# ROBOTICS TRAVELING VAN

Robots on the Road

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ME 476C Sec.2

# PROJECT DESCRIPTION

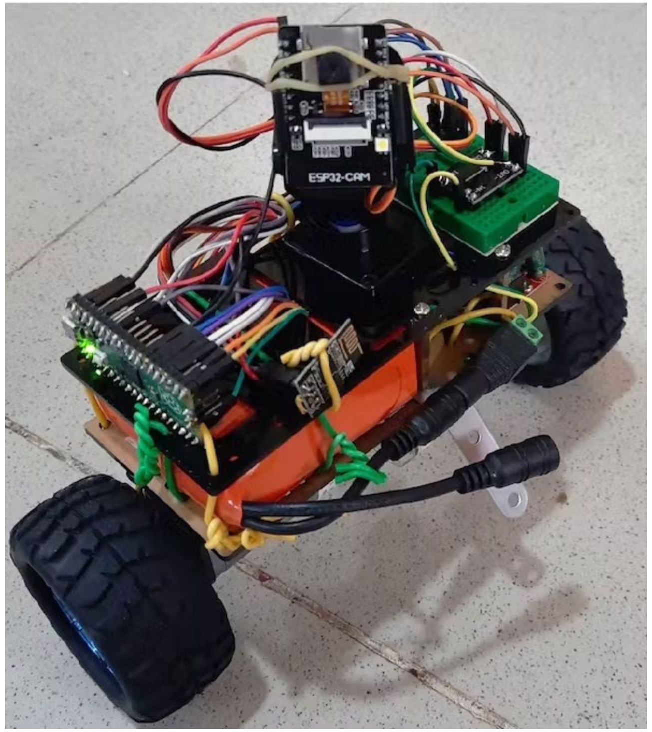



*Fig. 1. Self-Balancing Robot Using PID [31], source: Elektor Magazine (2022).*

- Design and develop a small-scale **Pendulum Balancing Robot** and a **Control-Based Robot** to demonstrate control systems
- Robot uses **PID control** with adjustable parameters to maintain balance in real time, integrate a **RaspPi or Equivalent** with a touchscreen
- Intended as a **K–12 educational tool** to spark interest in robotics and engineering
- Sponsored by **Michael Shafer (NAU)**, emphasizing the importance of **STEM outreach and hands-on learning**

# CUSTOMER REQUIREMENTS

Objective: To demonstrate how feedback controls affects the functionality of robots on continuous systems for K-12 students.

- Durable
- Inexpensive
- Functionality
  - Battery powered
  - Interactive interface (touchscreen)
  - Operating space
- Educational
- Kid friendly
  - Emergency button
  - Chamfer and fillet parts
  - Reduction of pinching (3mm between wheels)

Colin

# ENGINEERING REQUIREMENTS

- Dimensions:
  - 14" by 10" by 5" (the dimensions of a shoebox)
  - Operate within a 20" by 20" space
- Power Source:
  - On a single set of batteries, system should be able to operate regularly for an hour to an hour and a half
- Arduino or RasberryPi:
  - RasberryPi allows more flexibility in programing and offers touch screen capability, Arduino is more space efficient and power efficient
- U.S. CPSC Guidlines:
  - Guidlines regulating design elements of childrens toys, includes numerous requirements such as no exposed batteries or wiring, hazerdous edges, etc.
- Drop Test:
  - Survive a 30" fall onto concrete surface and continue functioning.
- Programming Diagrams:
  - Method of organizing program functions into if-then trees

# BACKGROUND & BENCHMARKING

- **Focus of Our Project**

  **Since our project targets K–12 students**, benchmarking emphasizes:

  → Simplicity & visibility

  → Interactivity

  → Excitement & engagement

Existing Designs → Comparison → Insights → Our Project.

Ziyi

# BENCHMARKING-COMPETITORS

## Shay Sackett's Inverted Pendulum Robot:

- Strengths: Low cost, small size, demonstrates core concept
- Best-in-Class: Design simplicity
- Project Relavence: good baseline design to expand off of

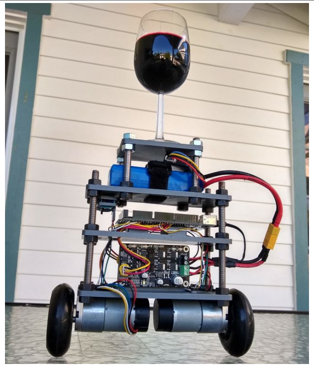


*Fig 2. Shay Sackett's Inverted Pendulum Balancing a glass of wine [23]*

## "Roolie" Self-balancing Interactive Robot:

- Strengths: voice controlled, small size, Rasberry Pi based
- Best-in-Class: most advanced interactive system
- Project Relavence: Very similar in concept to our desired final design

