**Problem Overview**

**Problem Context**

- **Objective**: Control the manufacturing process to maintain the fiber diameter within a specified range.
- **Context**: Industrial controller at Sterlite Technologies.

**Optical Fibers**

- **The Backbone of Modern Global Connectivity**
  - Thin, flexible strands of glass
  - Transmit data through light pulses
  - Based on Total Internal Reflection

**Controller**

- **PID Controller**: Feedback control algorithm to regulate systems to reach desired setpoints.
- **Ziegler-Nichols Heuristic**: Chooses ideal PID parameters, without navigating the entire search space.

**Solution**

- **Ziegler-Nichols Heuristic**
  - Solves: Traditional PID Controller suffers from linear assumptions.
  - Solves: Reinforcement Learning Controller.

**Data**

- **Data Description**
  - Data sampled every ~100ms
  - High Frequency Time-Series
  - 800K Daily Datapoints
  - 1.7m Features of Interest
  - 5 Outputs (Target)

**Preprocessing**

1. Batching
2. Interpolation
3. Filtering
4. Sanitization
5. Smoothing

**Analysis**

- Cross-correlations of inputs with diameter
- Cross-correlations of inputs with tension

**Methdology & Results**

- **Predictive Modeling - Sequential LSTM**
  - LSTM Experiments:
    - Architecture Choice: Vanilla Model is fast and has fewer parameters without compromising on performance.
    - Modeling Choice: Multi-Output Model captures interdependencies between diameter and tension output relationship.
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- **Parameter Optimization - Ziegler-Nichols Heuristic**
  - Controller Equation: $u(t) = K_p e(t) + K_i \int e(t) dt + K_d \frac{de(t)}{dt}$
  - Existing Controller Network at Sterlite Controls 3 Variables:
    1. Preform Velocity Controller: Feedback from Diameter (125 microns)
    2. Capstan Velocity Controller: Feedback from Diameter (125 microns)
    3. Furnace Power: Feedback from Tension (130 units)

- **Alternate Control System - Reinforcement Learning**
  - Training Setup:
    - Task: Maintain Fiber Diameter within ±0.1 microns
    - Environment: LSTM model used to simulate the manufacturing process
    - Action: Changes in input (set-points)
    - Reward: Changes in output (diameter)

- **Conclusion**
  - Built a cutting-edge solution to improve the Optical Fiber Manufacturing Process by utilizing a combination of Long Short-Term Memory (LSTM) Modeling and Reinforcement Learning (RL).

- **Impact and Future Work**
  - Maintained fiber diameter within an incredibly tight range of 125 ± 0.1 microns on test simulations, providing potential savings of $1.5 million/month.
  - Future Work:
    - Make the LSTM model more robust by training and re-training across multiple weeks.
    - Improve identified PID parameters and explore alternate heuristics for optimization.
    - Thoroughly test the RL-based control system on the physical manufacturing units.