The Use of a Piezoelectric Transducer to Improve Bandwidth of a CMM

Precision Machining Research Consortium

Industrial Advisory Board

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Jennifer Morrisette

Advisor: Dr. Tom Kurfess

Outline of Presentation

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- ❖ Background
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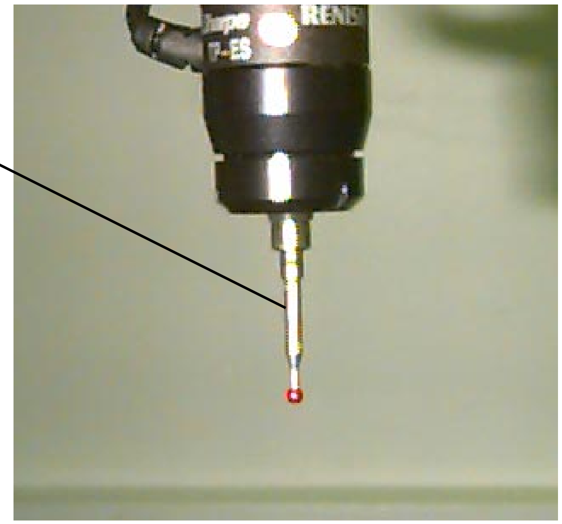
Motivation

- Coordinate Measurement Machines (CMMs) operate in Cartesian, cylindrical or polar systems
- Can quickly perform surface profiles of parts otherwise hard to measure
- CMMs can save manufacturing plants up to 90% in time and money as part of quality control feedback loop
- As tolerances shrink, need for more precise CMMs grows

Background: Current Probes

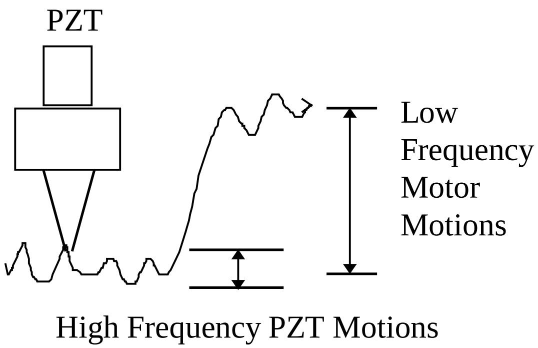
- Touch Trigger
  - Very accurate, but slow
  - 98% of CMMs in USA (NIST)



- Contact Scanning
  - Faster, but less accurate
  - Probe deformation errors
  - Overshoot
- Non-Contact Scanning (Laser, Eddy Current)
  - Variations in surface reflectivity (due to surface oils, surface finish)
  - Obstructing parts may block laser
  - Surface must be metallic or magnetic (Eddy Current)

Dual Servo Mechanism

- Servo Motor
  - Low frequency
  - High amplitude
- Piezoelectric Transducer
  - Expands or contracts based on input voltage
  - Maximum travel at 1000 V
  - High bandwidth (kHz)
  - Limited stroke (60 microns)
  - Nonlinearities: Hysteresis and Drift



