Adaptive Gain Control

Wavefront Sensing in the VLT/ELT Era V
AO Workshop Week II

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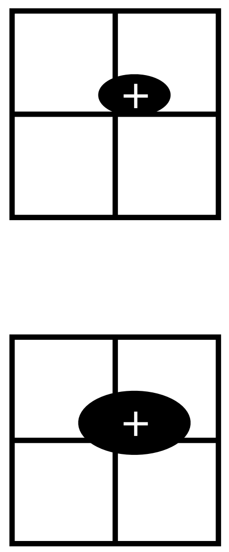
Introduction

- Previous work reported in SPIE and AO4ELT
  - Montera, et al., Adaptive gain in closed-loop tilt control and adaptive optics, Proc. SPIE 10703, Adaptive Optics Systems VI, (2018 July 10)
  - Flanagan, et al., Adaptive gain control for adaptive optics closed loop, Adaptive Optics for Extremely Large Telescopes AO4ELT6, (2019 June 11)
- Motivation: optimum closed-loop gain changes with varying conditions (e.g., angular size of object or beacon)
- Approach: learning algorithm to adjust gain in real time
- Results: improved tilt and high-order performance (lower RMS phase error)
- Currently: optimal gain applied for tilt and globally to all sub-apertures
- Future: compute and apply unique gain for each sub-aperture

Motivation

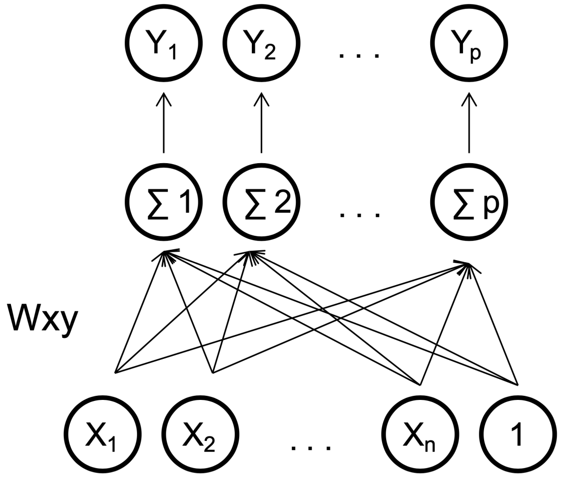
Objects have same position, but different gradient



- Optimum closed-loop gain changes under varying conditions
  - Angular extent of object or laser beacon (sensitivity)
  - Signal-to-noise ratio of measurement
  - Strength and spectrum of disturbance
- AO operator would manually adjust system gain based on subjective judgement of performance
  - If gain set too low, then reduces closed-loop bandwidth
  - If gain set too high, then loop unstable
  - Does not adapt for quickly varying conditions (e.g., satellite)
  - Single value for x-y tilt or for all sub-apertures

Approach

Linear neural net

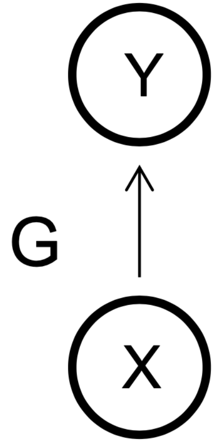


Single-input linear neural net

Outputs

Weights

Inputs



$$Wxy_t = Wxy_{t-1} + (\eta * (Yp_t' - Yp_t) * Xn_t)$$

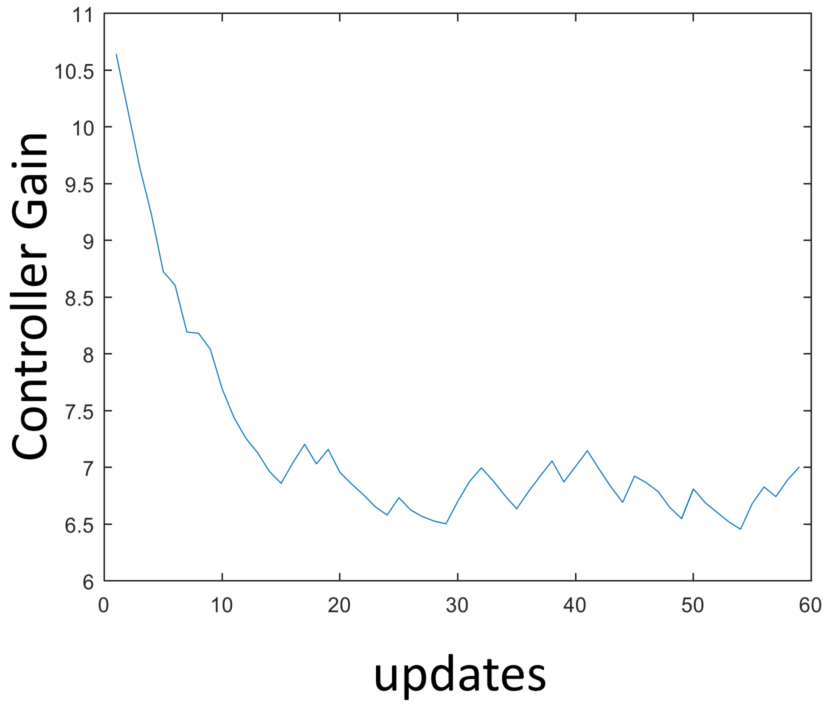
Learning rate (η)