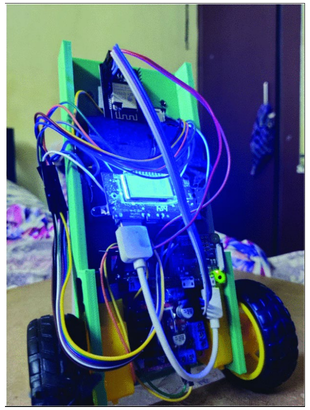


*Fig 3."Roolie" Self-Balancing interactive robot prototype [15]*

## Line Follower Robot with Arduino:

- Strenghts: Unique, simple, compact design
- Best-in-Class: Most cost effective in terms of materials
- Project Relavence: serves as a concept for our secondary design

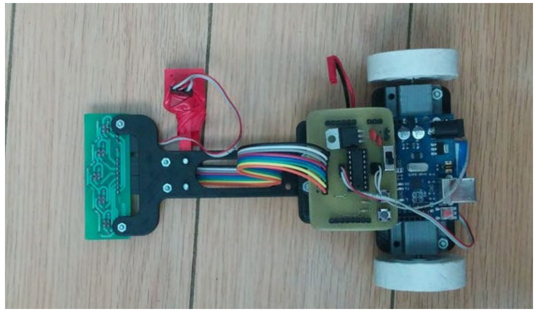


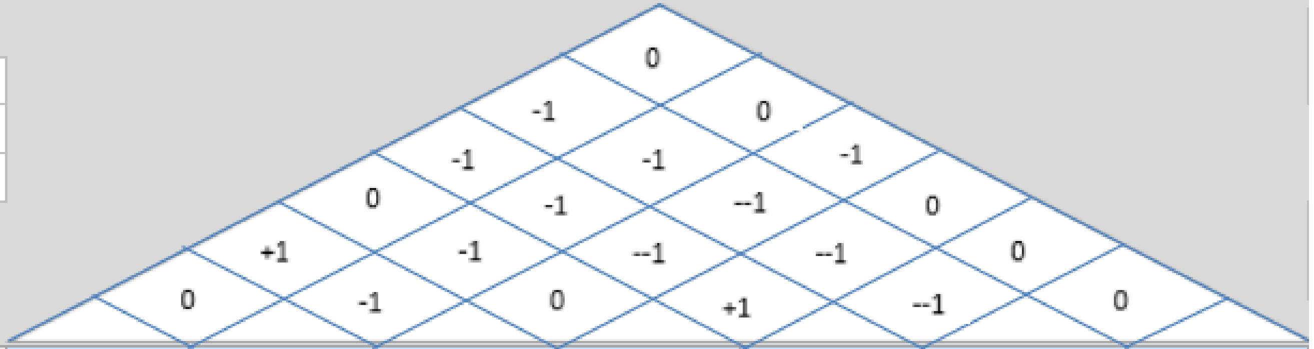
*Fig. 4 "Line Follower Robot with Arduino completed assembly [8]*

Andres

# QFD

## Quality Function Deployment

Project title: Robotics Travelling Van
Project leader: Freddy Rivera
Date: 9/16/2025




1: low, 5: high

| | Customer importance rating | Functional Requirements (How's) → / Customer Requirements - (What's) ↓ | Dimensions of robot | Power source | Arduino or RasberryPi | U.S. CPSC (guidelines) | Drop Test | Manufacturing Cost | Programming Diagrams |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 5 | Operating Space | 9 | | | | | 9 | |
| 2 | 5 | Battery Powered | 3 | 9 | 3 | 9 | 3 | 9 | 1 |
| 3 | 4 | Mass Producible | 3 | 3 | 9 | | 1 | 9 | |
| 4 | 3 | Kid-Friendly | | | 1 | 9 | | | |
| 5 | 4 | Durable | 3 | 3 | 9 | 9 | 9 | 3 | |
| 6 | 3 | Price | 9 | 3 | 9 | 3 | 3 | 9 | |
| 7 | 4 | Interactive Interface (Touchscreen) | 1 | | 9 | 3 | | 3 | |
| 8 | 3 | Educational Props | | | | | | | 9 |
| 9 | | | | | | | | | |
| 10 | | | | | | | | | |

Andres

# QFD

## Quality Function Deployment

Project title: Robotics Travelling Van
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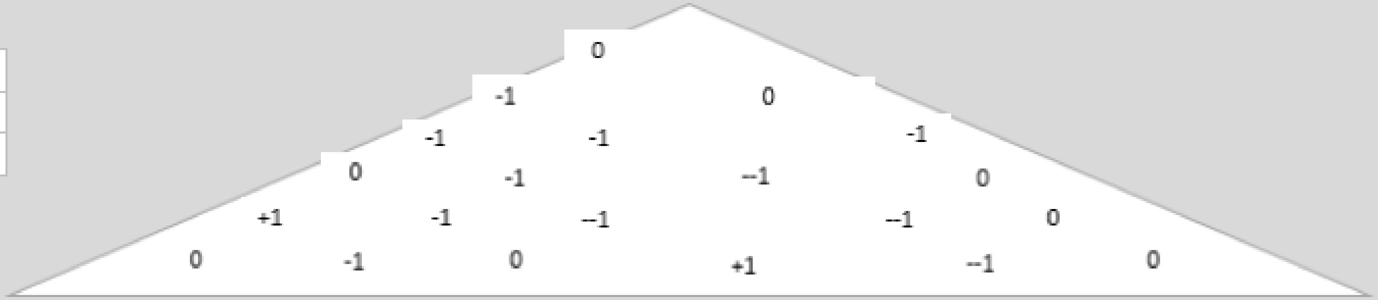


