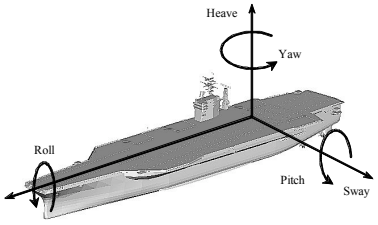
Ship Motion Compensation for Force Control Systems (SMCFCS)

Objective

Develop a methodology that will enable Human Strength Amplification previously demonstrated by ORNL to be used aboard U.S. Naval vessels while at sea.

Challenge – Implement force control of variable payload system on a moving platform

- Ship is in constant motion resulting in variable inertial disturbance forces that act on the payload.
- Disturbance forces are not at a single frequency.
- Disturbance forces are potentially very large.
- Magnitude and frequency of disturbance forces are in the same range as the command input.



Disturbance forces generated by ship motion interfere with force control applications

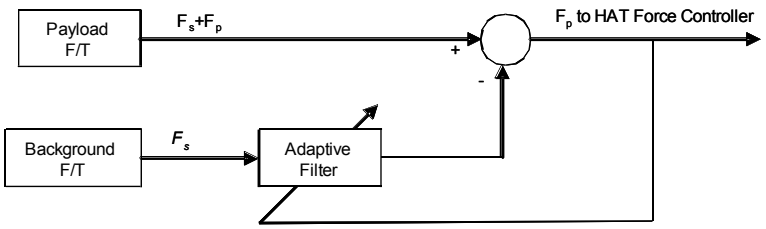
Example: 6000-lb load in sea state 5

Large ship; f_{ah}= 420 lb, f_{ar}= 937 lb (~23% load)

Small ship; f_{ah}= 1020 lb, f_{ar}= 1553 lb (~43% load)

Approach

- Waves are not periodic → Repetitive Learning Control (RLC) will not work.
- An approach similar to noise cancellation in headsets does work.
  - Secondary force/torque sensor measures disturbance forces.
  - Adaptive filter correlates payload mass to reference sensor mass.
  - Disturbance force is subtracted from feedback that the operator senses.



Sea state spectrum is highly variable.

Results

- Hardware testing on ORNL's Ship Motion Simulation Platform confirmed modeling and simulation results showing a ten-fold reduction in disturbance loading and ten-fold improvement in tracking.
- Operator retains control of the payload:
  - Can feel contact with the environment, but
  - Does not feel the ship induced disturbance forces.
- Improved safety and efficiency: the operator can concentrate on the task and not on overcoming disturbances due to ship motion.

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