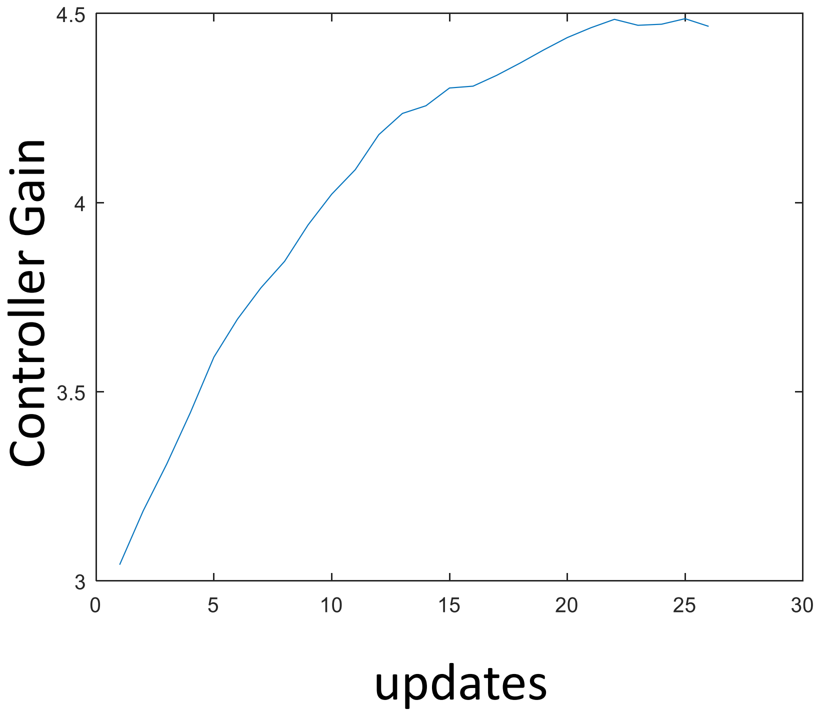
$$G_t = G_{t-1} + (\eta * Yerror * X_{t-v})$$

Gain (G_t); Measured residual error (Yerror); Mirror command (X); Latency (v)

