



Self-Leveling Base

Graduation Project 1 | Faculty of Engineering, An-Najah
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BACKGROUND

Introduction & Background

Why Stabilization Matters

Stabilizing mechanisms are essential across many industries – from camera stabilizers and helicopters to medical devices and anti-motion sickness chairs.

How Stabilization Works

A stabilizing platform measures the angle of tilt and uses a motor to compensate for angular fluctuation. Angle measurement can be done via potentiometers or advanced sensors; motors range from servo to DC.

Project Focus

This project analyzes how feedback-control using accelerometers and gyroscopes can stabilize a platform. System built on an Arduino platform with an IMU providing feedback to two DC-motors.

Research Questions

- How does the system respond to a load placed asymmetrically on the platform?
- Is it possible to compensate for the resulting imbalance?

Theory Overview



IMU

Inertial Measurement
Unit

Combines accelerometers
and gyroscopes to
measure platform tilt



KALMAN

Kalman Filter

Fuses accelerometer and
gyroscope data to
produce a low-noise angle
signal meeting system
requirements



PID

PID Control

Two independent
controllers per axis
designed for fast rise time,
minimal overshoot, and
stability



MOTOR


DC-Motor Model


Each motor modeled with
resistance, inductance,
back-EMF, and friction as
independent subsystems


Theoretical model based on a 125g load placed at the center of the platform


Demonstrator: Hardware & Software


HARDWARE

-  Arduino microcontroller platform


-  Two DC-motors with gearheads for tilt compensation


-  Motor drivers for microcontroller interface


-  IMU sensor (accelerometer + gyroscope)


-  ABS plastic structural parts via CAD design

SOFTWARE

-  Kalman filter for sensor fusion and noise reduction

-  Two independent PID control loops (one per axis)

-  Signal processing on Arduino microcontroller

-  Motors driven via PWM signals

Test Results Confirmed Effective Sensor Fusion and Minimal Mechanical Stress

Metric

Value

Outcome

Rise time

0.75s

Fast response

Settling time

1.35s

Quick stabilization

Kalman Filter: Produced angle signal with noise within requirements

Step Response Test (11.4° input):

Short rise time and small overshoot confirmed minimal stress on motor shafts

Asymmetric Load Test:

- Greater distance from center → larger angular fluctuation and longer settling time
- System compensated for imbalance in all tested configurations
- Theoretical model sensitive to off-center load deviations

Discussion & Conclusion

Key Findings

Kalman filter

PID & step response

Asymmetric load

Error sources

Outcome

Successfully reduced sensor noise to acceptable levels

Met speed and stability requirements with minimal overshoot

Greater load distance from center increases angular fluctuation and settling time

Friction, sensor calibration, and model simplifications acknowledged

Conclusions:

- Self-leveling platform successfully compensates for tilt from asymmetric loads
- IMU + Kalman filter provides reliable, low-noise angle measurement
- PID controllers deliver fast, stable responses meeting performance requirements