Robotics
Written Exercises 1: Introduction and Actuation
CS 603, Spring 2020

Name: Kunjal Panchal
Student ID: 32126469
Email: kpanchal@umass.edu

February 1, 2020

Contents

1 Chapter 1: Introduction

1.1 Problem 1: Transfer

1.1.1 Tacit Knowledge

How is it passed?
For an agent (animal), tacit knowledge is selected by objective measures of fitness in the course of genetic variation and natural selection

It is complied into neuroanatomical structures including peripheral sensors, body size and mass distribution, and programs for growth and maturation.

Animals are born with this considerable knowledge built in. It is encoded in the agent's physical and pre-cognitive configuration.

Examples:

- Structures like hard head, strong muscles, good eyes are built in by the genetic code.
- Functions like being able to duck without thinking.
- Special behavioral adaptation like actions animals take to survive in their environments: hibernation and migration.
- Instincts like monogamous mating in animal courtships.

1.1.2 Implicit Knowledge

How is it passed?
Agents acquire it as they explore direct interactions with the environment.

This knowledge encodes the policies for transforming sensor feedback into control inputs with respect to an objective function.

It cannot be completely engineered by a third party agent, nor can it be created in a manner that is completely independent of how it must be used.

It detects patterns of co-occurring simulation that actually occur during interaction now with the real world and so it obviates the problem of circular semantics.

Implicit knowledge represents sensory and motor interaction that unfold in reliable sequences and, thus, reflect both the agent and the environment.

Examples:

- Riding a bike
- Playing an instrument
- Remembering grass by the keyword “green” and apple by the keyword “red”

1.1.3 Explicit Knowledge

How is it passed?
Agent acquires it in a codified manner which is compact, symbolic and easily articulated; from other agent. Two agents communicate and transfer new tasks.

The agent presumes a “common ground” between themselves and the agent who is the consumer of information.

Linguistics tokens encapsulate the concepts that require the consumer agent to provide proprietary associations according to their individual experience.

Agents doesn’t need to learn this knowledge by involving bodily functions implicitly.

Examples:

- Represented in encyclopedias, dictionaries, and user manuals
- Documents, procedures, and how-to videos
- Company data sheets, white papers, research reports
- Books, stories, myths, notes on a subject, recipes

1.2 Problem 2: Knowledge

(a) "apples are red" - Explicit
We can see an apple's color, we can see that an apple is red. Without anyone having to tell us the color of the apple. We can memorize it by making an association between the color and the fruit. But in this question, a statement is given. Someone is explicitly stating it. Someone is explicitly conveying the information. The color red is called *red* is explicit knowledge, but apples have *that color* can be acquired through implicit senses or explicit statements like the above one. We do not need to re-learn that knowledge every time we think about an apple.

(b) an expert golf swing - Implicit
With time and practice, one can hard-wire the precise movements applied to make an expert golf swing, into one's body. It comes as a natural reflex after this training, given enough practice. We do not have to think about a procedure or algorithm needed to make a perfect golf swing, every time we make a swing. Nor can anyone tell us the procedure and we can be an expert just by knowing the procedure.

(c) the distance between your eyes - Tacit
This is something we are born with. It is in our genes and the facial features, like any other physical features are hereditary.

(d) your hair/skin color - Tacit
Just like the previous answer, hair and skin color are something we are born with. It is encoded in the agent's physical and pre-cognitive configuration.

(e) the difference between keys and loose change in your pocket - Explicit
Other agents can talk about visual and auditory features of key and loose change to differentiate between them. Just by this knowledge, we can guess which thing is which just by looking or touching at it, even without any prior experience. Just the descriptive knowledge about these objects are enough to know what they do and how they will look. This is how we learn about most of the objects as we grow. We are not born with this knowledge, neither it comes to us intuitively.

(f) shivering/perspiring - Tacit
Heat sensitive receptors are present in the skin, viscera, and spinal cord where they receive information from the outside environment,

and send it to the thermoregulatory center in the hypothalamus.

Shivering is a bodily function in response to cold in humans and other warm-blooded animals. When the core body temperature drops, the shivering reflex is triggered to maintain homeostasis. Skeletal muscles begin to shake in small movements, creating warmth by expending energy.

This both reflexes are hereditary and are a common feature of the species and often of the genus.

