Weston Robot

RSE2107A - Lecture 7

Computer vision and OpenCV

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Agenda

01
Computer Vision

02
OpenCV

03
PID Control

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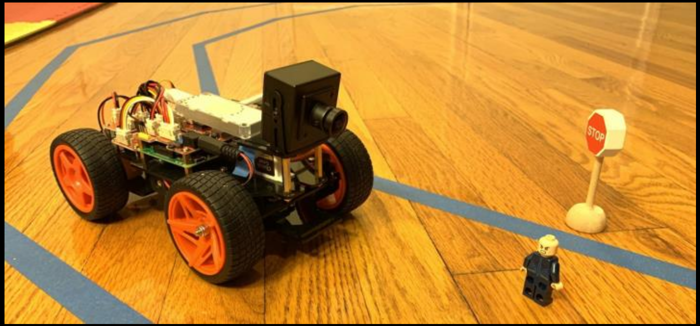
Vision-based Robot Control

- Using feedback information from vision sensors (visual feedback) to operate and control the motion of a robot
    - i.e. Cameras



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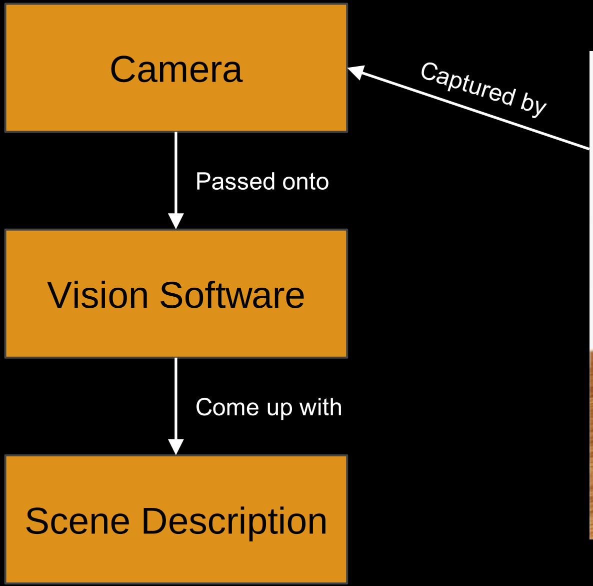
Vision-based Robot Control

- Image Processing (Computer Vision)
  - detect road lane marking and calculate lateral distance from vehicle C.G and center line of road
- Control System (PID Controller)
  - used to keep vehicle in the centre of the lane

Computer Vision

Basic Element



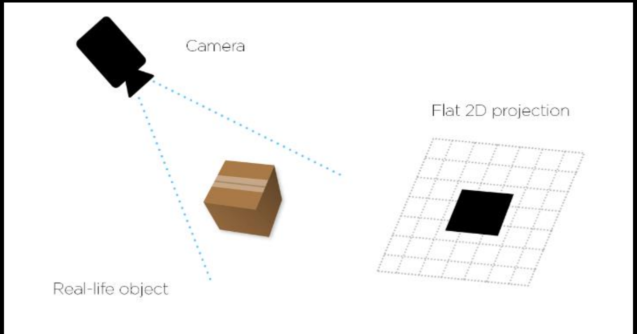
Scene

What is it?

- Computer vision is a field of AI which enables computers and systems to derive meaning information from digital inputs
  - automating human visual processes
  - information processing

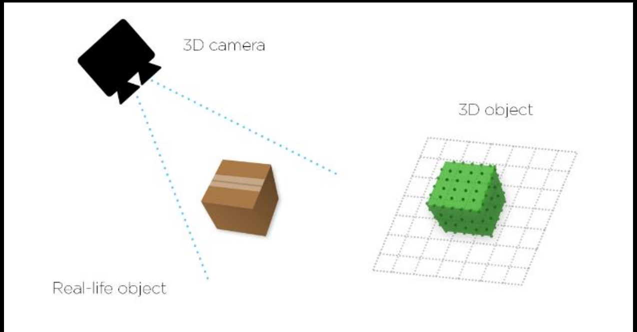
2D Computer Vision

- Uses digital camera to capture image of an object
- 2 dimensional map (X,Y) of reflected intensity is captured and processed
- Processing normally consist of comparing variations in intensity(contrast) of image



3D Computer Vision

- Captures depth of target using scanning technologies like Triangulation (using laser signals) or Time of Flight (LiDAR)
- Outputs a point cloud, which is a digitized model of the shape and location of the object(s)
    - Can stitch together point clouds from multiple scanners for digitizing large and complex objects