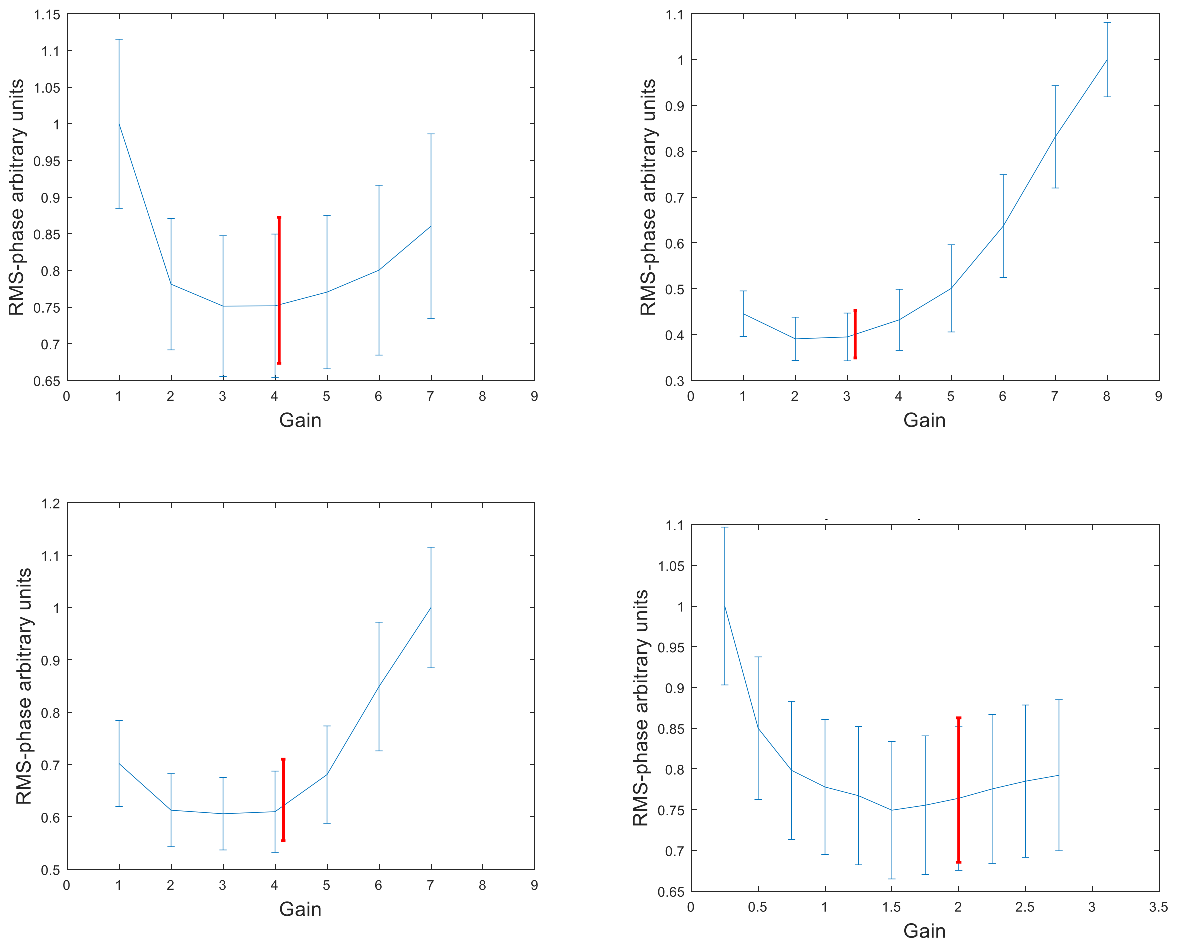
Results

- Start gain at arbitrary value
- Gain reaches steady state after a several seconds





Results



- RMS phase error vs. gain
- Top, bottom: two different nights
- Blue: sweep through different gains
- Red: adaptive gain steady state

Discussion and Conclusion

- Learning rate
  - Different learning rate for each WFS frame rate
  - If too low, slow convergence; too high, then oscillatory behavior
- Latency
  - Due to mirror command and sensor latency, must adjust frame offset (typical frame offset 2 to 4)
- Neural net
  - Dynamically adjusts to choose optimal gain based on conditions
- Implemented for tilt and high-order control
  - Plans to implement gain control for each sub-aperture

Questions?