| | 1: low, 5: high<br>Customer importance rating | Functional Requirements (How's) →<br>Customer Requirements - (What's) ↓ | Dimensions of robot | Power source | Arduino or RasberryPi | U.S. CPSC (guidelines) | Drop Test | Manufacturing Cost | Programming Diagrams | Competitive evaluation (1: low, 5: high)<br>Shay Sackett's Pendulum Robot | Self-Balancing Interactive Robot | Instructibles Line Following Robot |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5 | Operating Space | 9 | | | | | 9 | | 4 | 5 | 5 |
| 2 | 5 | Battery Powered | 3 | 9 | 3 | 9 | 3 | 9 | 1 | 2 | 3 | 4 |
| 3 | 4 | Mass Producible | 3 | 3 | 9 | | 1 | 9 | | 4 | 4 | 2 |
| 4 | 3 | Kid-Friendly | | | 1 | 9 | | | | 3 | 5 | 3 |
| 5 | 4 | Durable | 3 | 3 | 9 | 9 | 9 | 3 | | 3 | 2 | 3 |
| 6 | 3 | Price | 9 | 3 | 9 | 3 | 3 | 9 | | 4 | 3 | 5 |
| 7 | 4 | Interactive Interface (Touchscreen) | 1 | | 9 | 3 | | 3 | | 1 | 4 | 1 |
| 8 | 3 | Educational Props | | | | | | | 9 | 3 | 2 | 3 |
| | | Technical importance score | 103 | 66 | 117 | 129 | 60 | 141 | 41 | | | |
| | | Importance % | 14% | 9% | 16% | 17% | 8% | 19% | 5% | | | |
| | | Priorities rank | **4** | **5** | **3** | **3** | **5** | **2** | **4** | | | |
| | | Current performance | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | |
| | | Target | 12" X 12" x 12" | 2hr run time | A or R | Qualifies | 36" drop test | <$500 | Educational | | | |
| | | Benchmark | 6.3" x 2.5" x 5.8" | 4hr run time | A | ASTM F963 Toy Safety | 36" drop test | $300-500 | Block Diagrams | | | |
| | | Difficulty | 4 | 2 | 5 | 1 | 4 | 3 | 1 | | | |

# STATE OF THE ART
# (SOTA)

# LITERATURE REVIEW

TO BETTER UNDERSTAND WHAT AN INVERTED PENDULUM AND HOW IT IS IMPLEMENTED IN EVERYONE'S LIVES

| | |
|---|---|
| Comparison of CoP estimation and center-of-gravity sway measurement in human standing posture using inertial sensors [1] | Center of Pressure (COP) of humans using sensors to analyze gait patterns. |
| Effect of the hip motion on the body kinematics in the sagittal plane during human quiet standing [2] | • Standing still affects hip motion due to the center of mass (COM). |
| Human stick balancing: Tuning Lèvy flights to improve balance control [3] | • Concept of stabilization of rapid human movements which is determined by equilibrium and limit cycles with motor controls analysis like closed loop control (automatic control systems). |
| Balancing of an inverted pendulum with a SCARA robot [4] | Balancing an inverted pendulum with a robotic manipulator is a benchmark problem requiring precise sensing and compensation for nonlinear effects like friction, backlash, and elasticity. |
| Erecting and Balancing of the Inverted Pendulum by an Industrial Robot [5] | Inverted pendulum on an industrial robot by using one algorithm to swing it up and a state-space controller with offset adaptation to balance it. |
| Stabilizing an Inverted Pendulum with PID Controller[6] | Stabilizing an inverted pendulum with a reaction wheel and PID (Proportional Integral Derivative) controller is simulated to balance it effectively and efficiently. |
| Research on Inverted Pendulum Control System Based on Vision Sensor[7] | Vision-based control system for an inverted pendulum, using OpenCV to calculate its deflection angle and verify effective stabilization without relying on encoder sensors. |

