National Aeronautics and Space Administration

Nanometer Motion Control for Space Optical Instruments

JPL PI: Yen-Hung (James) Wu, 383
UCLA Personnel: Kenny Pyle, T-C. Tsao, Robert M'Closkey
Program: SURP

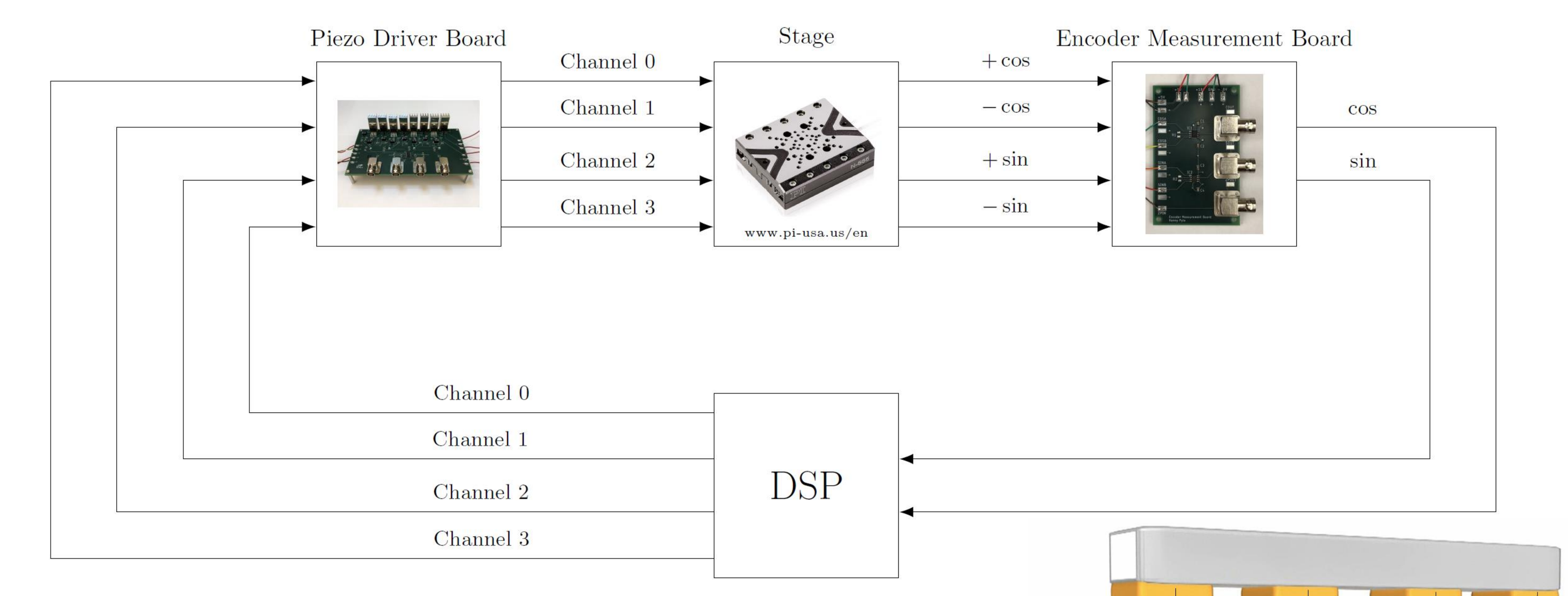
Project Objective:

The outcome of this task will enable the miniaturization of a JPL hyperspectral imager (PanFTS). At the end this task, we will demonstrate the nanometer absolute position accuracy over 26 mm travel of the Physik Instrumente (PI) piezo motor N-565, by implementing the necessary feedforward and feedback control loops to compensate for the fixed pattern error and velocity ripple, respectively.

A. Experimental Setup

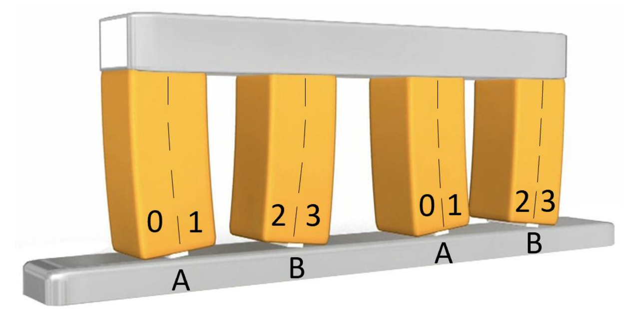
The N-565 hardware is a linear stage that relies on as set of piezoelectric (PZT) drive modules with an integrated Mach-Zehnder interferometer encoder. The stage can be actuated using PI's E-861 controller, however, large, periodic velocity disturbances about the mean velocity are present at many velocity setpoints.

