methods: Method 1, Method 2, Latching, No Control.](image-url)
Results

➢ Actuator Optimization

Power take off Parameters: dependent on control scheme

\[
\log_{10} B_{pto} \quad (N \cdot s \cdot m^{-1})
\]

\[
\log_{10} \frac{G}{M+\mu_\infty} (kg^{-1})^2
\]
Results

- Actuator Optimization

*Power take off Parameters: dependent on control scheme*

\[
\log_{10} \left( \frac{G}{M+\mu_\infty} \right) (kg^{-1}) \\
\log_{10} B_{pto} (N s m^{-1})
\]
Summary

- **Conclusion**
  - *Inexpensive and globally convergent optimal control method*
  - *Control Characterization, Device optimization*

- **Related Work**
  - *Observer design for radiation and excitation forces:*
    - *A bilinear system design*
  - *Efficient ODE solvers for bilinear systems and PDE systems*