

In The Name of God

Introduction to Control Theory and Applications

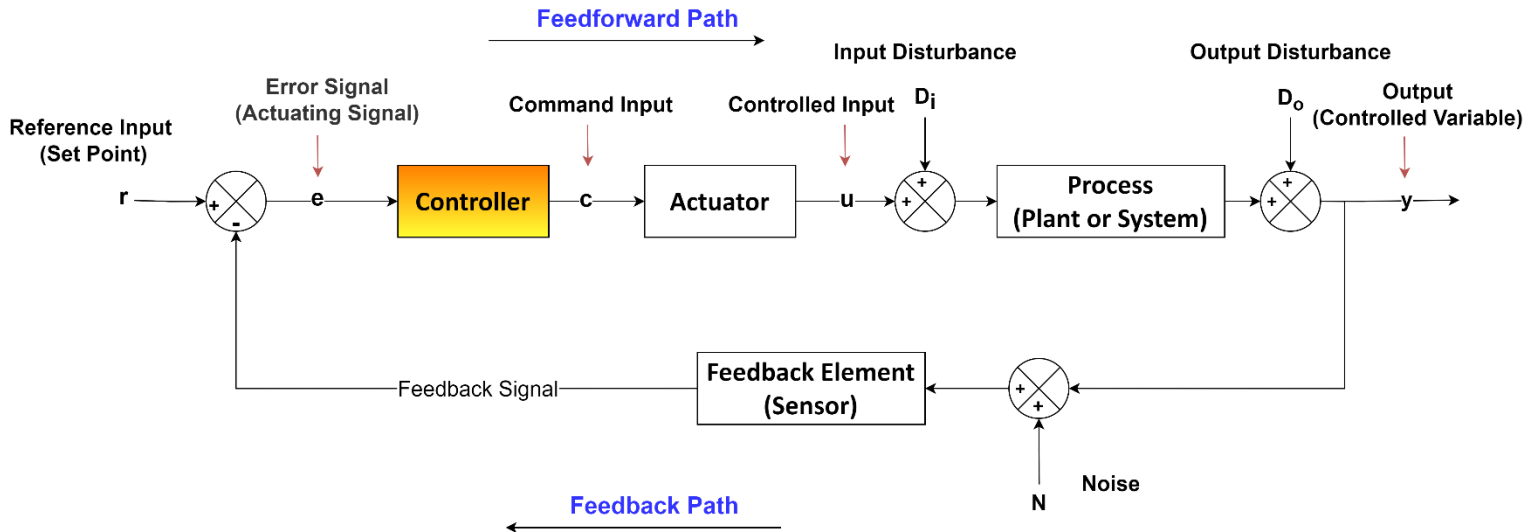
Amirkabir University of Technology
Department of Electrical Engineering

