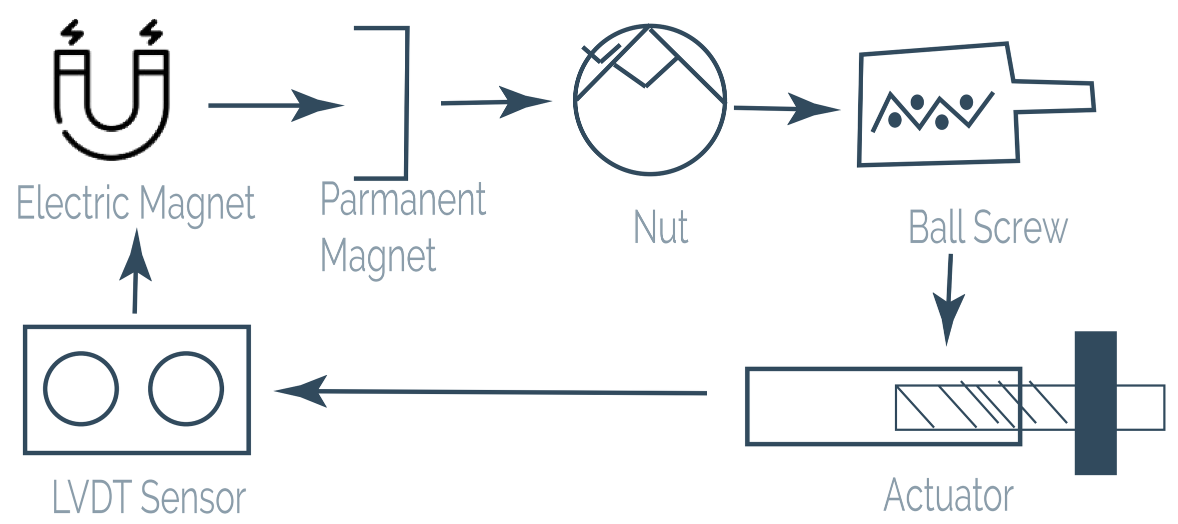
Rolls Royce Electrical Actuator

SINGAPORE UNIVERSITY OF TECHNOLOGY AND DESIGN

Problem Statement

High safety standards and high efficiency are required for aerospace applications. Current Variable Stator Vanes (VSV) Actuation are done by fueldraulic actuators which receive pressurized fuel from the engine's fuel pump. These fuel pumps are required to be oversized to fulfil the fuel pressure requirements of both the VSV and the engine. Activation of the VSV draws pressure from the fuel system to power the fueldraulic actuator, causing a period of uneven distribution of fuel pressure. This would lead to uneven distribution of fuel flow to the engine, causing inefficiency. Fueldraulic Actuators are also susceptible to leakage and pose a threat to safety. Our project is intended to design and prototype a scaled model of a VSV Actuator that proposes a new solution to resolve the existing problems faced by the fueldraulic VSV, using lightweight materials to ultimately save fuel and operational cost.

