# TAS Project: Hardware

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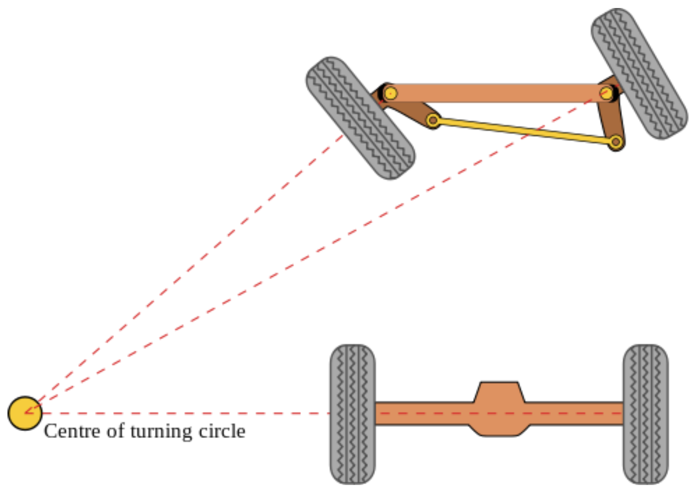
# What if …

- … we saw a perfectly beautiful Remote Control (RC) and decided to give it a mind if it’s own!
- 40 cms x 60 cms
- 50 km/h
- 4 Wheel Drive


- How would you do that?, and what would you need?

# How do we do that? What do we need?

- We need to sense the outside world
  - Layout of the world around us
  - Obstacles
  - Goals
  - Images
- A high level planner to reason about achieving goals
- We need an interface to the motor… any idea how?
  - Cars follow Ackermann steering where wheels on the inside and outside of a turn needing to trace out circles of different radius
  - So we have 3 controllable degrees of freedom, but only two motors! This is known as nonholonomic.
  - This means we cant rotate on the spot ☹
  - Nor can we turn the car in any direction!



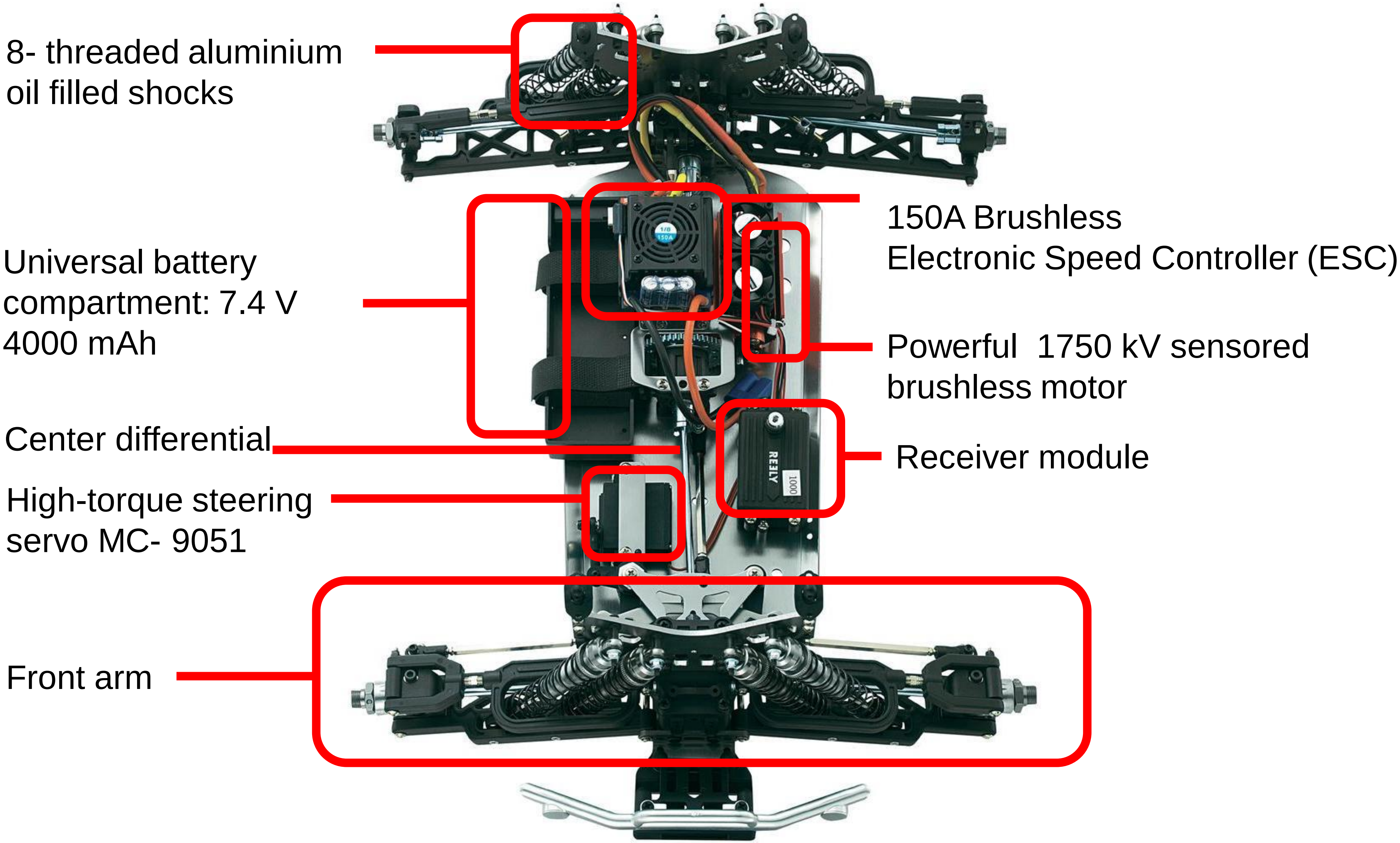
# What is an RC car?