# LITERATURE REVIEW

Colin

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|---|---|
| Manufacturing Robotics: Basic Issues and Challenges [8] | Explains various methods used in the manufacture of robots, particularly those for mass manufacture, useful since we are trying to design for a product run of at least 100 |
| How to include User eXperience in the design of Human-Robot Interaction [9] | Highlights methodology of human robot interactions, useful when setting up our interactive elements |
| Designing robots with movement in mind [10] | Discusses the Benefits of Robots capable of human motion and expression, something to consider in the design of our robots in order to make them appealing to k-12 students |
| Design and Implementation of an Open-Source Educational Robot for Hands-On Learning Experiences in IoT [11] | Presents a design for a modular educational robot that utilizes Arduino hardware, as well as making use of some laser cut parts, good baseline for prototyping |
| Design and control of a multi-DOF two wheeled inverted pendulum robot [12] | Breaks down the math behind a multi-Degree-of-Freedom inverted pendulum robot, has some useful equations and can serve as a model for other types of robots |
| Mechanical Design and Dynamic Modeling of a Two-Wheeled Inverted Pendulum Mobile Robot [13] | Showcases a design for an inverted pendulum robot designed for navigating small obstacles and inclines, some design elements could be useful if robot proves unstable |
| Design and Implementation of Self-Balancing Interactive Robot [14] | Proposes a design for a Pendulum robot companion with voice control features, overall design is comparable to our desired design for pendulum robot |

# LITERATURE REVIEW

Andres

| | |
|---|---|
| Bacterial foraging-optimized PID control of a two-wheeled machine with a two-directional handling mechanism [15] | • Uses a bacterial foraging optimization algorithm to tune a PID controller for a 5-DOF two-wheeled robotic system (with payload in two directions) and shows improvement in stability and performance over conventional PID control across multiple work scenarios. |
| A Self-adaptive SAC-PID Control Approach based on Reinforcement Learning for Mobile Robots, Mandeno [16] | • Introduces a hierarchical control method: a soft actor-critic RL agent selects parameters for an incremental PID controller in real time, improving adaptability and robustness in varied environments with mobile robots. |
| A Wheeled Inverted Pendulum Learning Stable and Accurate Control from Demonstrations [17] | • Learns stable and accurate control policies for a wheeled inverted pendulum from demonstration data, offering a way to replicate expert performance in balancing while reducing design of controllers from scratch. |
| Theory and Application on Adaptive-Robust Control of Euler-Lagrange Systems with Linearly Parametrizable Uncertainty Bound [18] | Proposes an adaptive-robust control (ARC) scheme for uncertain Euler-Lagrange systems with uncertainties satisfying linear-in-parameters bound, addressing over/underestimation of switching gains, and demonstrates experimental gains over adaptive sliding mode control. |
| K. Ogata, *System Dynamics*, 4th ed; Chapter 11 [19] | • Modeling and feedback control concepts from Ogata's *System Dynamics* guided our system modeling and controller design. Enabled accurate simulation of system behavior and stability analysis before hardware implementation. |
| Design of an inverted pendulum laboratory stand to teach mechatronics [20] | Presents a physical laboratory setup (a real inverted pendulum stand with USB I/O card control) designed for mechatronics teaching—students can implement and observe control algorithms in real time on actual hardware. |
| Inverted Pendulum Control — PythonRobotics documentation [21] | • Explains standard implementations of inverted pendulum control algorithms in simulation (e.g. linearization, PID control, swing-up control), providing code examples and visualizations for education or prototyping. |
| U.S. Consumer Product Safety Commission, "Toys," Safety Education — Toys, *CPSC.gov*. [Online].[22] | • Explains standards for toys and devices intended for use of children, different standards for different age ranges. Useful for knowing what aspects of our robots need modifying for children use. |

# LITERATURE REVIEW

Ziyi

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|---|---|
| Embedded Computer Vision System Applied to a Four-Legged Line Follower Robot, 2021 [23] | • The study proposes an embedded vision-based line-following system that uses color space segmentation and thresholding methods to extract track features, achieving real-time path recognition and control on resource-constrained hardware platforms. It provides practical insights into deploying vision-based line-following algorithms on low-power devices. |
| S. P. Mamidi, *AI model on Raspberry Pi*, M.S. thesis, Linnaeus Univ., 2019. [24] | • This thesis goes in depth on deploying AI models onto Raspberry Pi, including optimizations and hardware interfacing. It's directly useful for us because it gives a framework for connecting sensors and motors efficiently, which is exactly what we need for balancing and stabilization. |
| Raspberry Pi Ltd., *Raspberry Pi 5 Product Brief*, 2023. [25] | • The product brief provides the specs for the Pi 5. This document lets us match processing power, GPIO availability, and I/O speeds with the requirements of our touchscreen interface and motor drivers. |
| Raspberry Pi Ltd., *Raspberry Pi Documentation*, 2023. [26] | • This is the official setup and wiring guide. It's basically our roadmap for integrating the touchscreen, coding the PID interface, and wiring up motor drivers to the Pi. |
| ISO/IEC 29182 Sensor Network Reference Architecture [27] | • This standard defines a layered reference architecture for sensor networks, covering nodes, gateways, service, and application layers. It provides interoperability and scalability guidelines |
| H. Kerzner, *Project Management*, 12th ed., 2017. [28] | • Kerzner's book gives us a structure for managing the capstone. We're applying his frameworks for milestone planning, like building Robot #1, Robot #2, and then finalizing, so we stay on track with deliverables. |
| AACE Int., *Cost Estimation for Manufacturing Projects*, 2020. [29] | • This guideline shows how to do professional cost estimation for manufacturing. It's critical for us when we justify that our design isn't just a one-off prototype, but can be scaled to 100 units realistically within the sponsor's budget. |