Mahdi Shahrajabian

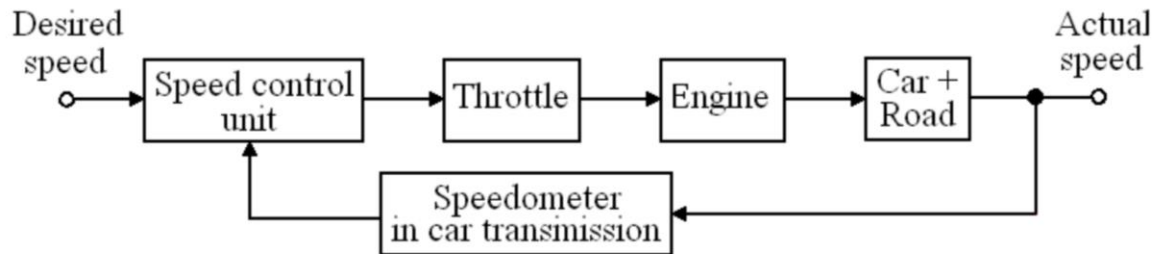
Fall 2024

Control System

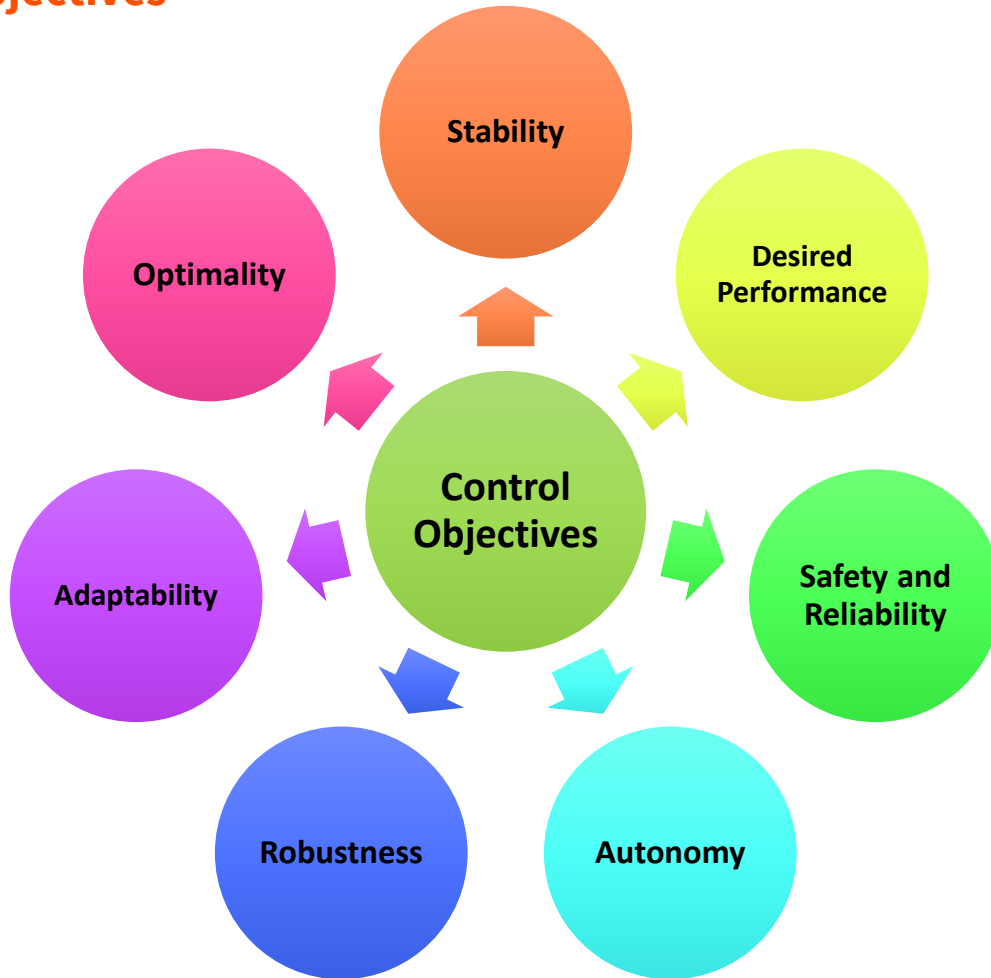