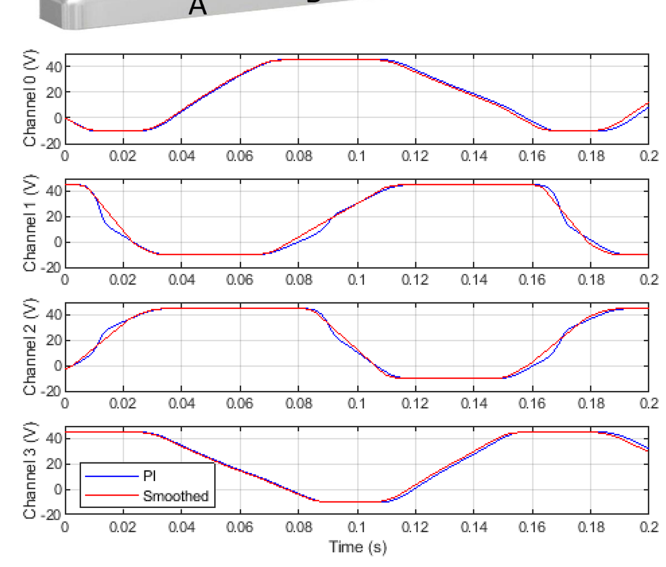
Three circuit boards have been fabricated to eliminate reliance on the PI controller for stage motion. The boards are designed to measure the encoder quadrature signals, capture the piezo actuation waveforms from the PI controller, and drive the piezos with customizable waveforms. The final two boards serve as buffers and also translate waveforms generated by a COTS DSP into the voltage levels required by the piezos. The DSP is used for real-time signal processing, rapid prototyping of arbitrary PZT voltage waveforms, and implementation of feedback control algorithms (refer to schematic below). The COTS DSP replaces the PI controller.



B. Kinematics of stage motion

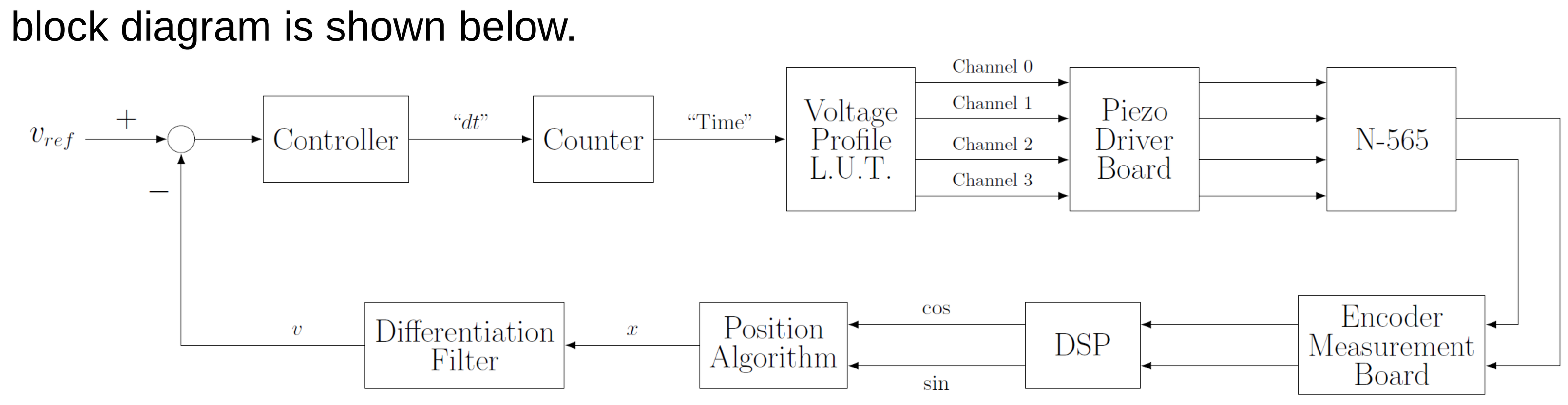
The "legs" are PZT bimorphs that are paired to move every other leg in unison (see figure at right). The voltage waveforms generated by the PI controller for each PZT "channel" (0, 1, 2, or 3) have a unique patterns, even accounting for translations in time —representative waveforms are also shown at right. The PZT signals in a given leg (either 0-1 or 2-3) are equivalent to corresponding "feed" and "clamping" voltages and determined how the leg interacts with the runner.