- Big brands: TRAXXAS, Exceed, HPI, Tamiya, … etc.
- Different car types:

| Racing | Drift | Buggy | Monster Trucks |
|---|---|---|---|
|  |  |  |  |

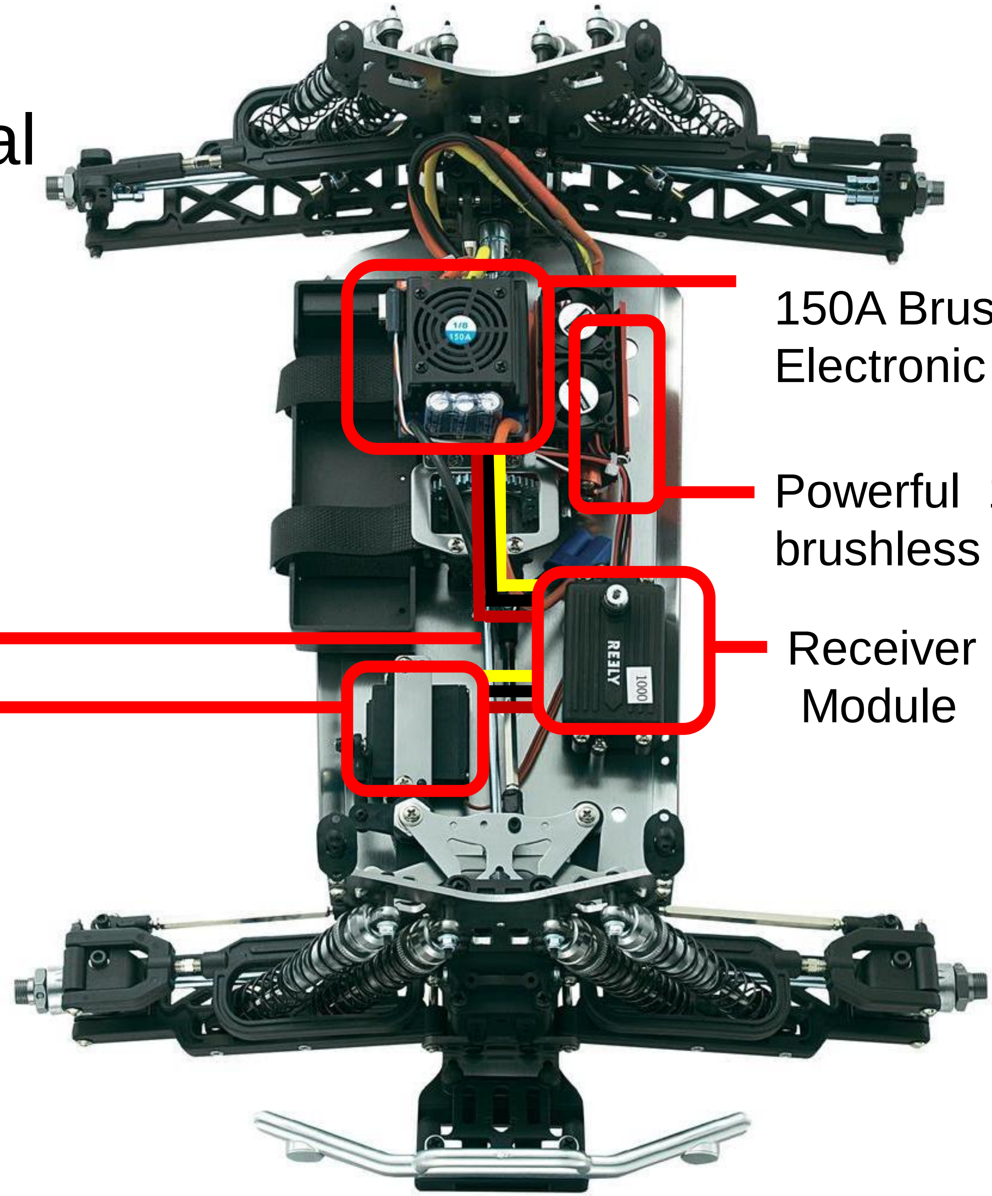
- They can be powered electrically or from Nitro