(g) the ratio of the circumference of a circle to its diameter - Explicit
This kind of mathematical knowledge comes from learning through books, and other people. This is not something we are born with or we can know without any explicit context. We are taught mathematics, and we gain and retain knowledge from external sources.

(h) laughing when tickled - Tacit
Not all people have same response intensity for being tickled, but it can still cause a laughter reflex. An area of the brain related to involuntary responses (the hypothalamus) is active when tickling generated laughter. This suggests that the tickle response is involuntary and tacit.

2 Chapter 2: Actuation

2.1 Problem 2: DC Motor Physics

2.1.1 (a) What electromagnetic phenomenon is responsible for the transforming electrical energy to mechanical energy in the permanent magnet DC motor?

The equation

$$\mathbf{F} = q\mathbf{v} \times \mathbf{B}$$

says that the "mechanical" force exerted on a charged particle q moving with velocity $\mathbf{v}$ through a magnetic field $\mathbf{B}$. The entire electromagnetic force $\mathbf{F}$ on the charged particle is called the **Lorentz force**. See Figure 1

This whole phenomena works on **electromagnetic induction**, which

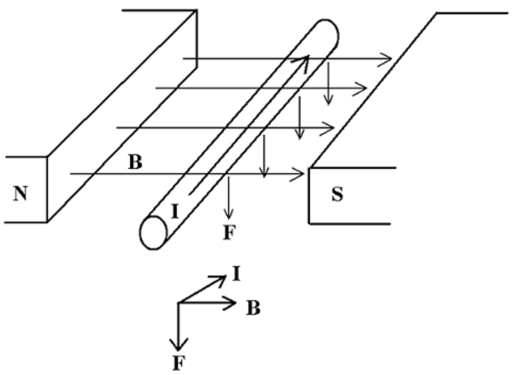

Figure 1: A charge q moving along a conductor at velocity $\mathbf{v}$ through a magnetic field, $\mathbf{B}$, from north to south magnetic poles

is when a voltage is induced by a changing magnetic field.

When a current loop is fashioned out of the conductor and it is positioned in the magnetic field parallel to the field lines, the result is an upward force on the right side of the loop and a downward force on the left. Therefore, a torque is developed, causing an angular acceleration. To keep it continuous, the current in the loop must be shut off as the coil approaches 90° and reversed after it passes this point, this is called commutation.

Therefore, a **change in the current through an inductor** corresponds to a changing magnetic field and, thus, creates an induced voltage. Back emf is generated by the motor velocity. And that's how torque is generated. The mechanical power will be in proportion to electrical power and resistive loses.

2.1.2 (b) What physical phenomenon accounts for the backward electromotive force (back emf)? How does it contribute to the behavior of the DC motor?

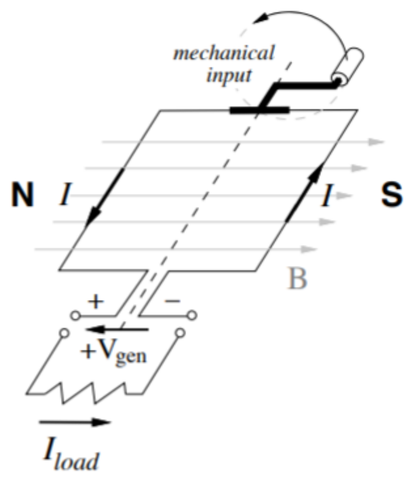

Figure 2: Lorentz force generating electrical current in response to a mechanical input energy [2]

As shown in Figure 2, a hand crank rotates the generator in the same direction that the motor would have turned, if there was no crank at the one end.

Here, the current induced by the generator is in the opposite direction of the current supplied by the battery in the DC motor. Both effects are present simultaneously in the commutated DC motor.

The rotating motor produces a **backward electromotive force** - a kind of barrier potential that throttles the net current in the rotor as a function of the rotational velocity.

As the rotor speed increases the sum of the supply voltage and the back emf approaches zero. At the point, no current flows in the rotor and, therefore, no additional torque is produced in the motor.

If the motor velocity increases further, then the back emf will decelerate the rotor until it once again balances the supply voltage and the back emf.

The steady state velocity of the motor is determined by the applied voltage - determined by the velocity at which the back emf equals the supply voltage.

Therefore, the back emf in a DC motor **regulates the flow of armature current** i.e., it automatically changes the armature current to meet the load requirement.

2.1.3 (c) What role does commutation play in a DC motor?