Ideation Box Diagram

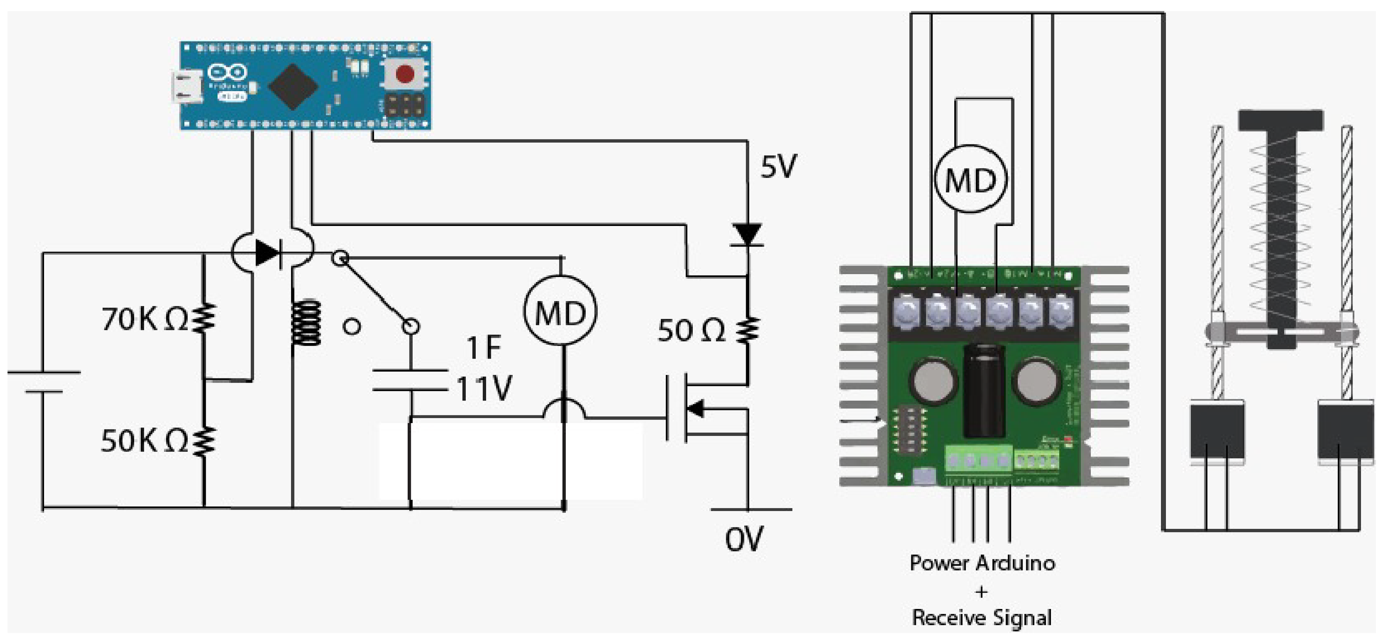


Fail-Safe Mechanism

In the fail-safe design, we consider the worst-case scenario; if a key part suddenly fails to function. If this outcome is intolerable, then safeguards must be engineered to mitigate or prevent that outcome.

Fail-Safe Electric Circuit

This simple circuit uses a mosfet to switch off capacitor charging circuit preventing overcharging of capacitor. This uses an arduino as a voltmeter to measure the voltage which will determine when to turn on charging and when to turn on discharging circuit.



Mechanism Architecture

Micro Light Detection and Ranging (LIDAR Sensor)

Use very narrow light source reflection in order to determine distance. The accuracy level in the optimal condition (indoor; white reflection target can reach 0.3 accuracy level.

Future Development

LVDT

LVDTs are used because of their robustness and longer life, and it canmeet the requirement of 0.1 accuracy level.