# Let us look under the hood of an electric car



# Let us look at what really matters to control this car

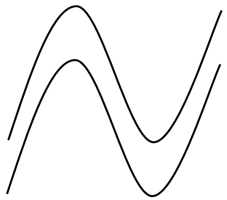
— PWM Signal
— Ground
— Power



150A Brushless
Electronic Speed Controller

Powerful 1750 kV sensored
brushless motor

Receiver
Module

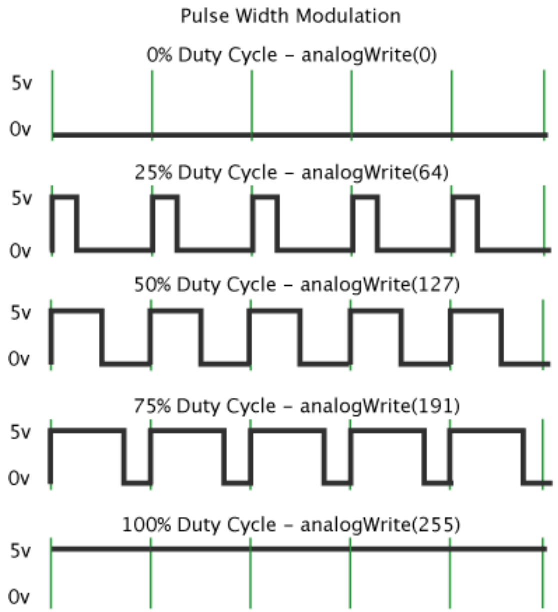


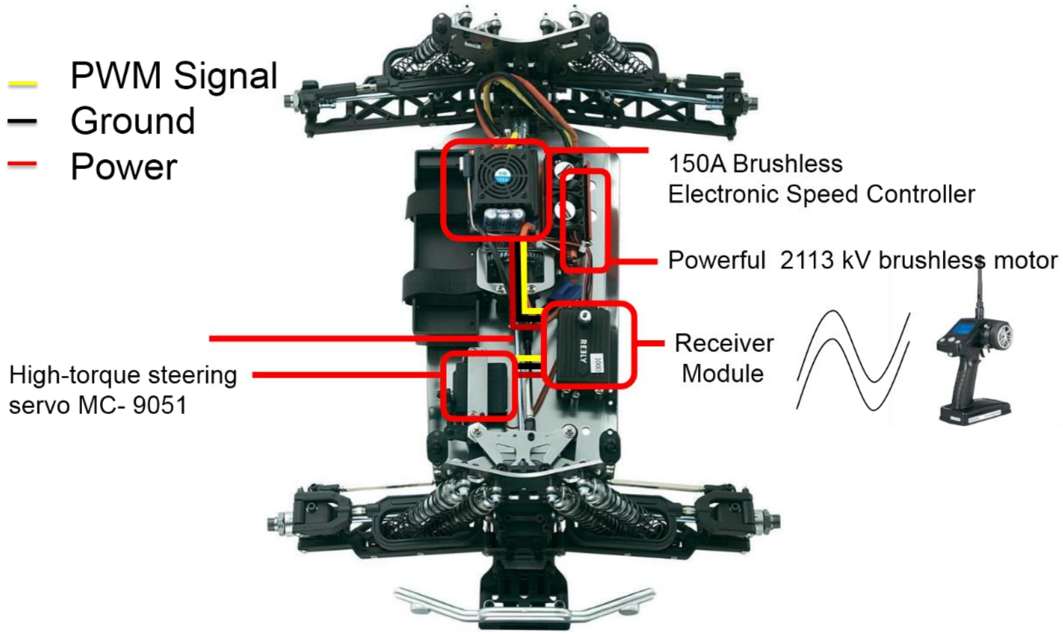
High-torque steering
servo MC- 9051

**How would you control the car now?**

# That might work! We know what PWM is

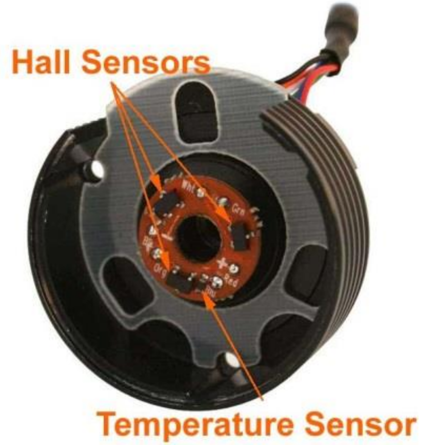
- Pulse width modulation signals use square waves to get analog signals with digital means.
- We can vary the voltage between 0-5V by switching a signal on and off. The duration of time on (pulse width ) as a portion of the whole cycle gives a steady voltage between 0-5!
- To change the voltage we “modulate” the pulse width.



# The Sensored Brushless Motor and ESC

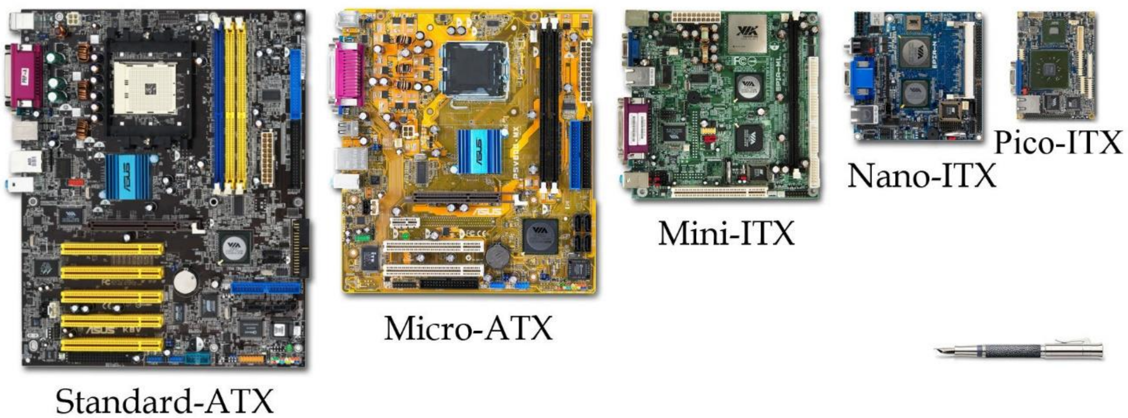
- Sensored means there is a connection between the motor and the speed controller.
- There exists three Hall effect sensors at the end of the motor that tell the speed controller the exact position of the rotor.
- Sensorless motors >> likely position of the rotor based on feedback called back- Electromotive Force. Back-EMF is the resistance or voltage pushing back against the current flowing to the motor.  These motor Work! Why Sensored?
- When the ESC knows specific rotor position, it can better control the throttle feel. Smooth controllable throttle feel and no hesitation at low speeds (cogging).
- If they are so great why not all motors sensored?
  - Power stop if no sensor detected,
  - Sensor loom can break or become loose , cost




# This seems simple enough, what do we use to generate PWM

- Well … before that, we have to think about the brain or processing unit for this car, can you think of a best way?
- What would you choose … why?
  - A laptop?
  - A raspberry pi?

  - A Motherboard with full PC capabilities?