Mono vs Stereo Camera

Comparison	Mono	Stereo
Number of image sensors	1	2
Frame rate	30 to 60 FPS	30 FPS
Image Processing requirements	Medium	High
Reliability of obstacle detection and emergency braking decisions	Medium	High
System is reliable for	Obstacle detection (lanes, pedestrians and traffic signs)	Obstacle detection and calculate distance to object
Software and algorithm complexity	High	Medium

Characteristics of Colour

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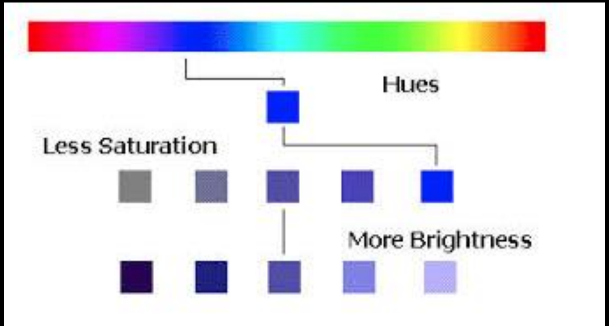
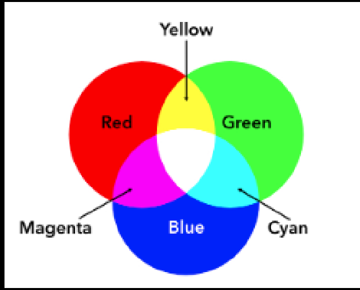
- Hue
  - Dominant colour or the name of the colour itself
    - Yellow, Red, Green, etc
- Saturation/Chroma
  - Pureness of colour or the dominance of the hue in the colour
    - Intense vs Dull
- Brightness/Value
  - How bright or illuminated the colour is
    - Black vs White, Dark vs Light



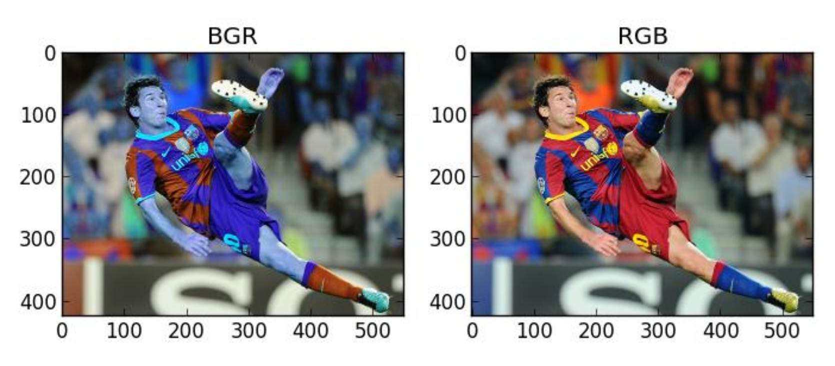
Colour Spaces

- RGB
  - Colours represented by adding combination of the 3 primary colours (Red, Green, Blue)
    - Full intensity: 255 ; Zero intensity: 0
      - e.g. White: RGB(255,255,255), Black: RGB(0,0,0)
  - Used as default colour space in OpenCV to *display* image



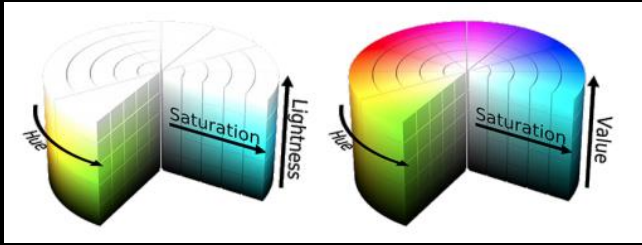
Colour Spaces

- BGR
  - In reverse of RGB format, with no adverse effect on colour vibrancy and accuracy
  - Used as default colour space in OpenCV to *store* image



Colour Spaces

- HSV & HSL
  - Cylindrical representation of colours
    - **H**ue: 0 ~ 360 (Starts and end with Red)
    - **S**aturation: 0 (No saturation) ~ 1 (Full Saturation)
    - **V**alue/**L**ightness: 0 (No light, Black) ~ 1 (White)
      - At full saturation, V = 1 (HSV), but L = 0.5 (HSL)