# LITERATURE REVIEW

Freddy

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|---|---|
| Inverted Pendulum: System Modeling (CTMS) [30] | Provides mathematical modeling and linearization of an inverted pendulum system, as well as MATLAB representation . Foundation for equations of motion used in project calculations. |
| Ball and Beam: System Modeling (CTMS) [31] | • Illustrates a comparable unstable control system as well as MATLAB representation. Useful analogy for understanding feedback control concepts. |
| Derivation of the Dynamics of the Ball and Beam System [32] | Detailed step-by-step derivation of nonlinear dynamics. Supports equation development for our pendulum system. |
| DC Motor Speed: System Modeling (CTMS) [33] | Explains motor dynamics and transfer functions with MATLAB representation. Helps link pendulum control equations to motor actuation. |
| Stabilizing a Cart Inverted Pendulum Using Pole Placement [34] | Academic paper applying pole placement to stabilize a pendulum. Serves as a benchmark design and guides control strategy selection. |
| Inverted Pendulum: Control Theory and Dynamics (Instructables) [35] | Simplified tutorial for hobbyists. Helps bridge theory to practical implementation. |
| Self-Balancing Inverted Pendulum Robot (Sackett) [36] | Independent project documenting design and challenges. Benchmark for real-world feasibility and lessons learned. |
| IEEE Standard for Ontologies for Robotics and Automation (ORA): Core Ontologies for Robotics and Automation (CORA) [37] | This standard provides a structured framework for describing robotics tasks, environments, and control actions. Helps us formalize how we represent the robot's balancing task, its interaction with users, and safety considerations. Referencing this standard ensures that our design follows professional best practices and that our inverted pendulum robot is consistent with established robotics system modeling approaches. |

# MATHEMATICAL MODELING

Florence

# INVERTED PENDULUM WITHIN HUMANS

- Ankle joint/Wheel axle (pivot point), Body(Pendulum), Feet/Wheels (Center of Pressure (COP))

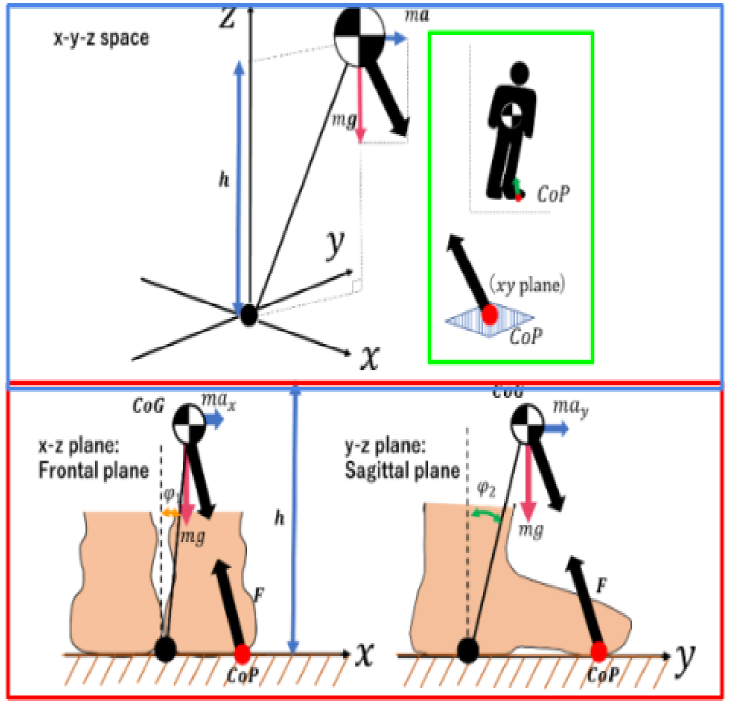



Figure 2: Diagram (left) representing the inverted pendulum model to show the relationship between the equations (right) displayed in Mr. Takamoto's paper [1]

$(x_G, y_G) = (h\sin\phi_1, h\sin\phi_2)$

$(x_{COP}, y_{COP}) = (x_G, y_G) + h/|g|(a_x, a_y)$

ma = F - mg

m=mass
a=acceleration
F=force
g=gravity
*h=height of COP*
$\phi_1$=body tilted in xz projection plane (forward)
*$\phi_2$=body tilted in yz projection plane (backward)*
$(x_G, y_G)$= position of COP
$(a_x, a_y)$= acceleration fixed near the COP

h=0.90 m (COM height above the ankle)
g= 9.81 m/s^2
Fx= 75 N  Fy= 0 N
m= 70 kg (Average Adult)
*$\phi_1$= 0.05 rad (~2.9 deg.)*
*$\phi_2$= -0.03rad (~-1.7deg.)*
$a_x$=a=0.8 m/s^2 (forward)
$a_y$=-0.5 m/s^2 (lateral)