# A mini-ITX is a good option

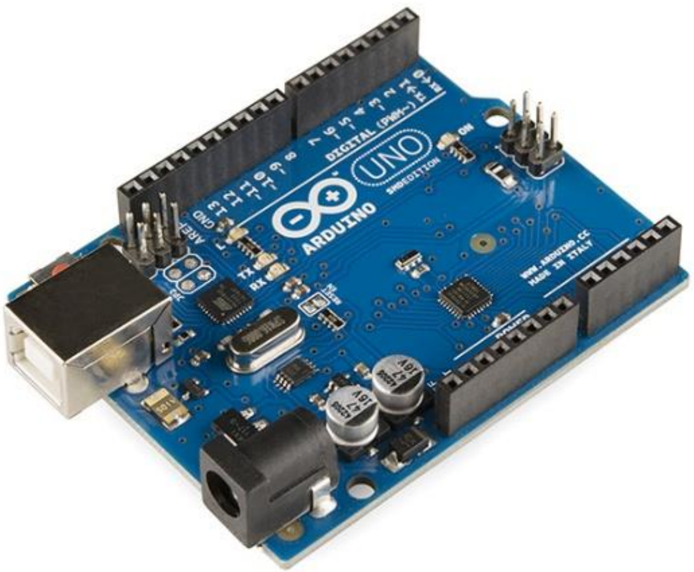
- Size: 17cm*17cm
- Weight: Less than 500gms
- Processor: i7 3GHz mobile processor
- RAM: 16GB DDR3
- 128GB Flash memory
- Lots of USB ports
- Works using 12V
- Can download a proper OS (Ubuntu) and a proper communication platform (ROS)
- Lots of processing power!

Mini-ITX

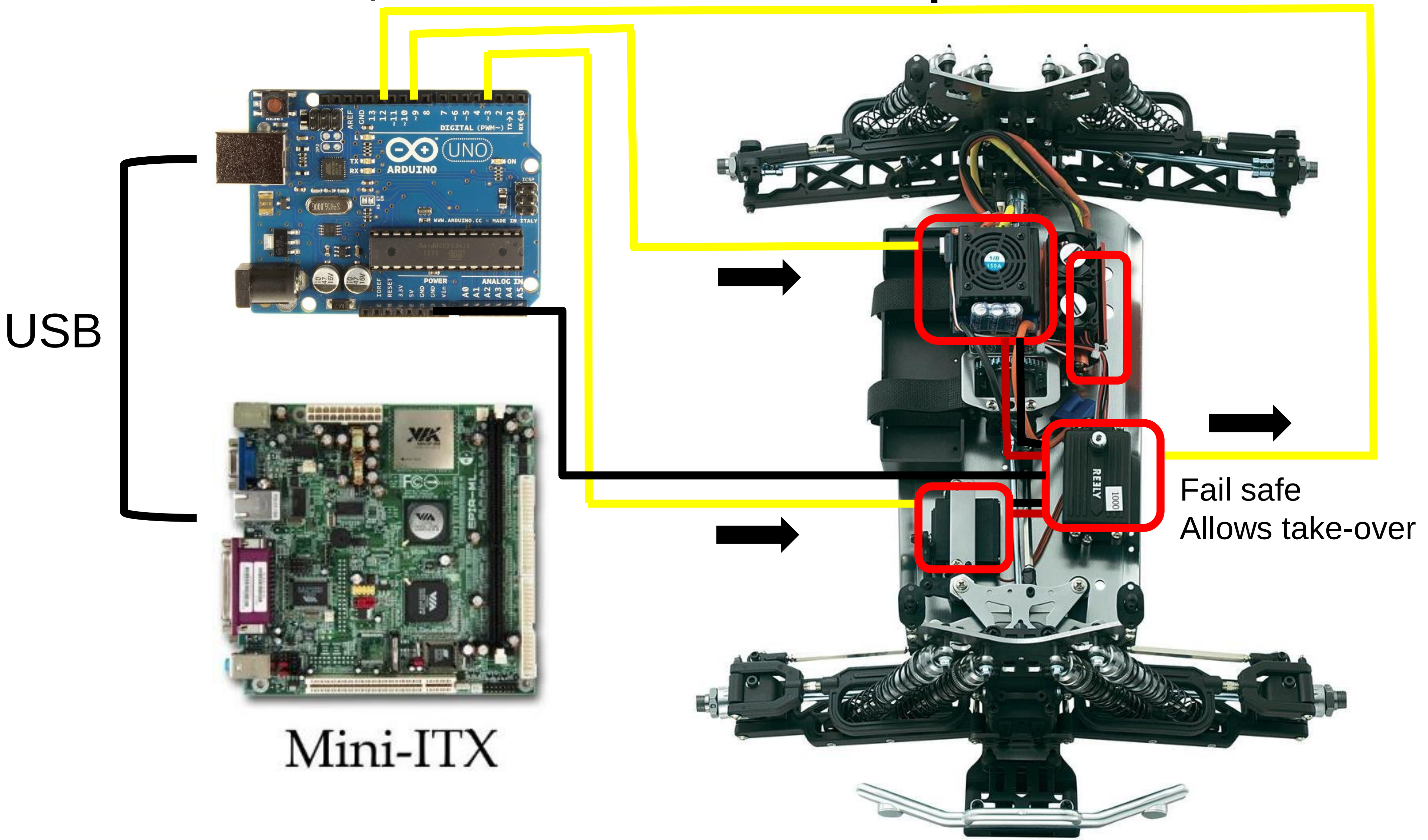
- **Still doesn't solve the problem of interfacing with the motors! …**