Requirement

Constant Speed: 0.1m/s
Max Force Output: 20KN
Full Extension Distance: 0.1m

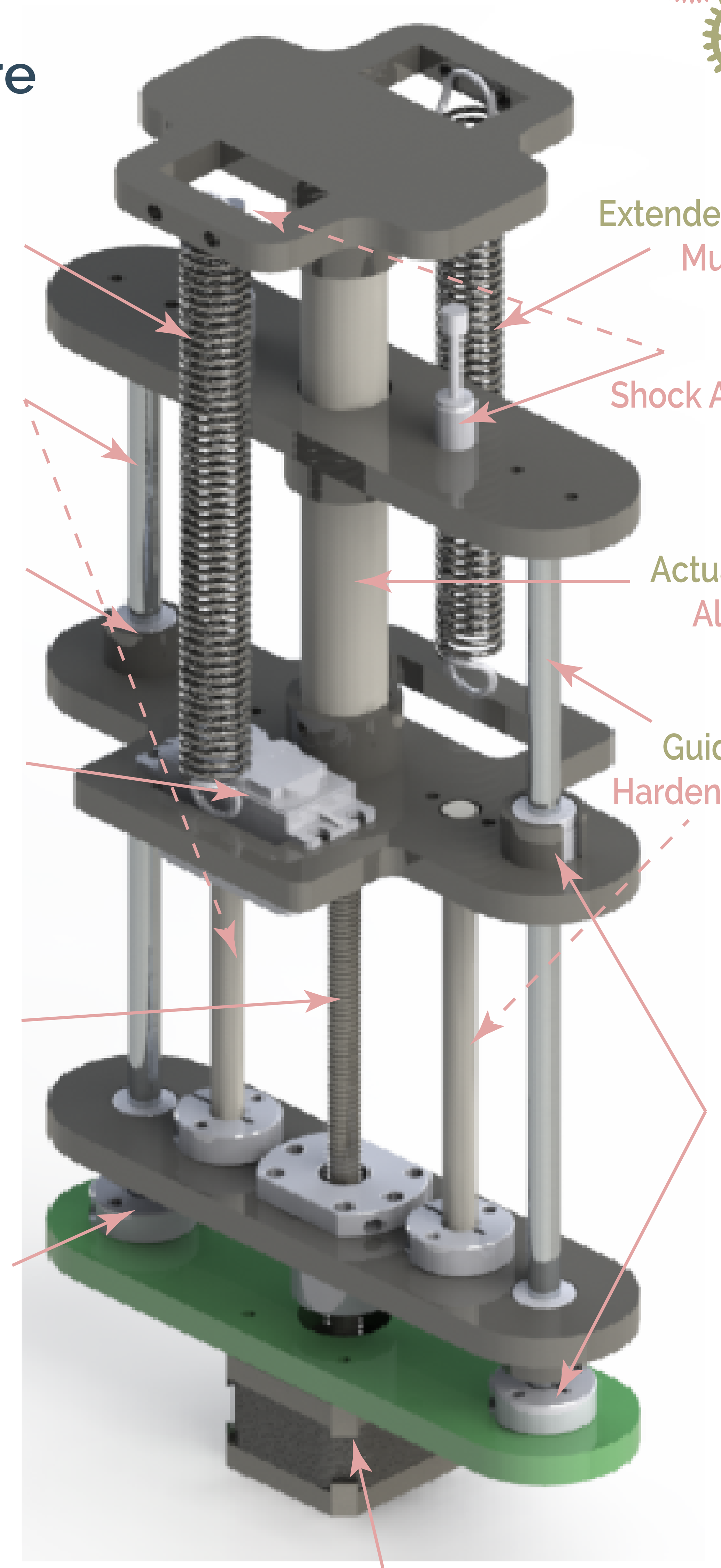
Scale Down

Constant Speed: 0.01/s
Max Force Output: 200N

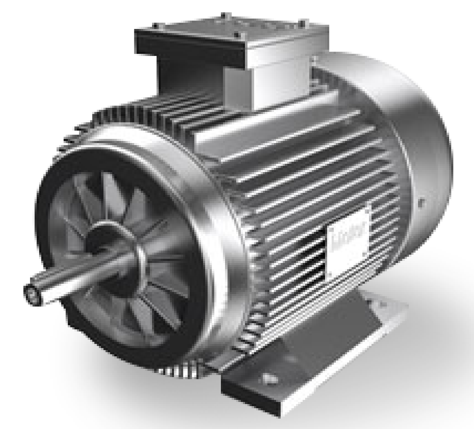
Platform Matrial

Current Material: Digital Acrylonitrite Butadiene Styrene (ABS)

Future → Titanium



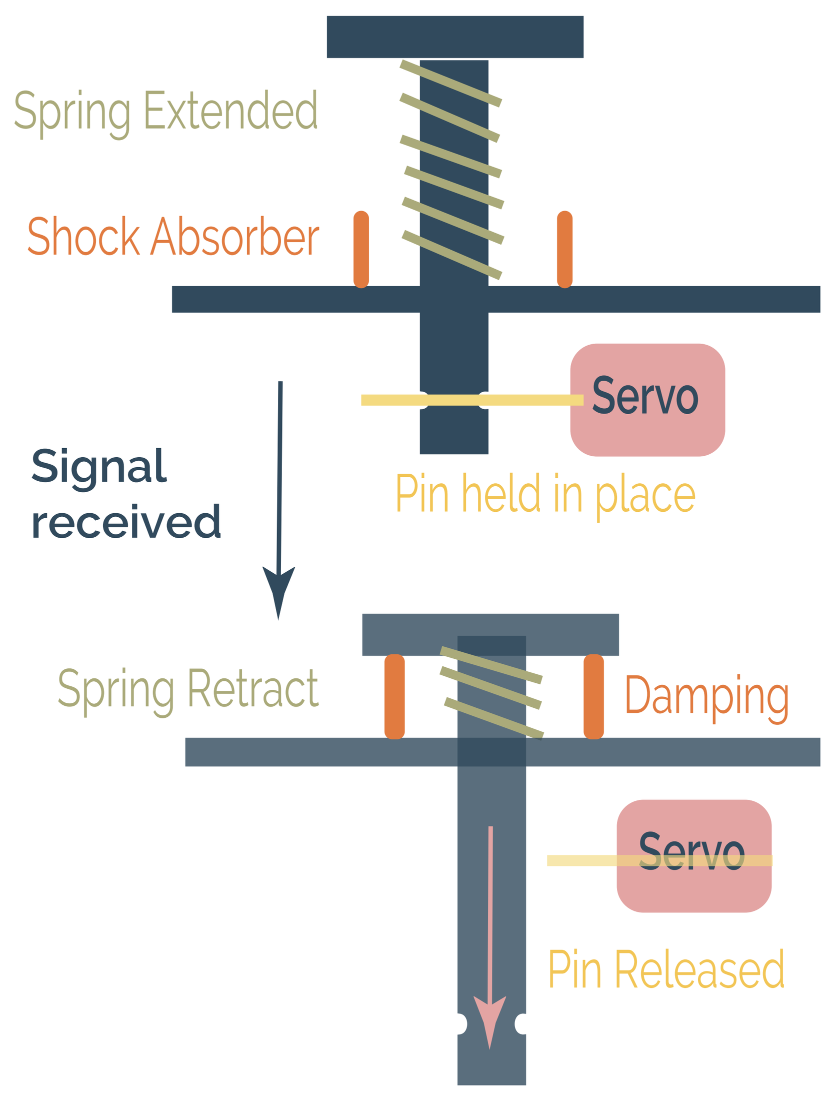
PMSM Motor
(Permanent Magnet Synchonous Motor)