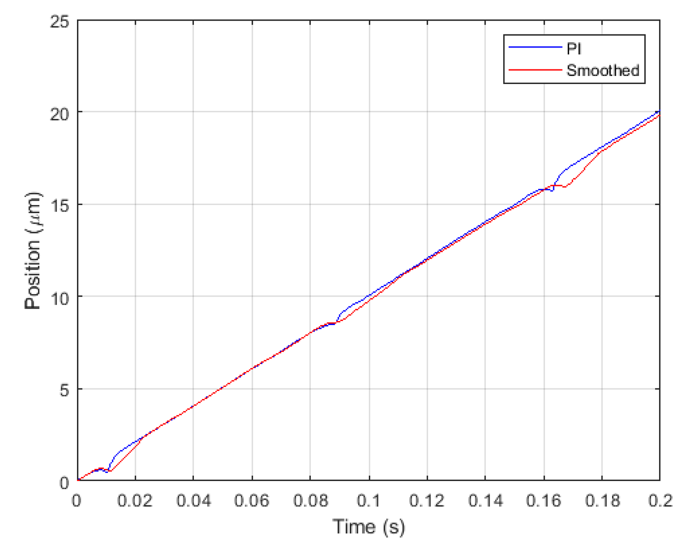


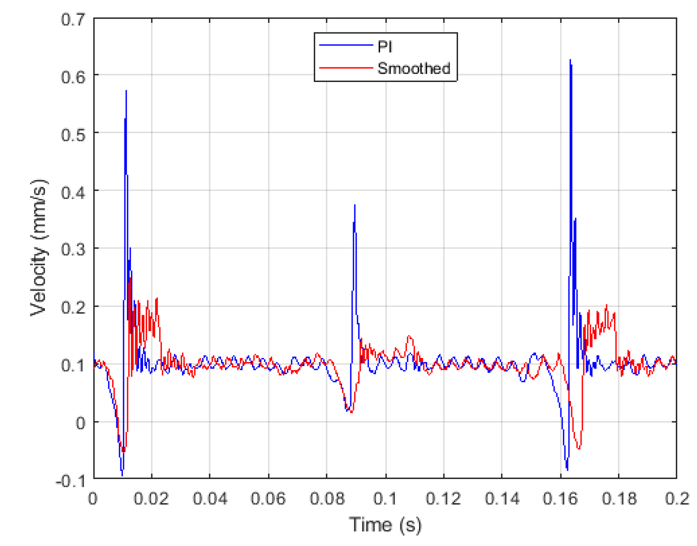
C. Experimental Results

Closed-loop experiments with the DSP are described. The encoder quadrature signals are processed in real-time to yield the stage position. The stage velocity is the variable to be controlled so the position signal is passed through a digital differentiation filter. The velocity error is integrated to produce a "time step" which determines how the waveform look-up table (LUT) is sampled. The closed-loop block diagram is shown below.



When the stage is operating with the PI controller, large, periodic impulsive transients are produced in the stage velocity (below right). These transients are phase-locked to the PZT voltage waveforms and are most likely created when a set of legs engages or disengages the runner. Although waveforms are fixed in the PI controller, the DSP can implement arbitrary waveforms, thus, the PI-specified voltages are subjected to a smoothing operation and these filtered waveforms are subsequently implemented by the DSP. The closed-loop results with the DSP show that the impulsive transients are eliminated, however, the transient duration is increased. The reference velocity for the PI controller and DSP is 0.1 mm/s in these experiments. The stage position is also shown.





Conclusion: These preliminary results demonstrate that it is possible to reduce the velocity perturbations by suitable modification of the baseline PZT voltage waveforms. Additional modeling is required capture contact dynamics between the legs and runner since greater insight will inform improvements of the waveforms to further smooth the stage velocity. This is the focus of the Phase 2 research.

Benefits to NASA and JPL (or significance of results):

PanFTS started out as an Earth Sciences atmospheric chemistry remote sensing instrument. The same technique can be applied to the Planetary Sciences, particularly for the planetary bodies with an atmosphere, such as Mars, Jupiter, Saturn, Neptune, Uranus and their moons. The same technique can also be applied to the Astrophysics Sciences as an integral field spectrometer, as successfully demonstrated by SITELLE instrument at the Canada France Hawaii Telescope.

A traditional FTS flight instrument typically uses a few single pixel detectors to map the target spatially and spectrally in high resolution. PanFTS uses a mega pixel focal plane array do perform the same measurements. The benefits are most notable in the observation efficiency and science throughput, simply by the sheer number of available pixels.

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

PI/Task Mgr. Contact Information:
818-393-5466
james.wu@jpl.nasa.gov

Poster No. RPC-152