# .. for that we need a microcontroller

- A nice option we can use is the Arduino microcontrollers
  - Why? We can set it up as a ROS node and allow it to subscribe to high level controllers! More on that later in next lecture about the software
- This is the arduino UNO, it can produce 6 pwm signals.
- If we hook this up instead of the receiver all our problems would be solved!
- Can you think of a problem this setup might present? How would you solve that?



# OK, let us see what the set up is so far



# We know how to send PWM, but what decides the speed/steering?

- What makes the “brain” decided on the signals?
- Sensors! Can you name a few?
  - Laser scanner
  - Color + depth (Kinect sensor)
  - Inertial measurement unit, accelerometers and gyroscopes
  - Shaft encoders
  - Global positioning system (outdoor)

# Let’s talk scanners

- The Hokuyo range of lasers are lightweight and powerful
- 5.6 metres range
- 240° scan window
- 0.36° resolution
- 10 scans per second
- 50mm x 50mm x 70mm
- Weight 160g
- Low power 2.6W
- 5V DC USB Powered
- LMS Laser measurement system
- LRF Laser range finder

URG-04LX-UG01


UTM-30LX

URG-04LX

# How does a Laser range finder- light radar (LIDAR) - work?

- Calculation of phase differences.
- Laser emits a monochromatic light wave (photons have same energy and same wave length) at frequency of 785 nm. It is a Class 1 laser so no harm.
- If light wave rebounds of obstacle and returns to the laser, the two waves (sent and received) are compared and the phase difference is used to calculate the distance.
- The phase difference is proportional to the time from when it left the laser and when it returned. We know the speed of light, so we know the distance it traveled.

$$A.B.(\cos(\omega.\Delta t) - cos(2.\omega.t - \omega.\Delta t))/2$$

$A.\sin(\omega.t) \rightarrow$ Multiplier

$B.\sin(\omega.(t - \Delta t)) \rightarrow$ Multiplier

Multiplier $\rightarrow$ Lowpass Filter

$(\cos(\omega.\Delta t)$

# That’s for one ray, what about a whole plane?

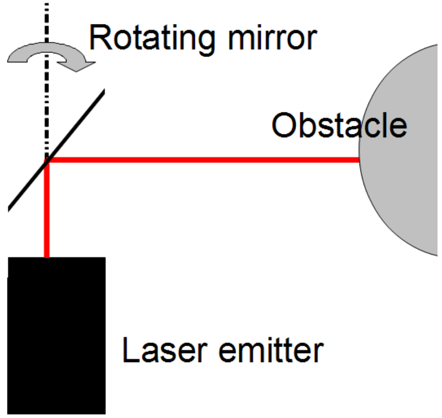
- A mirror that shifts by the resolution here its 0.36 degrees for each ray.

- Goes all around the 240 degrees.

- This means there are blind spots!

- If we have a map of the environment around us then we look for landmarks and have a position estimate using encoders and Kalman filter.