The voltage generated in the armature, placed in a rotating magnetic field, of a DC generator as shown in Figure 3 is alternating in nature. The **commutation in DC motor** is the process in which alternating cur-

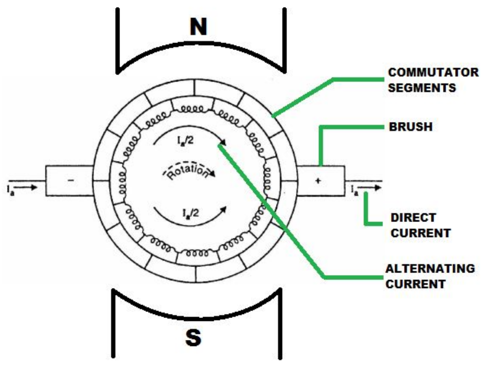

Figure 3: Commutation in DC motor

rent in the armature winding of a DC machine is converted into direct current after going through the commutator and the stationary brushes.

This transformation of current from the rotating armature of a DC machine to the stationary brushes needs to maintain continuously moving contact between the commutator segments and the brushes. When the armature starts to rotate, then the coils situated under one pole (let it be N pole) rotates between a positive brush and its consecutive negative brush and the current flows through this coil is in a direction inward to the commutator segments.

2.1.4 (d) What is cogging?

Modern motors package many commutated current loops into a functioning DC motor. Here, the rotor is a piece of iron with radial fingers that serve to columnate the magnetic field and provide a channel for several motor windings. See Figure 4.

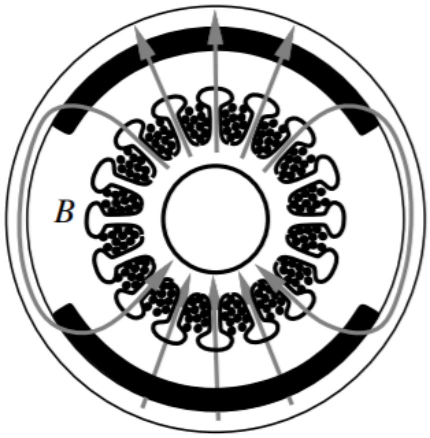

Figure 4: Iron core DC motor

However, the massive iron core rotor compromises motor performance. It can lead to a measurable ripple in the magnetic field strength as the motor rotates.

This is **cogging**. It can be observed as a preference for rotor positions that maximizes the amount of iron between the poles of the permanent magnet.

Thus, cogging torque of electrical motors is the torque due to the interaction between the permanent magnets of the rotor and the stator slots of a Permanent Magnet machine

2.2 Problem 6: DC Motor/Gearhead

2.2.1 (a) What is the steady-state angular velocity of the load for $10[V]$ in?

At steady state, input voltage V_{in} is same as back emf V_b generated. Hence,

$$\begin{aligned} V_{in} &= V_b = K_b \dot{\theta}_M \\ \therefore \dot{\theta}_M &= \frac{V_{in}}{K_b} \\ &= \frac{10}{0.02} = 500 \end{aligned}$$

$$\begin{aligned} \dot{\theta}_L &= \eta \dot{\theta}_M \\ &= 0.01 \cdot 500 \end{aligned}$$

$$\boxed{\therefore \dot{\theta}_L = 5 \ [rad/sec]}$$

2.2.2 (b) When the rotor is locked (i.e., $\dot{\theta} = 0$) and $10V$ is applied, how much torque is generated on the load?

$$\begin{aligned} \tau_M &= K_t I \\ \tau_M &= K_t \frac{V}{R} \\ &= 0.02 \cdot \frac{10}{10} \\ \tau_M &= 0.02 \end{aligned}$$

$$\begin{aligned} \tau_L &= \frac{1}{\eta} \tau_M \\ &= \frac{0.02}{0.01} \\ &= 2 \end{aligned}$$

$$\boxed{\therefore \tau_L = 2 \ [Nm]}$$

2.2.3 (c) If $J_M = 0.005[kg \cdot m^2]$ and $J_L = 1.0[kg \cdot m^2]$, which is most significant in the output inertia?

Net inertia is defined as:

$$J_{net} = J_M + \eta^2 J_L$$

Here, $\eta = 0.01$ and thus, the J_L part will become

$$\eta^2 J_L = (0.01)^2 \cdot 1 = 0.0001[kg \cdot m^2]$$

while J_M part stays at $0.005[kg \cdot m^2]$.