$x_G = 0.90\cdot\sin(0.05) \approx 0.045$ m (4.5 cm forward)
$y_G = 0.90\cdot\sin(-0.03) \approx -0.027$ m (2.7 cm left)
*COM shift*

# CART/ANGULAR ACCELERATION OF AN INVERTED PENDULUM

Freddy

Equation for the cart (horizontal motion):

- $(\boldsymbol{M}+\boldsymbol{m})\ddot{x}+\boldsymbol{ml}\ddot{\boldsymbol{\theta}}\cos(\boldsymbol{\theta})-\boldsymbol{ml}\dot{\boldsymbol{\theta}}^2\sin(\boldsymbol{\theta})=\boldsymbol{f}$

Equation for the pendulum (rotational motion):

- $\boldsymbol{l}\ddot{\boldsymbol{\theta}}+\ddot{x}\cos(\boldsymbol{\theta})-\boldsymbol{g}\boldsymbol{sin}(\boldsymbol{\theta})=\mathbf{0}$

**Variables:**

- $\boldsymbol{M}$ **= 1.0 kg (Cart Mass)**
- $\boldsymbol{m}$ **= 0.2 kg (Pendulum Mass)**
- $\boldsymbol{l}$ **= 0.5 m (Pendulum Length)**
- $\boldsymbol{g}$ **= 9.81 m/$s^2$ (Gravity)**
- $\boldsymbol{\theta}$ **= 10° = 0.1745 Rads (Initial Angle)**
- $\dot{\boldsymbol{\theta}}$ **= 0 rad/s² (Angular Velocity)**
- $\boldsymbol{f}$ **= 1.0 N (Applied Force)**

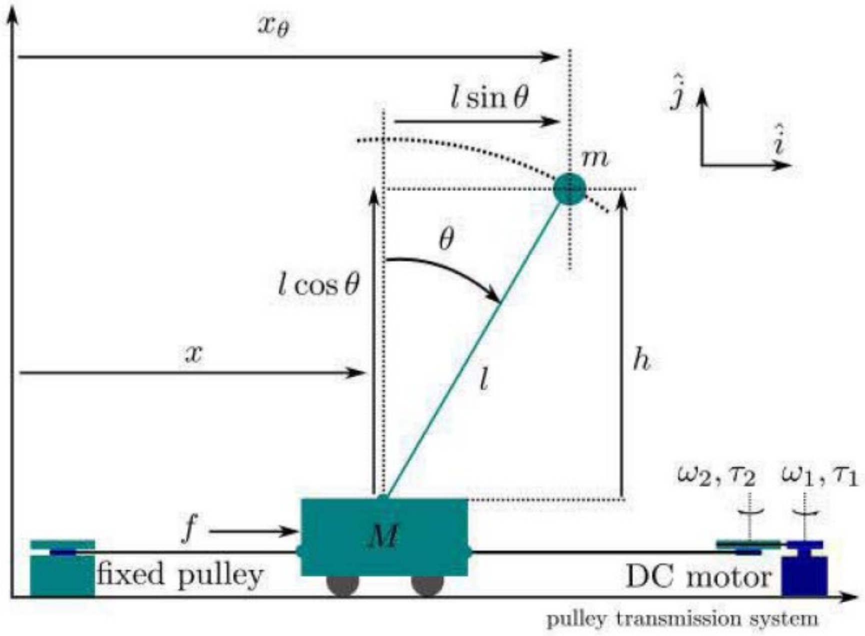



Fig. 3. Cart-Inverted Pendulum System [28].

**After Solving:**

- $\ddot{x}$ **= 0.661 $^m/_{s^2}$ (Cart Acceleration)**
- $\ddot{\boldsymbol{\theta}}$ **= 2.1 $^{rad}/_{s^2}$ (Angular Acceleration)**

# SELF-BALANCING OF INVERTED PENDULUM ROBOT

Equation of Motion

$I\ddot{\theta}$=mgl$\theta - \tau$

$\tau = K_P\theta + K_d\dot{\theta}$

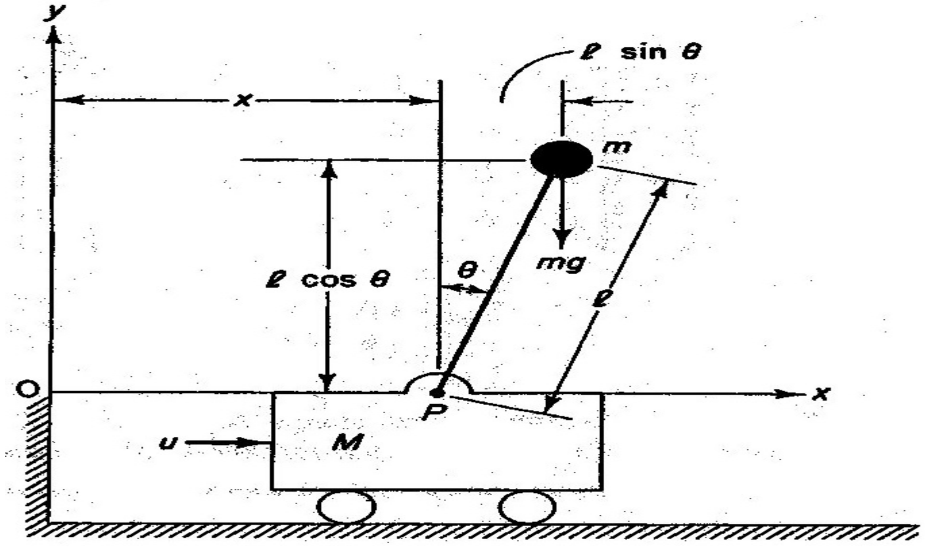
Stability: Kp > mgl

Variables:

m = 3.0 kg (Mass)
l = 0.15 m (CG height)
I = m * l^2 = 0.0675 kg·m^2 (Inertia)
g = 9.81 m/s^2 (Gravity)
m*g*l = 4.41 N·m (Gravity torque)

Target: Ts = 0.5 s, ζ = 0.7

After Solving:
ωn = 11.4 rad/s (Natural freq.)
Kp ≈ 13.2 N·m/rad
Kd ≈ 1.08 N·m·s/rad
At θ0 = 5°:
Control torque τ = 1.16 N·m
Gravity torque = 0.39 N·m



# LAPLACE TRANSFORMS - TIME DOMAIN FOR PID

Andres

Laplace Transform (pendulum)
Design Analysis on transfer function

$$u(t) = K_p e(t) + K_i \int e(t)dt + K_d \frac{d}{dt} e(t)$$

Apply Laplace to find T(s)

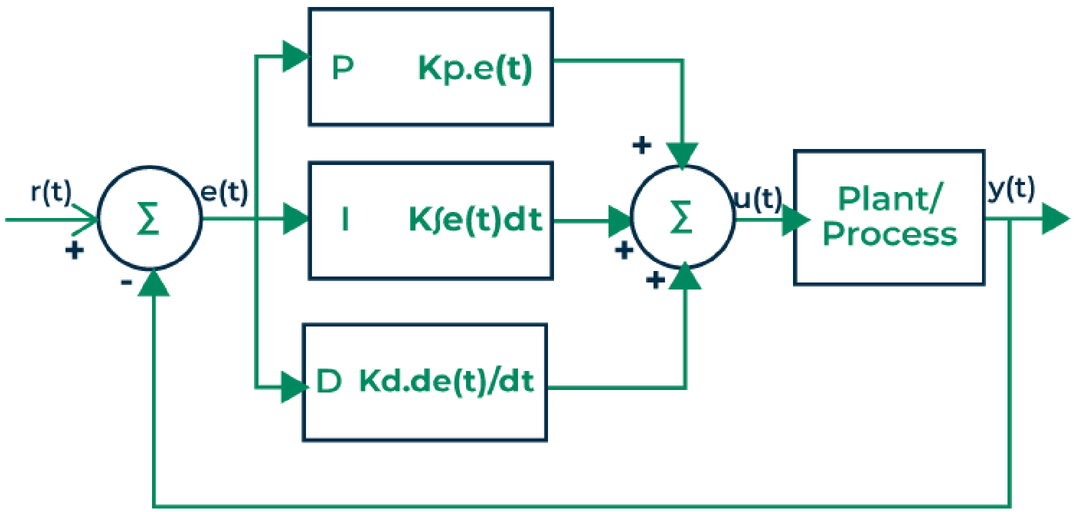
$$T(s) = \frac{20s^2 + 150s + 300}{0.6s^3 + 20s^2 + 161.772s + 300}$$

Fine tuning PID using coefficients of $K_p$, $K_i$, and $K_d$ help fine tune the system

$K_p$ = proportional gain (poles of response)
$K_i$ = integral gain (poles of error)
$K_d$ = derivative gain (dampen overshoot)

Assumptions:
M = 1 kg
m = 0.2 kg
L = 0.5 m

Partial – Integral – Derivative
Implementation




More...
...negative real parts = stability
...complex poles = speed of response
...complex parts = oscillations

Colin

# DETERMINING BASE-PLATE THICKNESS TO SURVIVE FALL TEST

Equations:

$v = \sqrt{2gh}$ $F_{avg} = \frac{mv}{\Delta t}$ $h \geq \sqrt{\frac{6FL}{b\sigma_{flex}}}$

Variables:

m = 3 [kg]

g = 9.81 [m/$s^2$]

h = 0.762 [m] (30 in.)