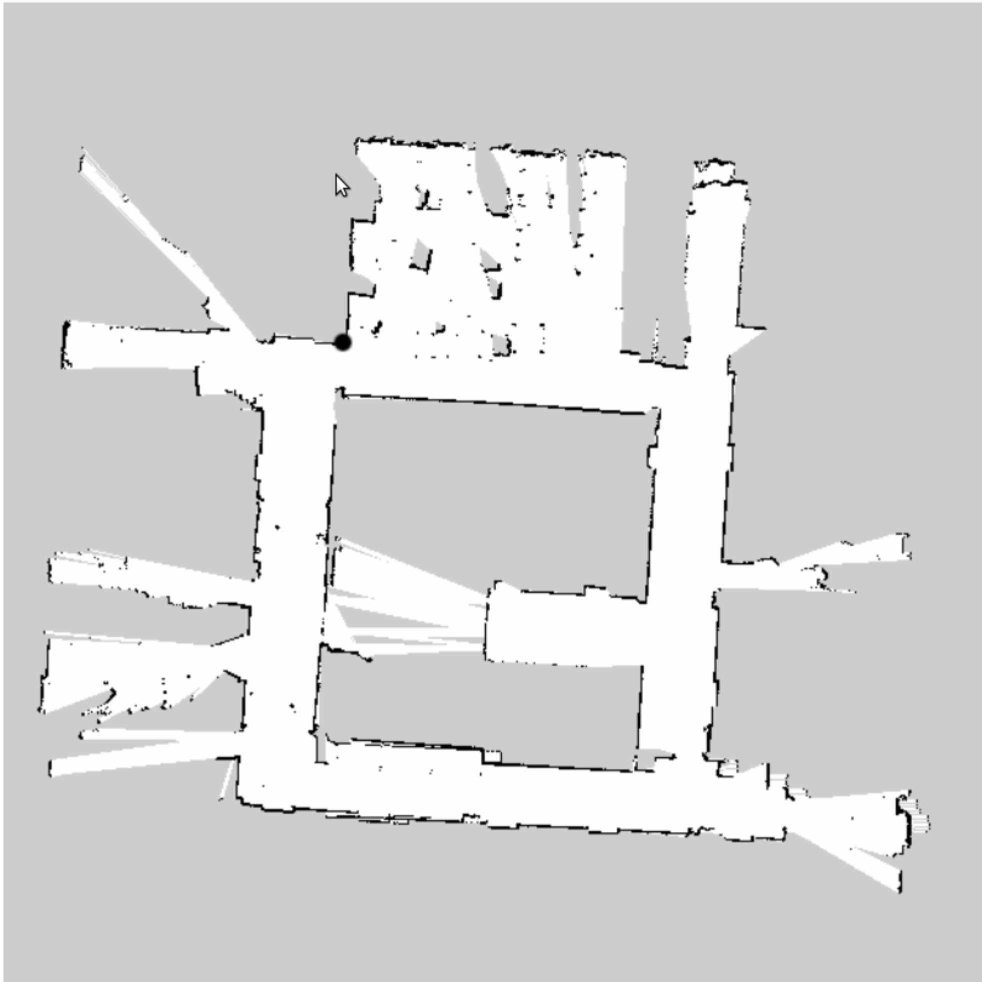
- No map of environment? We have to use SLAM: simultaneous localization and mapping.




# Map of the LSR's third Floor

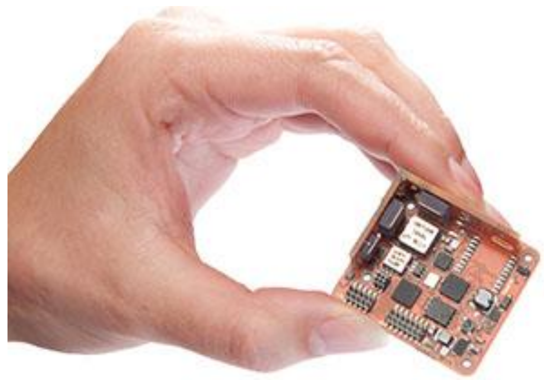
- We start with a map of the LSR third floor.

- This map was calculated given Laser scan information and wheel Odometery.



# Inertial Measurement Unit

- Sensors based on Inertia MEMS technology
- Accelerometers: mass-spring in vacuum
- Gyroscopes:
  - Inertial sensors:
    - Ring Laser/Fiber Optic Gyros: send light in two opposite directions through a set of mirrors/ fiber optic, a rotation influences the time one ray to the other side.
    - Very accurate and very expensive
  - MEMS gyros:
    - Small vibrating mass that oscillates @ 10’s kHz
    - Mass is suspended in a spring system, and read out Is in a capacitive system.
    - Rotation exerts a perpendicular Coriolis-force on the Mass.
    - We have a different output given the different oscillation which is directly prop. To rate of turn.