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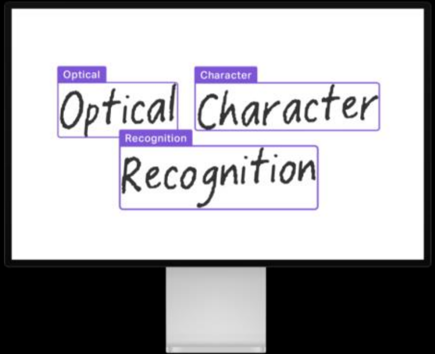
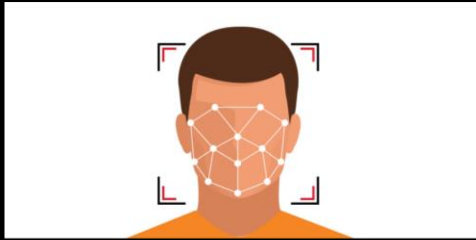
Typical application

- Factory Automation
  - Vision Guided Robotics
- Optical Character Recognition
  - Reading Licence Plates
- Biometrics
  - Face detection & recognition





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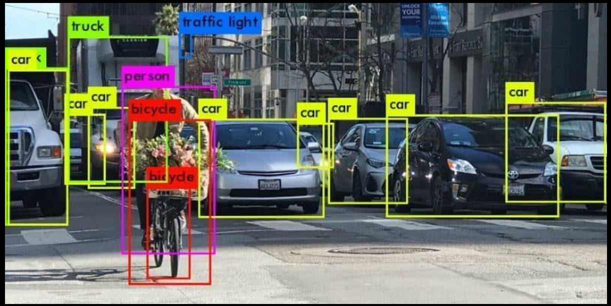
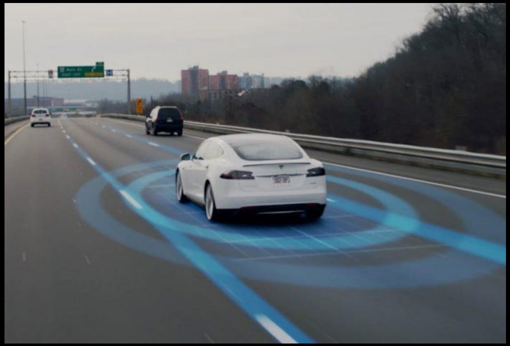
Typical application

- Security
  - Object detection & tracking
- Autonomous Navigation
  - Driverless car
  - Space Exploration





Now we will take a look at the software that we will be using for implementing Computer Vision

OpenCV

What is it?

- OpenCV is an open source computer vision and machine learning software library
  - Contains many algorithms that can be used for
    - Face detection and recognition
    - Identifying objects
    - Tracking moving objects
    - and many more functionalities

Examples in Jupyter

Now that we have all these image and data processed,

how are we going to use these data to control our robot?

Vision-based Robot Control

- Image Processing (Computer Vision)
  - detect road lane marking and calculate lateral distance from vehicle C.G and center line of road
- Control System (PID Controller)
  - used to keep vehicle in the centre of the lane