L = 0.254 [m] (10 in.)

b = 0.127 [m] (5 in.)
$\Delta t = 0.005s$

Flexural Strength Values: [16]

PLA: $\sigma_{flex}$ = 97 [Mpa]

TPLA: $\sigma_{flex}$ = 83 [Mpa]

ABS: $\sigma_{flex}$ = 60 [Mpa]

PC: $\sigma_{flex}$ = 89 [Mpa]

PETG: $\sigma_{flex}$ = 75 [Mpa]

N: $\sigma_{flex}$ = 75 [Mpa]

Minimum Height Values:

PLA: $h_{min}$ = 16.87 [mm]

TPLA: $h_{min}$ = 18.24 [mm]

ABS: $h_{min}$ = 21.45 [mm]

PC: $h_{min}$ = 17.61 [mm]

PETG: $h_{min}$ = 19.18 [mm]

N: $h_{min}$ = 19.18 [mm]

# SCHEDULE & BUDGET

Freddy

# PRE-PHASE 1

| | |
|---|---|
| **1. Project Management** | • **(WK4–WK15)** |
| 1.1 Planning & Scheduling | • Deliverable: Finalized project plan, Gantt chart, resource allocation |
| 1.2 Meetings & Reporting | • Deliverable: Meeting minutes, progress reports, risk assessments |
| **2. Requirements Analysis** | • **(WK4–WK5)** |
| 2.1 Literature Review | • Deliverable: Summary report of relevant prior work |
| 2.2 QFD Development | • Deliverable: Completed Quality Function Deployment document |

Freddy

# PHASE 1

| | |
|---|---|
| **3. Robot #1 Development** | • **(WK6–WK12)** |
| 3.1 Mechanical Design | • (WK6–WK8) |
| 3.1.1 CAD Modeling | • Deliverable: 3D CAD models of key components |
| 3.1.2 Material Procurement | • Deliverable: Purchase orders, BOM for Robot #1 |
| 3.1.3 Assembly of Prototype #1 | • Deliverable: Fully assembled mechanical prototype |
| 3.2 Electrical Design | • **(WK7–WK12)** |
| 3.2.1 Circuit Design | • Deliverable: Schematics and PCB layout |
| 3.2.2 Programming | • Deliverable: Control software with basic functionalities |
| 3.2.3 Testing & Debugging | • Deliverable: Verified hardware/software integration and debugging reports |

Freddy

# PHASE 2

| | |
|---|---|
| **4. Robot #2 Development** | • **(WK8–WK15)** |
| 4.1 Mechanical Design | • (WK8–WK14) |
| 4.1.1 CAD Modeling & Design | • Deliverable: CAD models for Robot #2 components |
| 4.1.2 Material Procurement | • Deliverable: BOM and purchase orders for Robot #2 |
| 4.1.3 Assembly & Prototyping | • Deliverable: Functional mechanical prototype |
| **4.2 Electrical Design** | • **(WK9–WK15)** |
| 4.2.1 Circuit Design | • Deliverable: Robot #2 circuit schematics |
| 4.2.2 Programming & PID Implementation | • Deliverable: Control software with PID controller integrated |
| 4.2.3 Circuit Assembly & Prototyping | • Deliverable: Assembled and tested electrical prototype |
| 4.2.4 Testing & Debugging | • Deliverable: Final test reports and debugging logs |

# PHASE 3

| | |
|---|---|
| **5. Final Testing & Integration** | • **(WK12–WK15)** |
| 5.1 Functional Testing Robot #1 | • Deliverable: Testing report & performance validation |
| 5.2 Functional Testing Robot #2 | • Deliverable: Testing report & performance validation |
| 5.3 Final Tuning & Optimization | • Deliverable: Optimized designs, ready for project close-out |

# BUDGETING

Ziyi

| Component | Quantity | Unit Price (USD) | Subtotal (USD) |
|---|---|---|---|
| Raspberry Pi 5 (4GB) | 1 | 60 | 60 |
| DC Motor with Encoder (Pololu 30:1) | 2 | 30 | 60 |
| Wheels (Pololu 32×7 mm) | 1 | 5 | 5 |
| Motor Brackets (Pair) | 1 | 7 | 7 |
| Motor Driver (TB6612FNG) | 1 | 15 | 15 |
| IMU (MPU-6050) | 1 | 15 | 15 |
| Battery (3S LiPo 11.1V 1000 mAh) | 1 | 30 | 30 |
| Buck Converter (5V 3–5A) | 1 | 10 | 10 |
| Touchscreen (Waveshare 5″ HDMI) | 1 | 40 | 40 |
| LiPo Charger | 1 | 20 | 20 |
| Miscellaneous (wires, screws, frame, etc.) | 1 | 25 | 25 |
| Shipping & Taxes | 1 | 20 | 20 |
| Total | | | 307 |

- Total budget : $5000
  Project 1 : Detailed cost estimate completed
- Project 2 : Budget allocated
- Project 3: Testing/development and scaling
- At least 10% fundraising ($500) will be performed to support the overall budget

| Project | Budget (USD) | Status |
|---|---|---|
| Pendulum Robot | 1500 | ☑ Detailed estimated |
| Line-Following Robot | 1500 | 🔄 Planned (details TBD) |
| Testing/development and scaling | 2500 | ? Not yet decided |

Freddy

# FUNDRAISING

## Grant

Applying for a $500 dollar research grant

## GoFundMe

Setting up GoFundMe to raise funds

## Panda Express

20% Give-Back in Neighborhood Fundraising

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