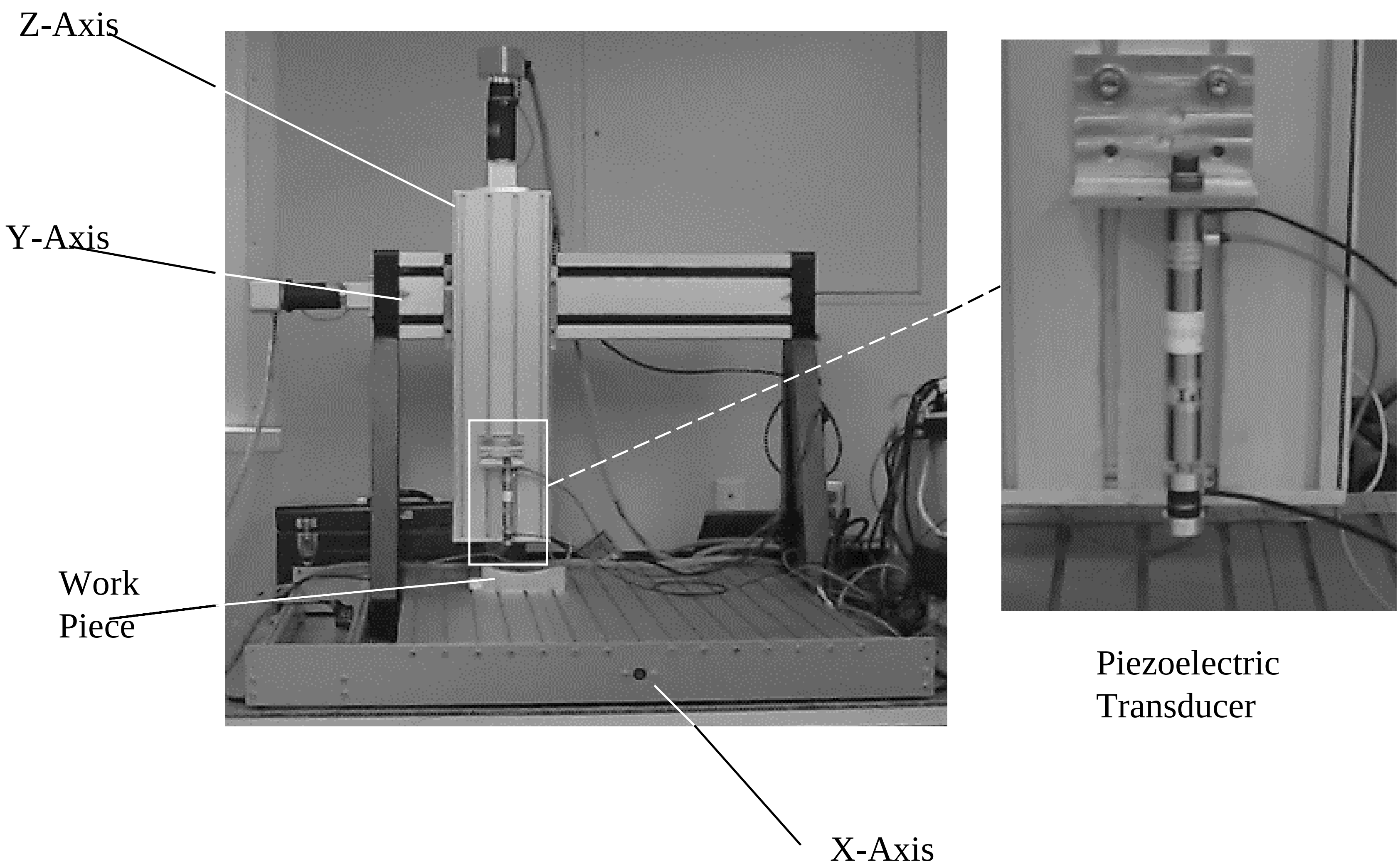
Objectives

- Perform analysis on existing experimental coordinate measurement machine
- Design controllers for motor and PZT
- Implementation and experimentation with controllers
- Design of Analog Controllers to “Retrofit” CMM