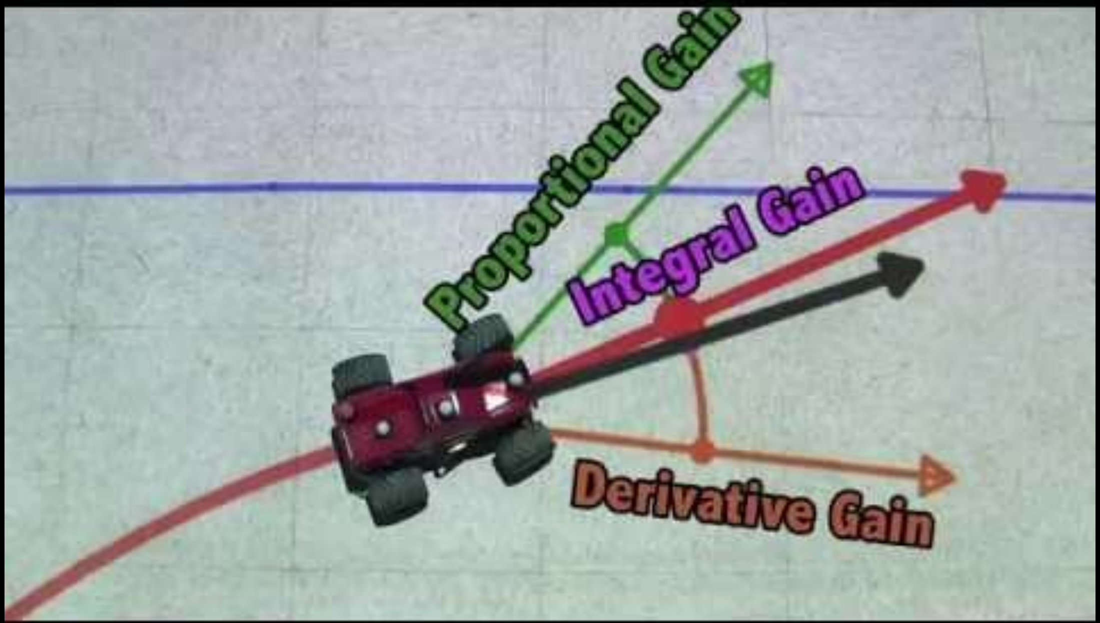
Control Systems types

- Open Loop Control System
  - Acts completely on the basis of the input, where the output has no effect on the control system
  - Only useful when output rarely changes and process is erratic
- Closed Loop Control System
  - Takes in the current output of the system and alters it to fit its desired condition
  - Advantages
    - Automatic corrections to process disturbances

PID Control

(Closed Loop Control System)

PID application



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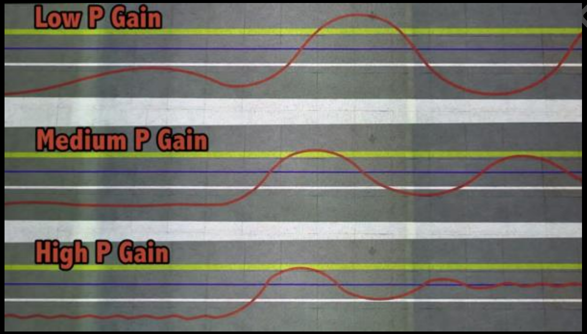
Feedback Control

- Bang Bang Control
  - Mechanically or electronically turns something on or off when desired target (setpoint) has been reached
    - Eg. If car is too far left from a target point (eg. a line), it turns right, and vice-versa
    - Issues with this form of control:
      - Small error results in extreme control signal

Feedback Control

- PID Control
  - Most common form of feedback control
  - Advantages:
    - Simple
    - Efficient
    - Effective

Proportional Control



- Control signal is proportional to the error
  - Proportional Term $P \cdot e_P$
    - Controller gain = P
      - Low P value: Oscillate
      - Higher P value: Better performance
      - Too high P value: Leads to instability due to large offset (overshoot desired setpoint)
    - Error = e_P
      - How far vehicle is from the desired path

However, it is not enough as vehicle may consistently overshoot its desired path (Causing oscillation along path)

Differential Control

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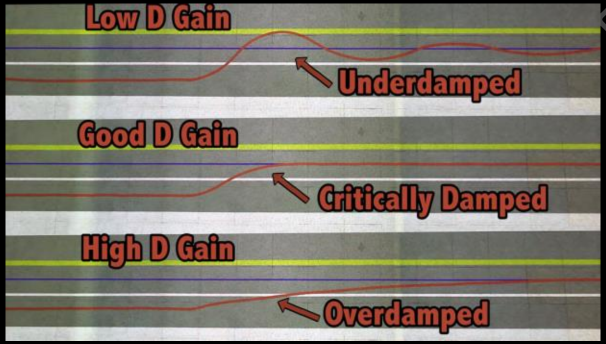

- Control signal is proportional to change of error
  - Derivative Term $D \cdot e_D$
    - Controller gain = D
      - Low D: Underdamp (Oscillation is still present)
      - High D: Overdamp (Take too long to reach steady-state)
      - Good D value: Result in critical damping (reach setpoint in the fastest time possible)
    - Error rate of occurrence = e_D
      - How fast vehicle is moving in perpendicular distance w.r.t. to desired path

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But what if there is external factors that causes changes to the vehicle’s nominal behaviour?

Integral Control

- Control signal is proportional to cumulative error
  - Integral Term $I \cdot e_I$
    - Controller Gain = I
      - Low I value: Take too long to resolve error
      - High I value: Unstable
      - Good I value: Can quickly correct misalignment and get back on its desired path
    - Integral of error = e_I
      - Sum of all errors from the last stable state

PID Control

- Steering Angle of vehicle

$$\text{steering angle} = \overbrace{P \cdot e_P}^{\text{Proportional Term}} + \overbrace{D \cdot e_D}^{\text{Derivative Term}} + \overbrace{I \cdot e_I}^{\text{Integral Term}}$$

**This value does not include direction, it just gives the angle that robot is supposed to turn.

Conclusion

- Computer vision enables the robot to process data obtained from its various visual sensors
- PID controller uses the data obtained to determine how the robot should adjust itself towards the path that it desires to follow