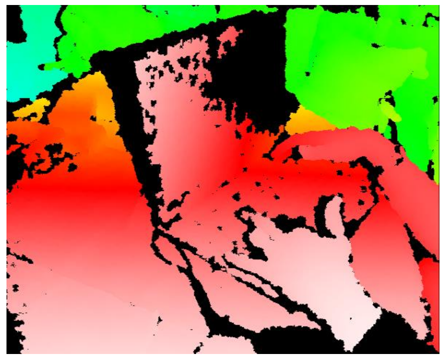


# Lets see some colors! … and depth

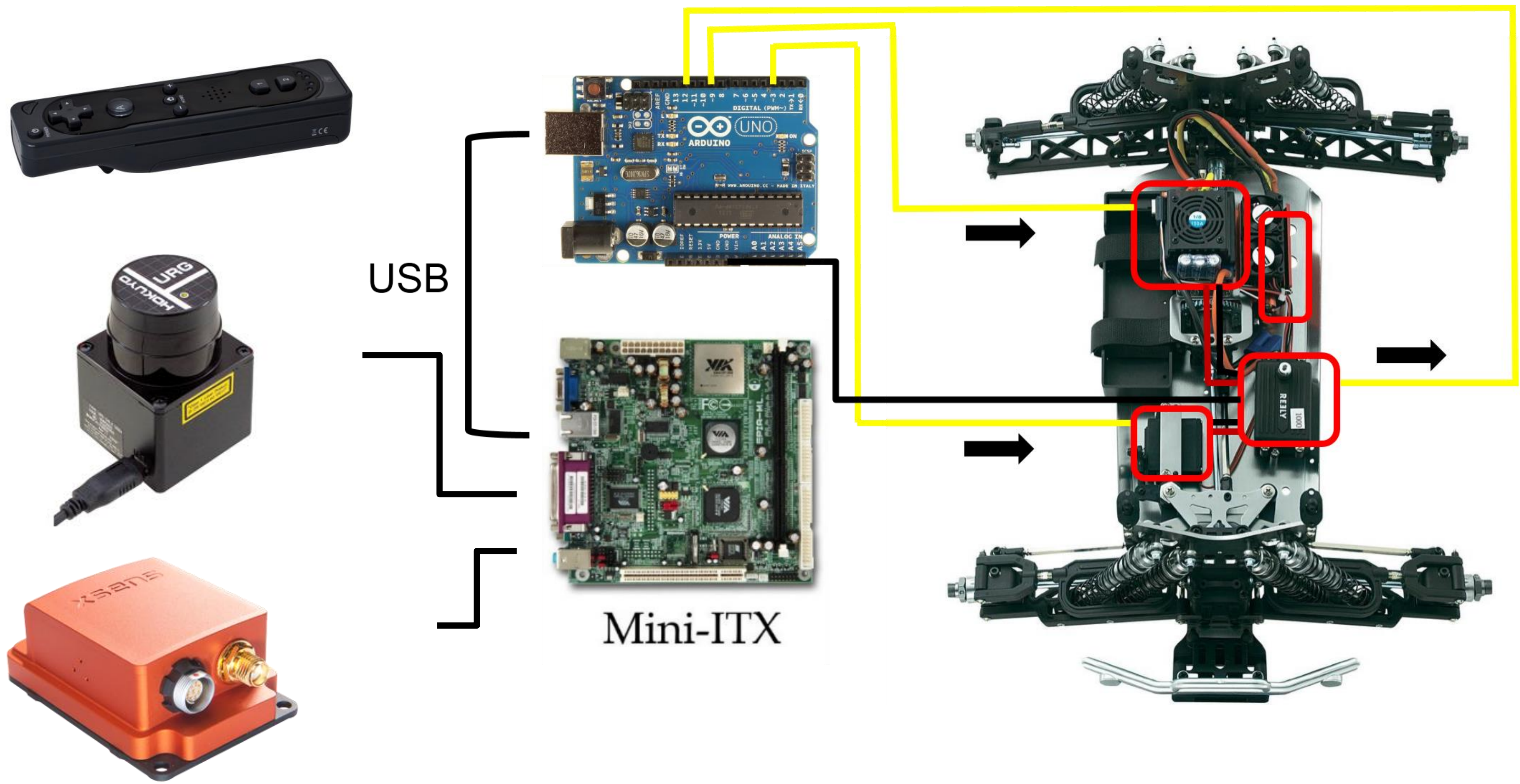
- Color VGA video camera: basic RGB video camera

- Depth sensor: infrared projector and a monochrome CMOS (complimentary metal-oxide semiconductor) sensors, register depth to see in 3D regardless of lighting conditions.

- Object recognition, facial recognition, SLAM … etc.

# What does the setup look like now?




The PC then houses all the algorithms to take a decision what to do next
Software will be discussed next time

## What is the task?

- Drive around the second floor hallways, compete with the team to do a lap and do it in less time. You will need to show contribution.
- Groups should pick between two tasks at the beginning: parallel parking and slalom course.
- You have to avoid obstacles (other cars too), maneuver through corners.
- Can you name some functions needed to achieve these tasks?
- Next time: Software
  - An introduction to ROS
  - An introduction to the packages that you might use in ROS
  - Programming session with the car