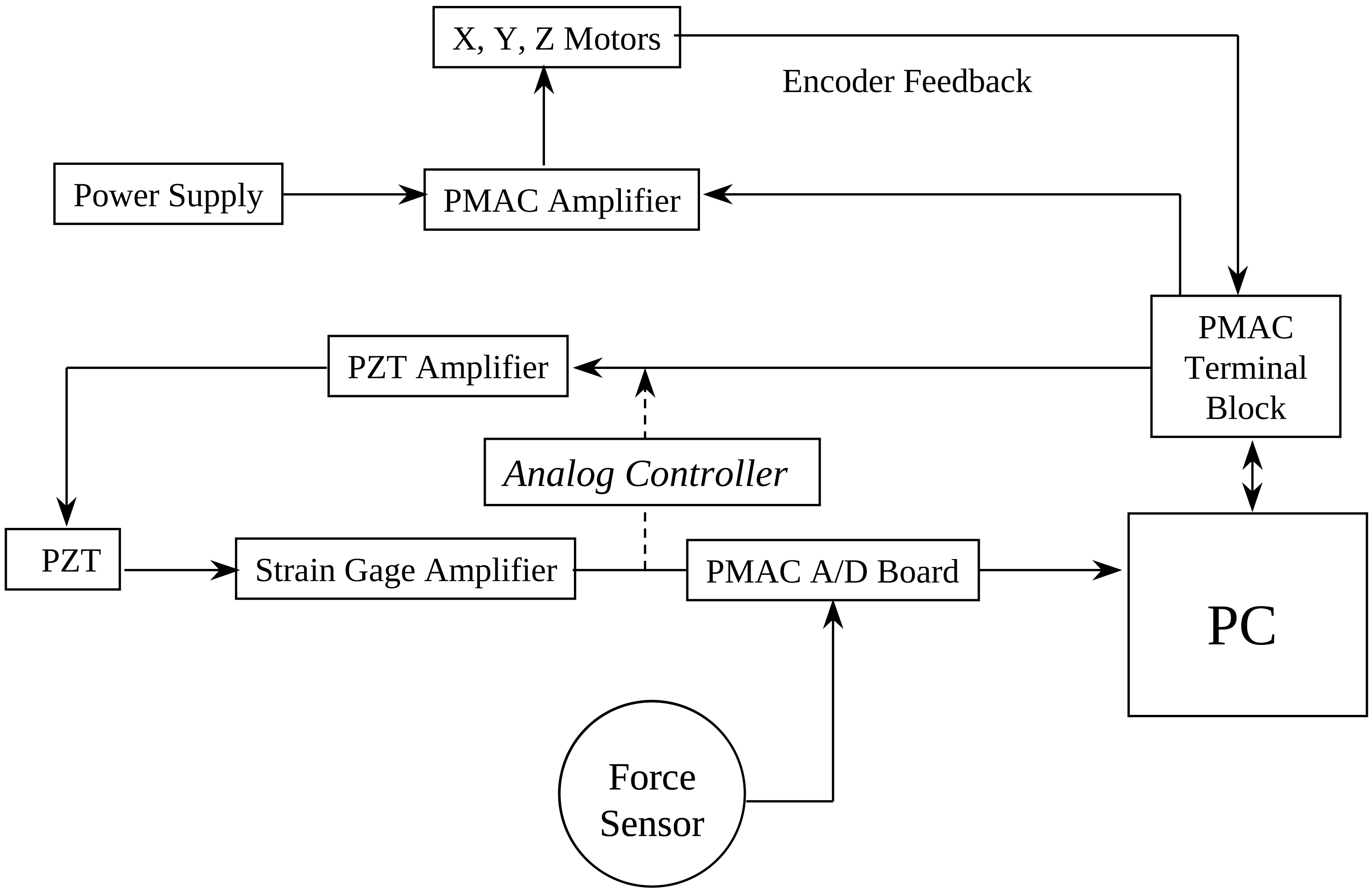
Probe Controller Design

- Passive probe:
  - Contact scanning probe without the PZT
  - Similar to current contact scanning devices
  - Serves as a comparison for the active probe
- Active probe
  - Contact scanning probe with the PZT
  - PZT operated closed-loop
- Controller goals
  - Follow profile of workpiece
  - Maintain constant contact force

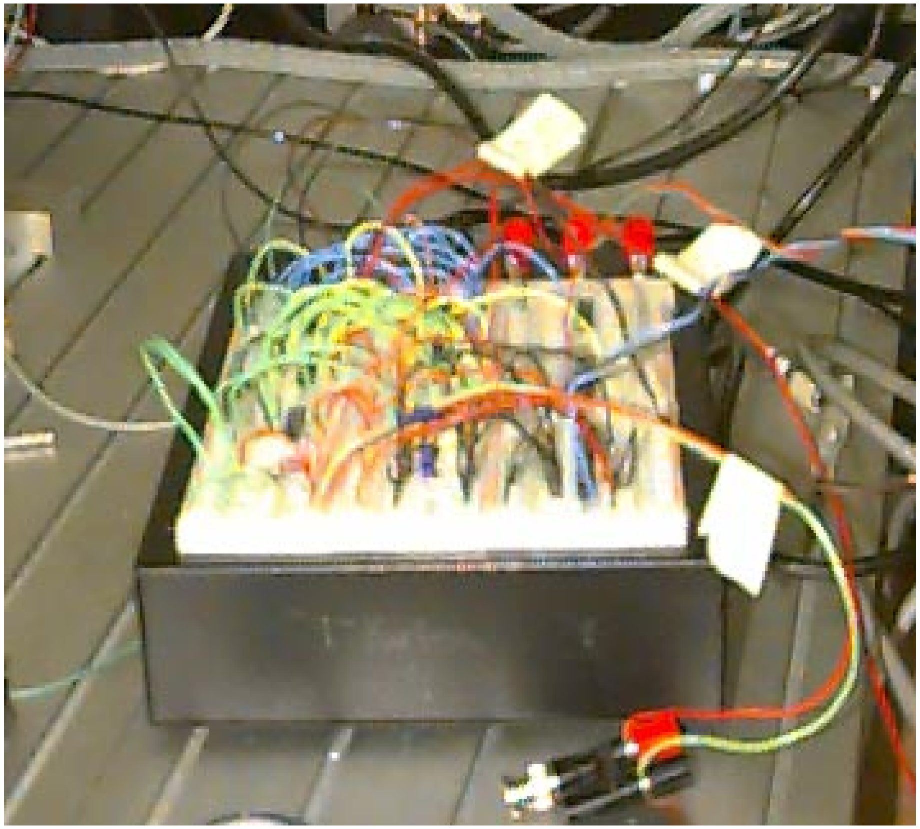
Mechanical Layout



Signal Flow Diagram



Analog Controller



Results

- Matlab simulations result in force error standard deviation of 0.85 N
- Passive probe average force error standard deviation of 0.87 N
- Matlab simulation of active probe shows 41% reduction in position error standard deviation over passive probe (1.95 mm vs. 1.15mm)
- Active probe has 36% reduction in position error standard deviation over passive probe (2.00 mm vs. 1.28 mm)

Conclusions and Future Work

- Active probe provides better precision
- At faster speeds, error reduction should be even higher
- Some future considerations:
  - More complex control design (PMAC allows for adaptive and model-based control)
  - Adapt probe to sense data in more than one direction (scan sides of surfaces, measure internal diameter of bores, etc.)