PMSM has higher resolution than stepper motor, and it operates silently with high speed.

Release PIns Fail-Safe Mechanism

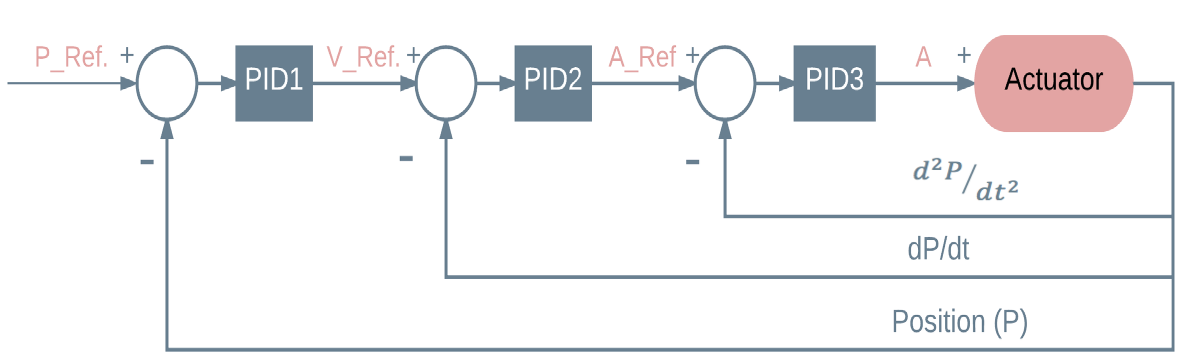
Once the failure signal is sent to the servo, it will release the pins, and the spring is retracting the actuator back to the safe position.



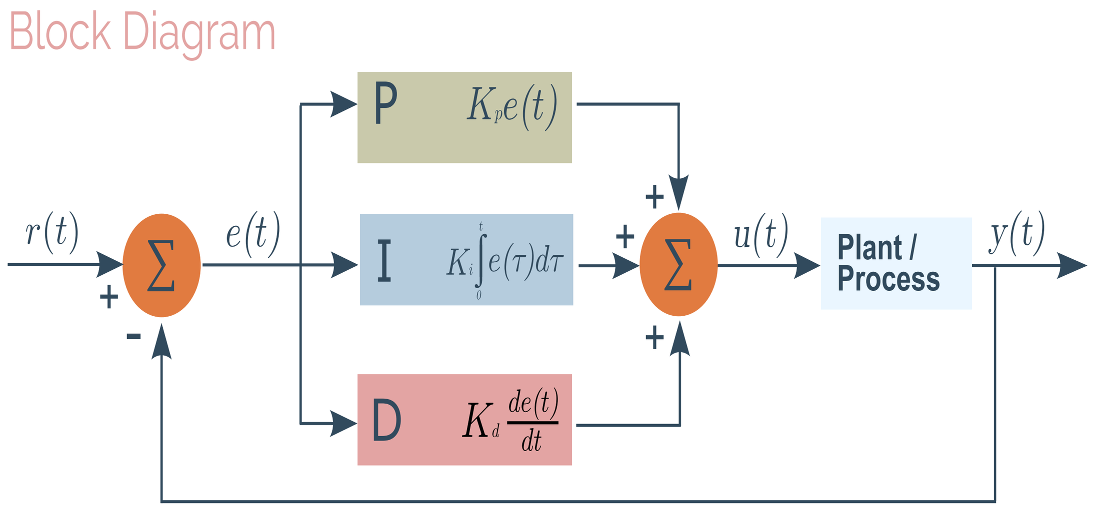
Motor Control

Proportional-Integral-Derivative (PID) Controller

PID Control Loop Feedback Mechanism



Block Diagram



Basic Formulas

$$u(t) = K_p e(t) + K_i \int_0^t e(\tau)d\tau + K_d \frac{de(t)}{dt} \quad ; \quad e(t) = Re(t) - Process\,Variable(t)$$

