Real World Optimization of Energy Efficient Vehicle Control

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Content

What is the project about?

Creating Energy Efficient Vehicle Controller

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What ML technologies are being used?

ANNs evolved using NEAT

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Creating Energy Efficient Vehicle Controller

What ML technologies are being used?

ANNs evolved using NEAT

What is the project based on?

Paper showing ANNs can compete with state-of-the-art approaches ([Gaier and Asteroth, 2014])

Minimum

- Evolve Energy Efficient Controller with Simple Model

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- Evolve Energy Efficient Controller with Simple Model
- Evaluate in Reality

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- Compare Simulation vs Reality

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Expected

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Maximum

- Use Multi-Objective Approach (i.e. Surrogate Modelling)

Content

Simple Vehicle Model

Time Based Model

$$\frac{ds}{dt} = \begin{pmatrix} t' \\ x' \\ v' \\ W' \end{pmatrix} = \begin{pmatrix} 1 \\ v \\ \frac{F(x,v)}{m} \\ F_u * v \end{pmatrix}$$

Where

- F_U: Force at wheel due to control command
- $F(x, v)$: F_U - some drag
- Motor Power assumed: 250 Watts

Content

Parameters

- Population size: 60
- Maximum Generations: 40
- Speciation algorithm: k-means
- Number of Species: 3
- Drop-off rate: 25
- Dataset of 30/5 tracks (Training/Test)

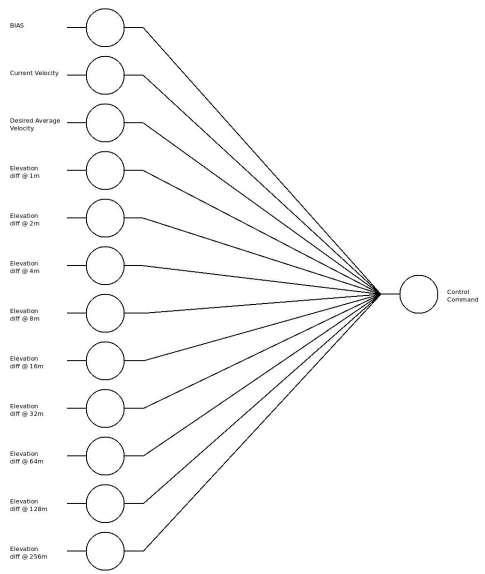

Figure : Initial Network Topology

On Set of Tracks

- Weighted Sum of Single Track Fitnesses

On Single Track

- Fitness: Saved Energy - Time Penalty
- Saved Energy: Maximum Energy Consumption - Actual Energy Consumption
- Time Penalty:

$$\begin{cases} 0 & \text{if } neededTime \leq desiredTime \\ (neededTime - desiredTime)^2 & \text{else} \end{cases}$$

- desiredTime: time needed at average speed of 5.5m/s

Results

- Total runs (so far): 218
- Average Best Fitness: 7.4569e+04
- Best Fitness: 10.3410e+04