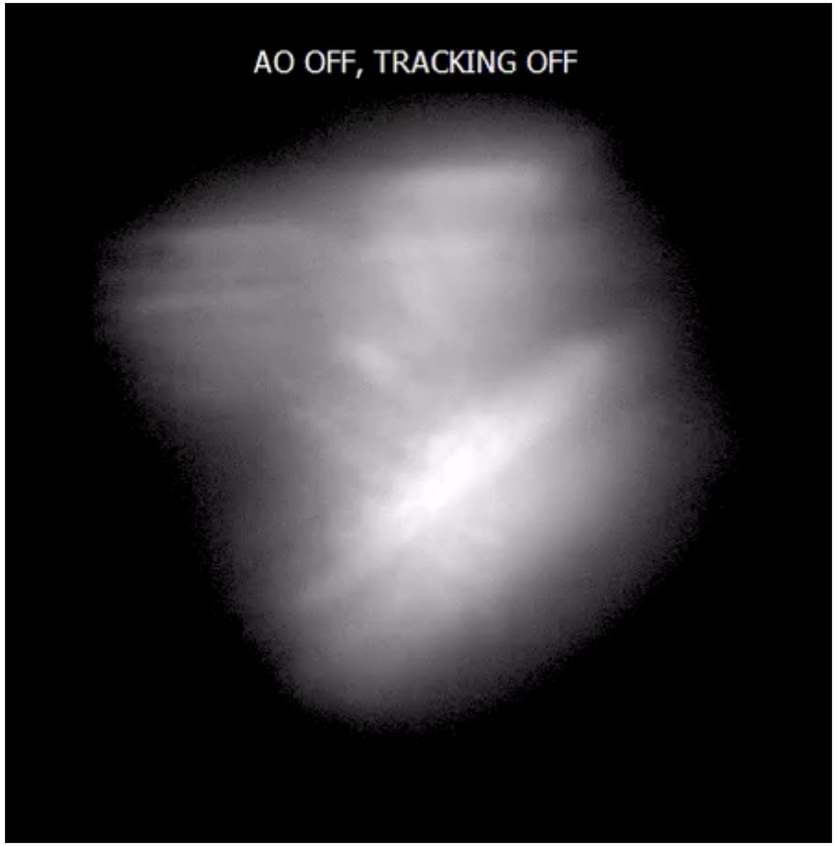
AFRL

Low-Earth orbit satellite

- SEASAT, NASA/JPL
- Launched in 1978
- 6 m in length
- ~1000 km range

NASA/JPL

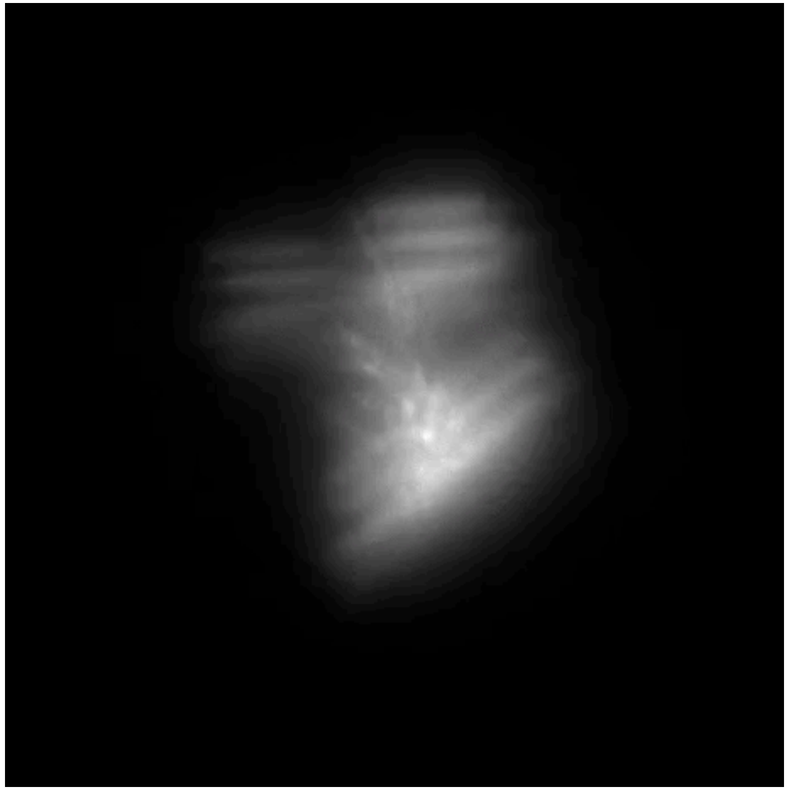
NASA/JPL



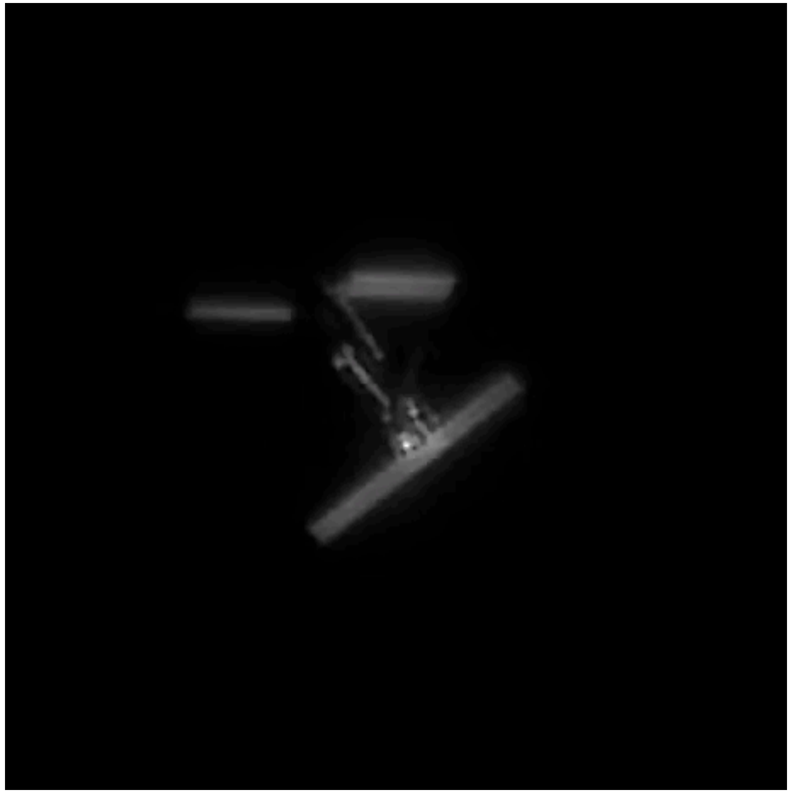
L. Kann

Low-Earth orbit satellite

No tilt control, no AO



AO, with post processing (MFBD)



Processing by L. Kann