We can see that J_M has more significance in the output inertia.

2.3 Problem 7: Torque-Speed Curves

See Figures 5, 6, 7, and 8.

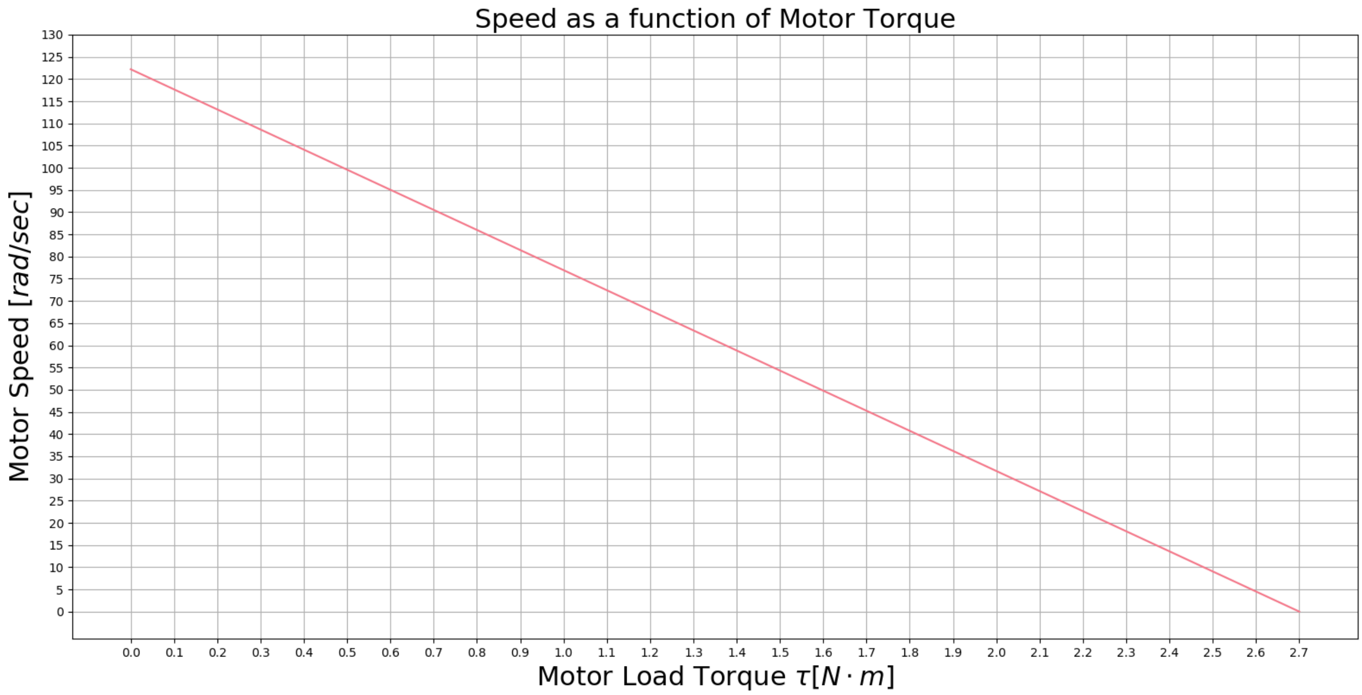

Figure 5: Speed curve for the eye motor in Roger

