Isolator Base: Seismic Damage Mitigation for Museum
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Research Question
How would you use an active system to prevent damage to artwork from ground movement like an earthquake?

Methodology
- Seismic waves can be very complex. Focusing on the longitudinal Primary waves (P-waves) and transverse Secondary waves (S-waves) of surface earthquakes makes analysis of ground movement and the influence of the ground movement on objects more approachable.

  - By focusing on two primary axes of motion, an object in a seismic event can be modeled as an inverted pendulum moving through both the P-wave and S-wave dimensions.

  - The inverted pendulum model becomes a well-defined system where a control effort can be designed to respond in a specific manner to the external forces of ground movement.

    - The platform can consist of a base which is secured to the ground, the object to be stabilized attached to a movable sled, which is part of the platform.

    - The interaction of the platform, sled and object to a seismic event can be modeled by a set of equations.

    - A Proportional plus Integral plus Derivative (PID) control compensate will provide the necessary precise sled movement to isolate the object from ground movement.

      - A PID controller reduces overshoot and time to steady state of platform

      - The root locus design method provides the control equation constants which allows for stabilization of a range of objects

Conclusion & Future Investigations
It is possible to develop a platform that can actively isolate an object with a high center of gravity from seismic events. Modeling the object and platform as an inverted pendulum is foundational to working with the complex nature of ground movements and how ground movements affect objects. From the initial implementation of the seismic isolator, there are additional areas for investigation:

  - Improvement and development of cooling system to ensure minimization of system heat production on the object's environment

  - Determine if error feedback will substantially improve control response of system

  - Integration of hardware to track sled position to confirm software position tracking and to reduce potential system failure

  - Include monitoring and communication system

    - User interface to program based on object’s characteristics

    - Provide information of seismic events and system performance to events

  - Further refinement of control compensation

    - Development and implementation of compensator that will provide more precise control effort based on specifics of object to isolate

    - Investigate platform cost when implementing scaling of platform for larger objects and aesthetic improvements

Results & Discussion
- The modeling of an object and platform as an Inverted pendulum adequately describes system behavior in seismic context.

  - Due to the nature of a generalized control equation, the platform is able to successfully stabilize objects with similar defining characteristics.

  - For stabilization of objects outside of controller range, control compensate will need to be recomputed.

  - Low power consumption is achieved through use of digital low pass filtering to reduce input noise. During periods of nominal seismic activity no control effort is provided and systems is passive.

  - When in active phase of seismic isolation, power consumption spikes. Spike is result of necessary motor drive (power and acceleration).

  - System can be implemented with standard, readily available materials. Although readily available materials reduce cost of system, aesthetic and performance compromises must be made.

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