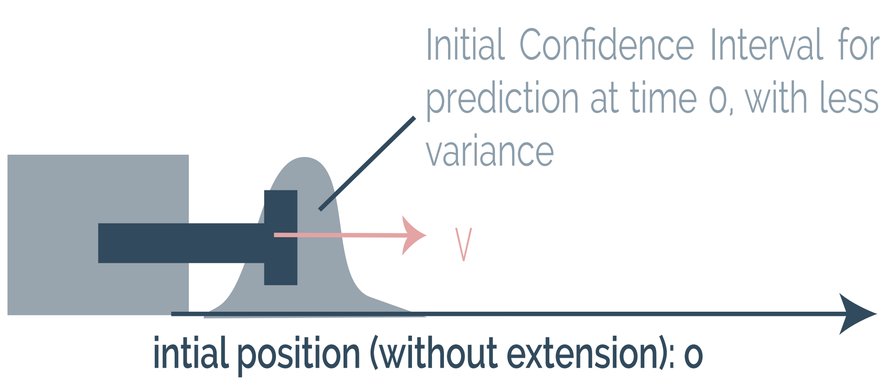
Process Variable Input with Kalman Filter Estimation

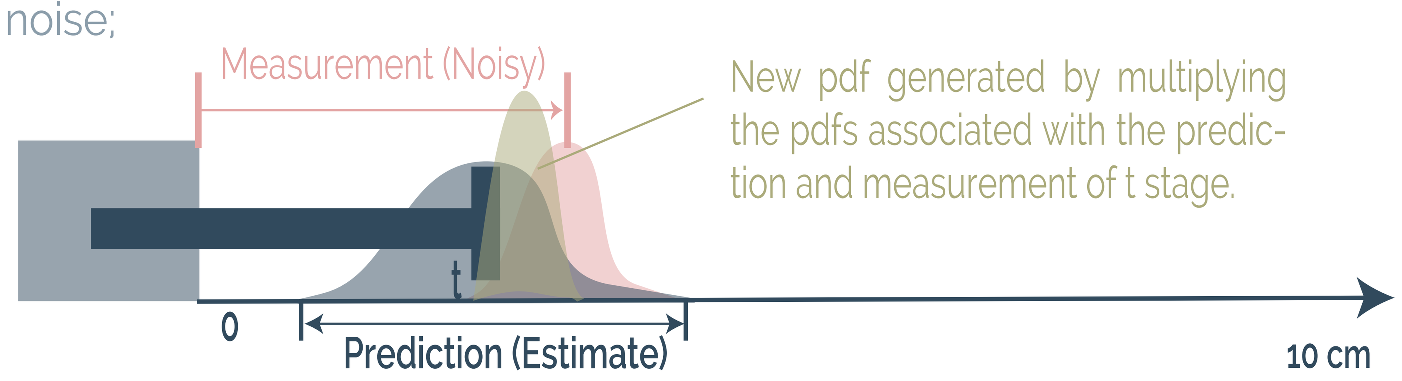
A better estimation on the position, acceleration & velocity input at each time instance of the actuator that is provided by combining our knowledge from both prediction and measurement.

Prediction: Update the stage t position, velocity and acceleration based on the previous stage(t-1) data.

Measurement: Real-time(t) readings from the sensor, which contains uncertain noisy.

Assumption: Zero mean multivariate normal distribution of measurement noise;





Experiment Test

Accuracy Test

Independent Variables: time instance (t), binary variable (ER) that denote retraction or extension, loaded weight (W), and position (P)

Dependent Variable: binary variable (A) that denotes Accuracy

Repeatability Test

Independent Variables: time instance (t), binary variable (ER) that denote retraction or extension, loaded weight (W), position (P), and Repeat Time (RT)

Dependent Variable: binary variable (R) that denotes Repeatability

Logit Regression Model

Logit Regression model predicts on the probability of one event happens (prob(Y=1)), where Y represents for either Accuracy or Repeatability

$$Log\left(\frac{prob(R=1)}{prob(R=0)}\right) = \beta_0 + \beta_1 t + \beta_2 ER + \beta_3 W + \beta_4 P + \beta_5 RT$$

$$Log\left(\frac{prob(R=1)}{prob(R=0)}\right) = \beta_0 + \beta_1 t + \beta_2 ER + \beta_3 W + \beta_4 P + \beta_5 RT$$

Fail-Safe Mechanism Test

To simulate failure mode, artificially declare component failure and send signal to fail-safe controller. → Failsafe controller activates servo to release pin and plunger retracts to neutral position.

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