Design Statement

*"Design an assistive device to aid elderly users and disabled users with handlebar control to stabilize a bicycle travelling on a **straight, flat path**."*

25% of single-sided accidents involving elderly cyclists occur due to a **loss of control on a straight path**

Why Handlebar Control?

- The elderly **rely more on handlebar maneuvers** than trunk sway to maintain their balance
- There is a **direct physical relationship between** the **roll angle** of a bicycle and **steering angle**
- Increasing speed would increase accident risk

Problem Space

Target Users:

- **Elderly Cyclists** who ride bicycles on trails or in neighbourhoods
- Cyclists with motor skill disabilities

For the elderly, cycling

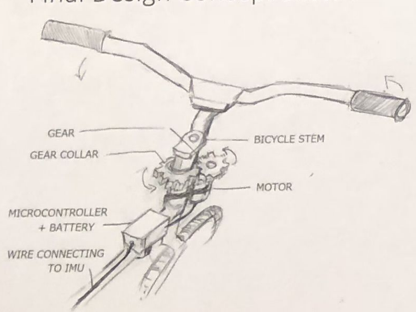
- Is an **Economic** and **Eco-friendly** form of **Mobility**
- Has various **Health Benefits**
- Is an enjoyable **Recreational Activity**

HOWEVER, elderly cyclists are:

3x more likely to **suffer fatal injuries** and are at higher risk of other injuries including:

- Fractures (Hip, Clavical etc…)
- Ulnar Neuropathy
- Carpal Tunnel Syndrome

Final Design Concept Sketch



Mathematical Modelling

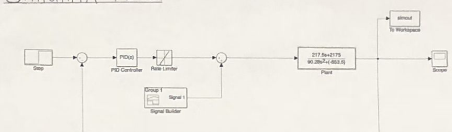
Non-linear General Equation

$$\left(I_1 + mh^2\right)\ddot{\theta} + \left(I_3 - I_2 - mh^2\right)\left(\frac{v_r \tan\delta}{b}\right)^2 \sin\theta\cos\theta - mgh\sin\theta = -mh\cos\theta\left(\frac{av_r}{b\cos^2\delta}\dot{\delta} + \frac{v_r^2}{b}\tan\delta\right)$$

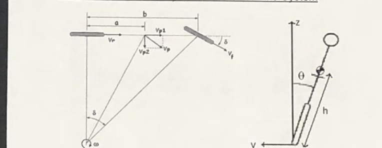
Linear General Equation

$$\left(I_1 + mh^2\right)\ddot{\theta} - mgh\theta = -\frac{mh}{-b}\left(av_r\dot{\delta} + v_r^2\delta\right).$$

Simulink Model



Ground Plane Geometry & Rear View of Bike System



Optimization

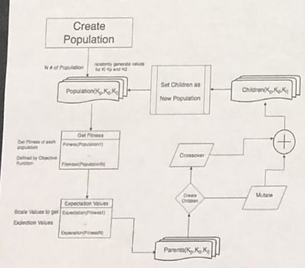
Objective Function

- Minimize Squared Error between Step input of 1 and response of our simulation

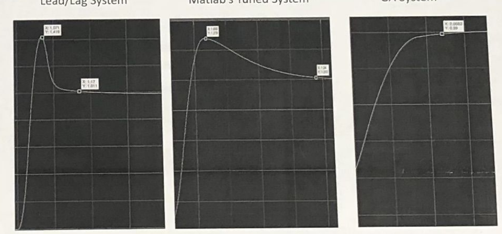
```
function [J] = pid_bike(x)

Kp = x(1);
Ki = x(2);
Kd = x(3);

% pushes variables to workspace
assignin('base','x_base',x);

a = sim('model_1','SimulationMode','normal');
b = a.get('simout');

dt = 0.01;
t = 0:dt:1;

error = 1 - b;

J = sum(t'.*abs(error)*dt);
```

- K_p, K_d, and K_i values from the population with the smallest J value is chosen for our PID Controller

Genetic Algorithm Optimization



Testing and Evaluation



$T_s = 0.17s$, OS% = 41.9% | $T_s = 0.24s$, OS% = 27.9% | $T_s = 0.0682s$, OS% = 0%

Varying Speed Test

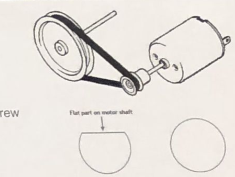
Speed (km/h)	1% Settling Time (s)	Overshoot %
13	0.1198	6.1
14	0.1132	5.1
15	0.1	3.1
16	0.0706	1.3
17	0.0602	0
18	0.0682	0
19	0.0758	0
20	0.0774	0
21	0.08	0
22	0.0824	0
23	0.0842	0
24	0.0866	0
25	0.0886	0

- Greater Overshoot at slower speeds
- Overshoot is negligible after 16 km/h
- Settling time change varying incrementally after 18 km/h
- 15 km/h to 25km/h satisfy Desired Specifications
  - settling time maximum 0.1 seconds
  - Overshoot maximum of 5%
- G.A. better than Lead/Lag system

Figure	Part Name	Model	Quantity	Manufacturer
	Motor	2028.940-12.111-025	1	Maxon
	DC Power supply	PA18-1.2A	1	Kenwood
	Accelerometer	AM3X	1	Sparkfun
	MicroController	Arduino Uno R3	1	Arduino
	Motor Controller	Adafruit Motor Shield v2.3	1	Adafruit

Figure	Part Name	Model	Quantity	Manufacturer
	EC Motor	EC 45 Ø45 mm, brushless, 150 Watt, with Hall sensors	1	Maxon
	Battery pack	Mini Portable DC-168 12V Rechargeable Li-ion Battery Pack	1	Generic
	Sensor	6DOF Sparkfun Razor IMU	1	Sparkfun
	MicroController	Arduino Uno R3	1	Arduino
	Frame gear	Cylindrical Spur Gear, Module 15, DIN 6, Z 20	1	DE Groups
	Motor gear	Wltoys A949	1	Wltoys
	Set screw	Wltoys A949-5	1	Wltoys
	Gearhead	Planetary Gearhead GP 42 C Ø42 mm	1	Maxon
	Motor Controller	Adafruit Motor Shield v2.3	1	Adafruit

Technical Challenges:



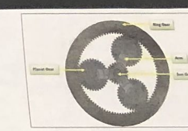
Prototype:

- Gear pulley system (string)
- Solid rods instead of string
- Custom motor shaft fitting and set screw
- Fixing rods with circular fixture

Final:

- Added rate limiter to limit rate at which angle can change in order to mimic realistic response
- Motor and Battery Decisions
- Make PCB board to plug in batteries
- Created casing for water proofing

Recommendations



1) Planetary gears
   - Mechanism for high torque output
2) Intentional turns vs tilts
   - Decrease error rate
3) Road conditions
   - Damping system