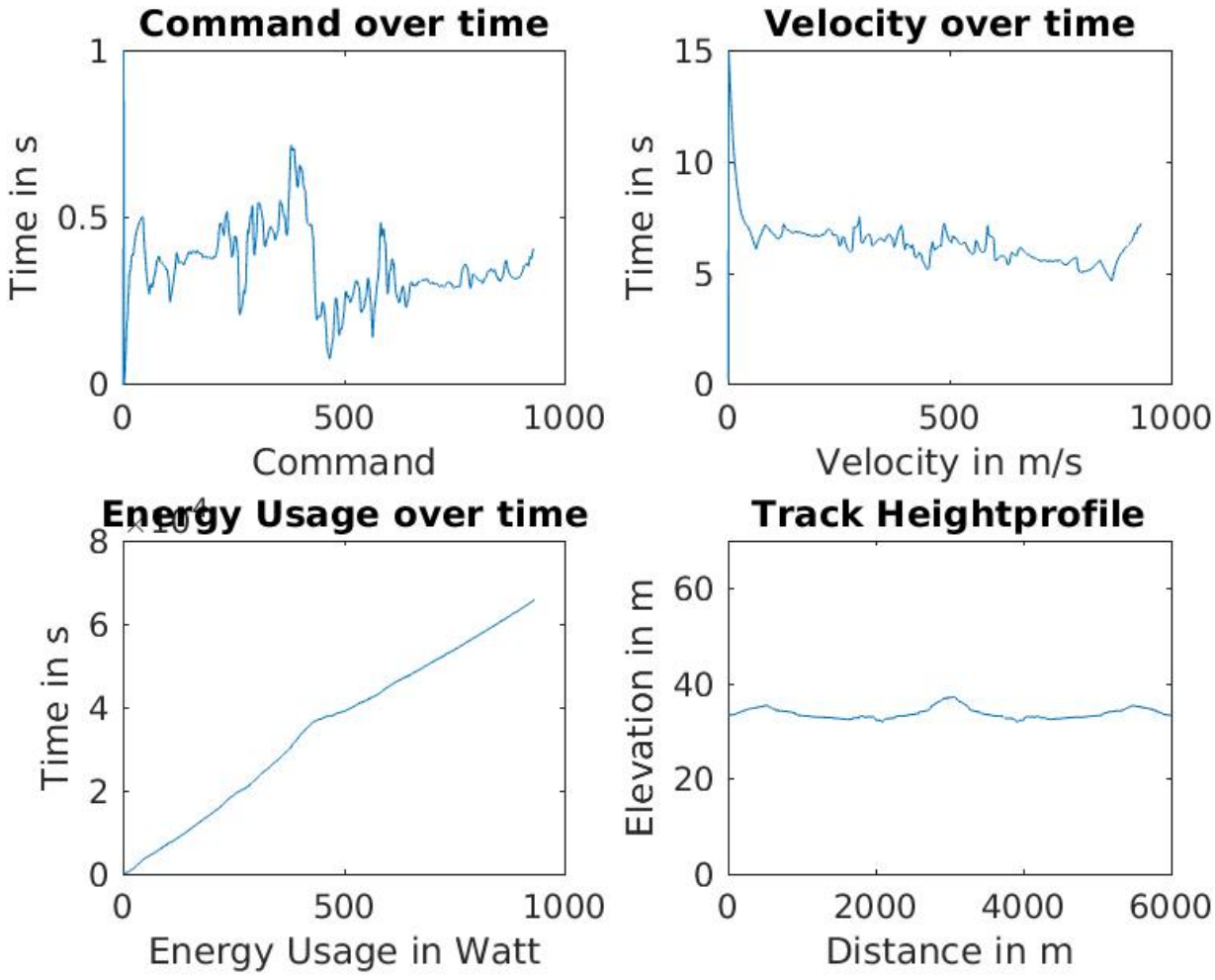

Figure : Simulation of Evolved Controller

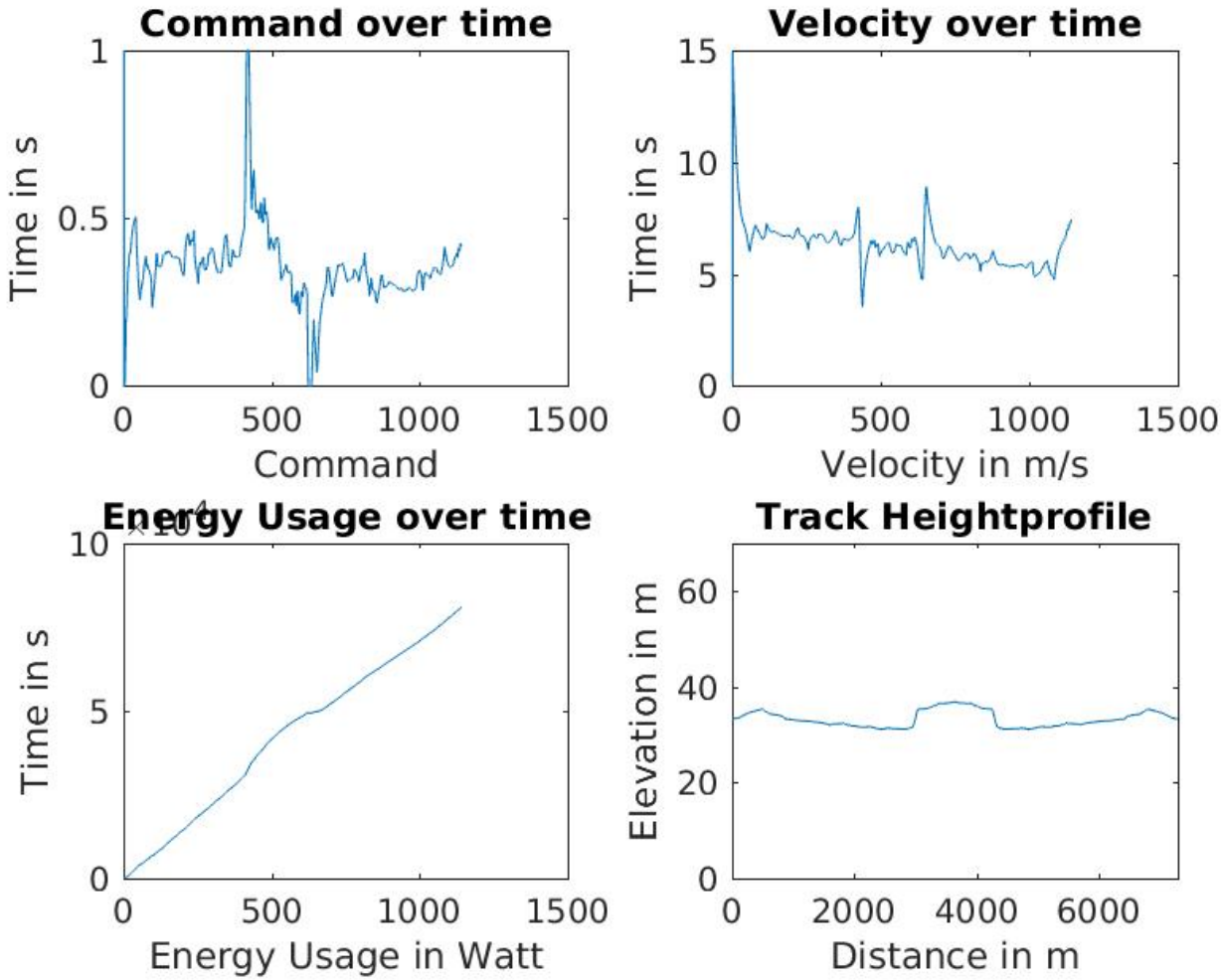

Figure : Simulation of Evolved Controller

Content

Hardware

- Velomobile
- Electric Motor (Vivax-Assist)
- Speed Controller (MasterSPIN 75 Pro OPTO)
- Brake Sensor
- Hall Sensor
- Power Sensor
- Simple Button

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Software

- Run motor on constant speed
- Read brake sensor
- Read hall sensor
- Shuts off above 25km/h
- Shuts off on brake activation
- Shuts off on button press

Problems

- Communication with hall sensor not working
- Needed for velocity data
- Python-code to read sensor
- C-code to control motor

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- Write/Read output stream $\rightarrow$ Python script needs to call C script and resets state

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Solution

- Write/read file in python/C $\rightarrow$ Synchronization
- Write/Read output stream $\rightarrow$ Python script needs to call C script and resets state
- Use socket communication

Problems

- No mechanism to adjust speed
- Needed for collecting data

Problems

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Solution

- Increase speed on button click

Problems

- No mechanism to adjust speed
- Needed for collecting data

Solution

- Increase speed on button click
- Shut motor off on brake activation

Problems

- No reaction to signal
- No signal measured
- Vehicle does not move

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Solution

- (Hardware-)Debug with working initial code

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- Only send signal on change

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- No reaction to signal
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Solution

- (Hardware-)Debug with working initial code
- Only send signal on change
- Range [7,19] instead of [0,100]

Problems

- Setting motor to 0 takes 5 seconds
- Motor waits for timeout
- Safety

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Solution

- Set signal to small value first

Problems

- Setting motor to 0 takes 5 seconds
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Solution

- Set signal to small value first
- Use hardware emergency off switch

Problems

- Obviously wrong data gets logged
- No synchronization during data access

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Solution

- Synchronize using mutexes $\rightarrow$ Still huge values

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- Remove all possible multi-threading → Hall Sensor

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Open Approaches

- Use C-code with wiringPi synchronization mechanism

Content

Open Tasks

- Fix Logging
- Evaluate Solutions Simple Model
- Collect Data
- Learn Model
- NEAT on DD Model
- Evaluate Solutions DD Model

Sources I

Gaier, A. and Asteroth, A. (2014).
Evolving look ahead controllers for energy optimal driving and path planning.
In *Innovations in Intelligent Systems and Applications (INISTA) Proceedings, 2014 IEEE International Symposium on*, pages 138–145. IEEE.