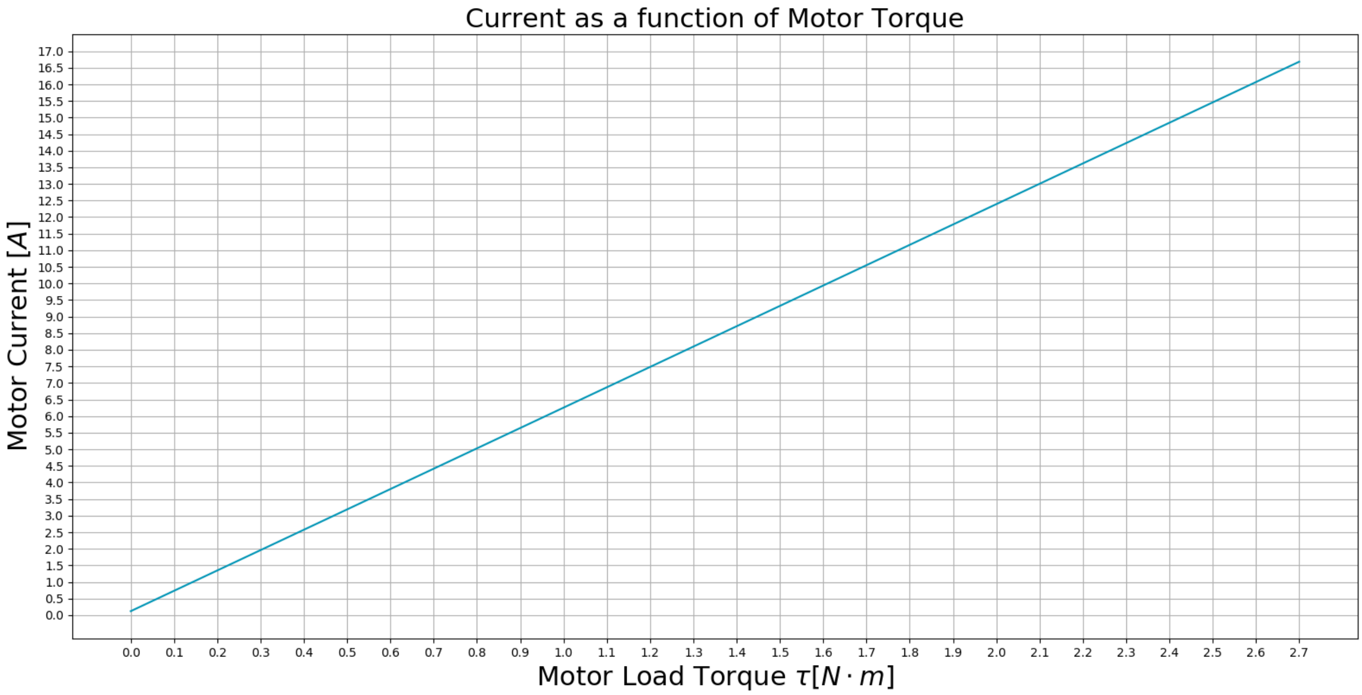

Figure 6: Current curve for the eye motor in Roger

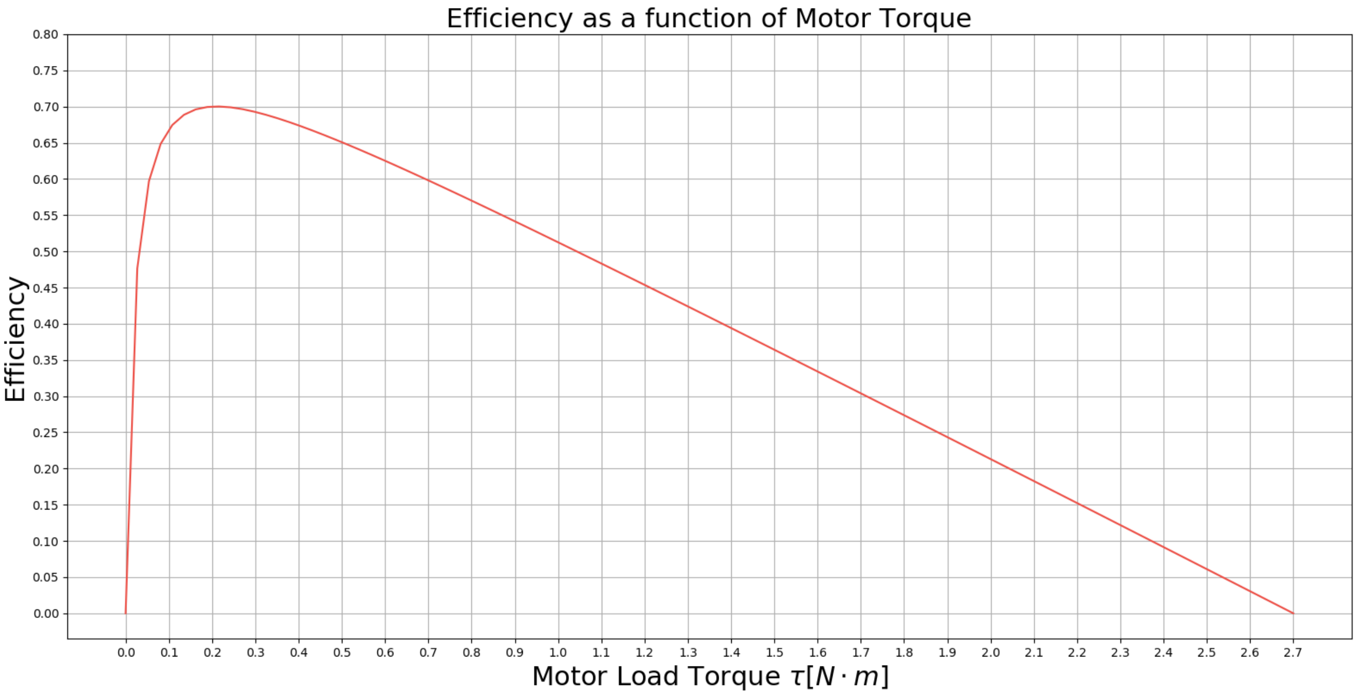

Figure 7: Efficiency curve for the eye motor in Roger

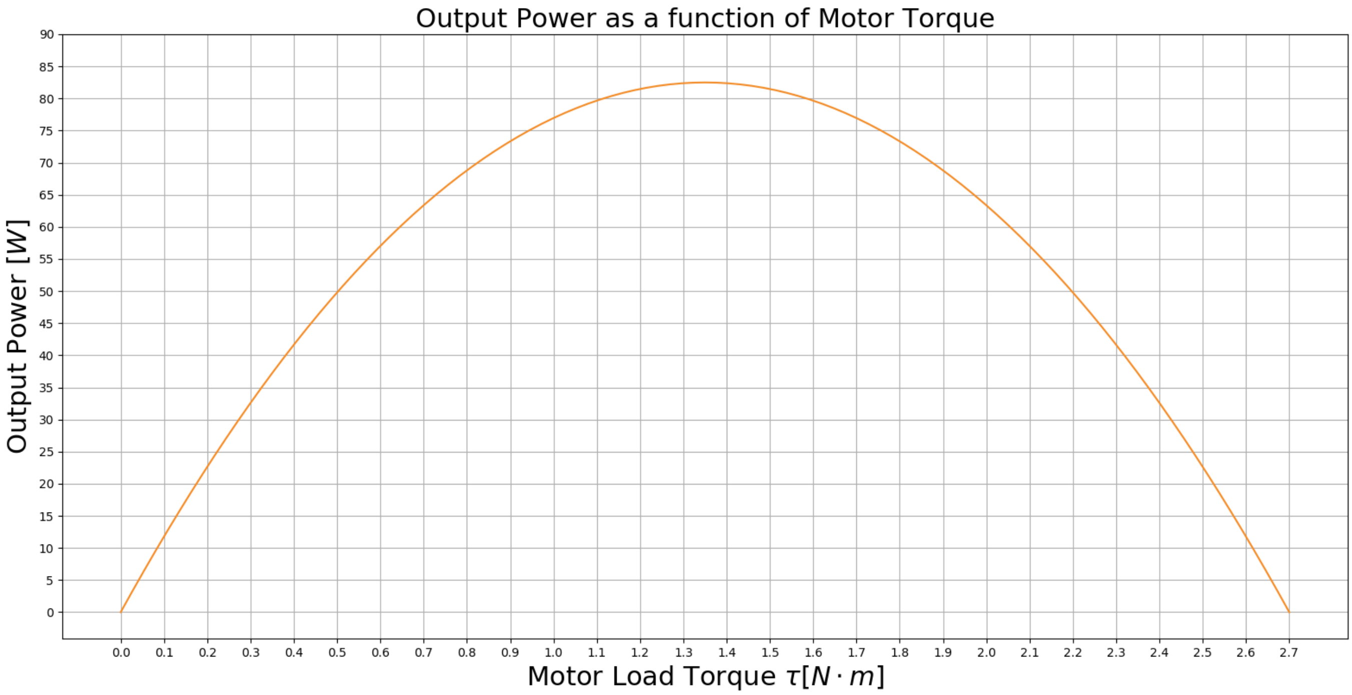

Figure 8: Power curve for the eye motor in Roger

References

[1] Rod Grupen, *Introduction* http://www-robotics.cs.umass.edu/~grupen/book2020/1-Introduction.pdf

[2] Rod Grupen, *Actuation* http://www-robotics.cs.umass.edu/~grupen/book2020/2-Actuation.pdf