Closed-loop (feedback) Control System



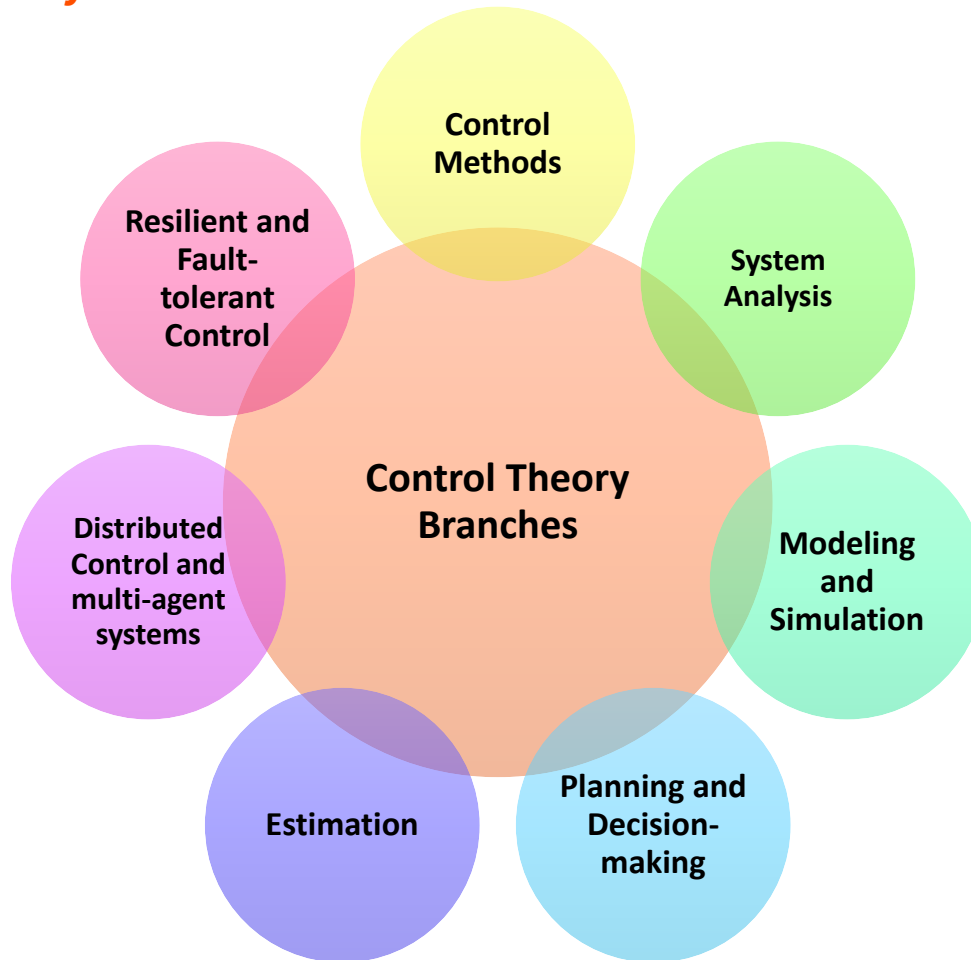
❑ Car Cruise Control Example:



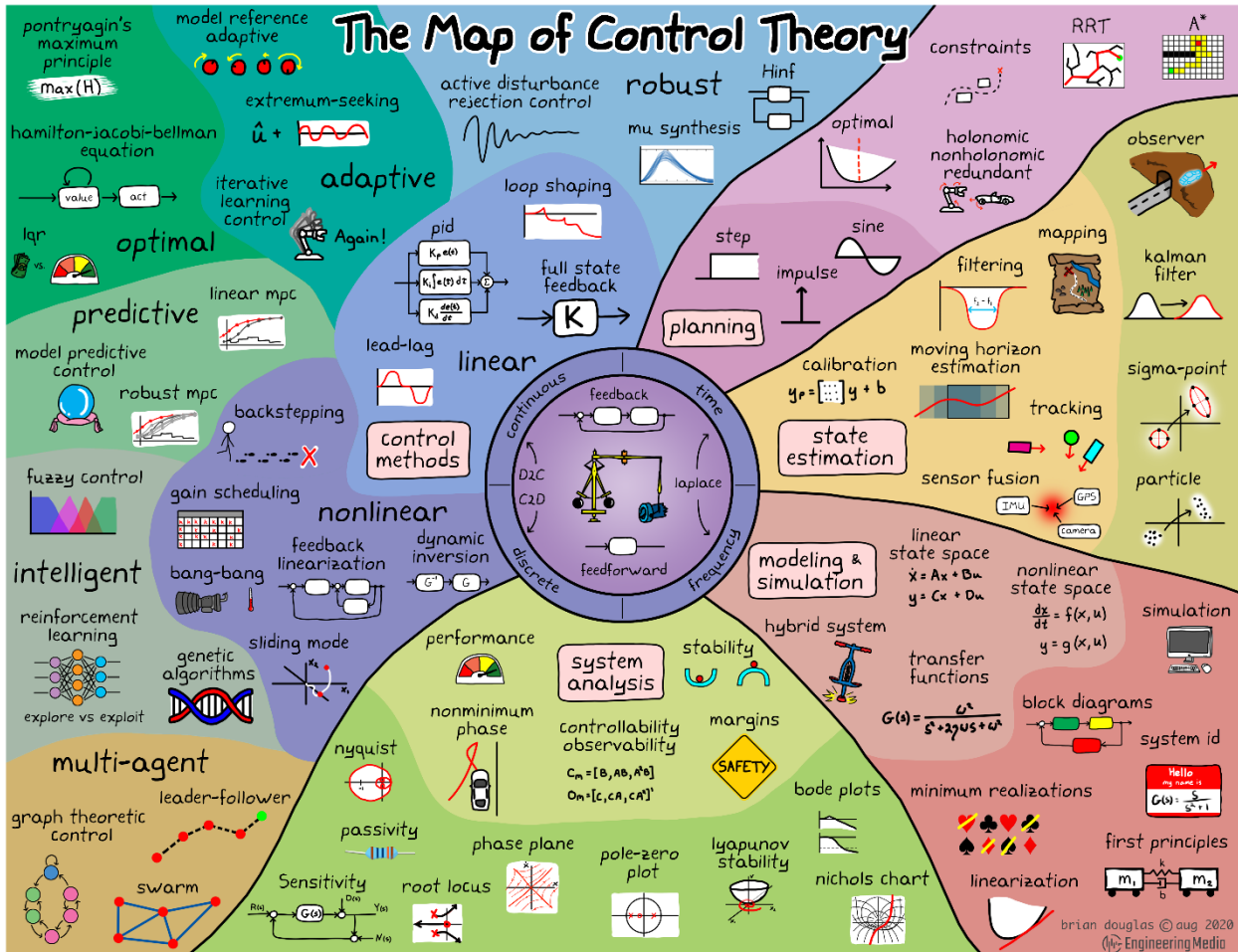
Control Objectives



Control Theory Branches

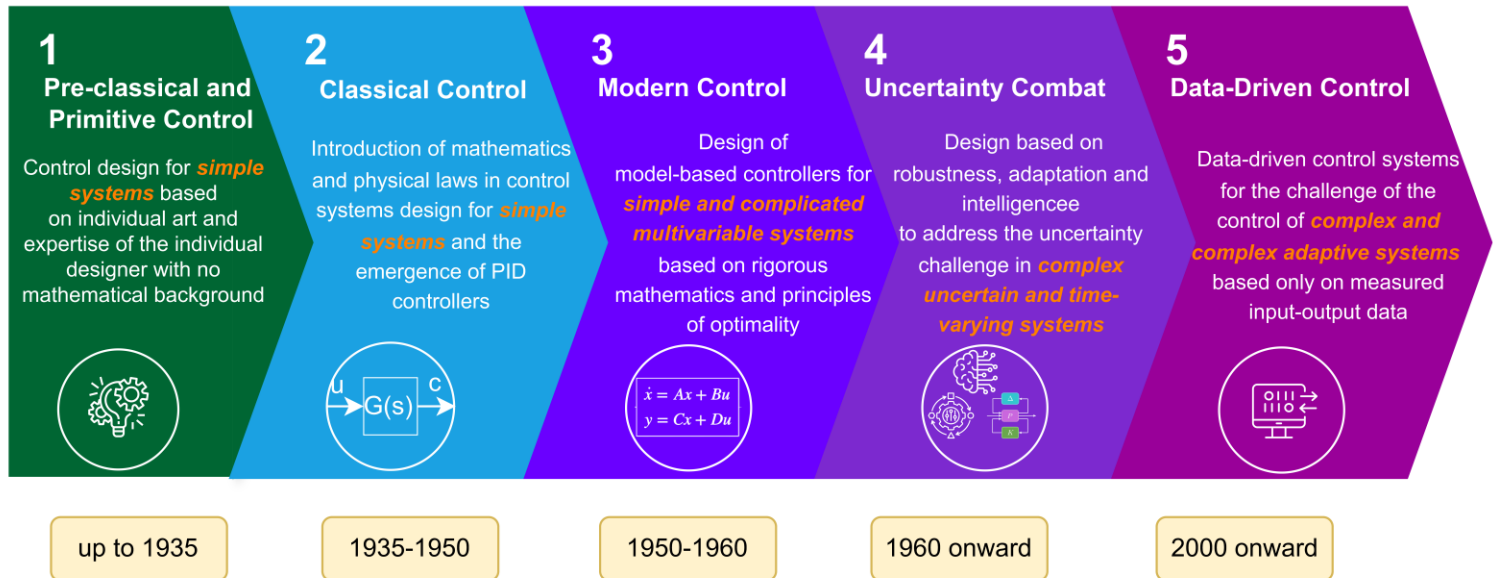


The Map of Control Theory



Paradigm Shift in Control Systems Design

Paradigm Shift in Control Systems Design

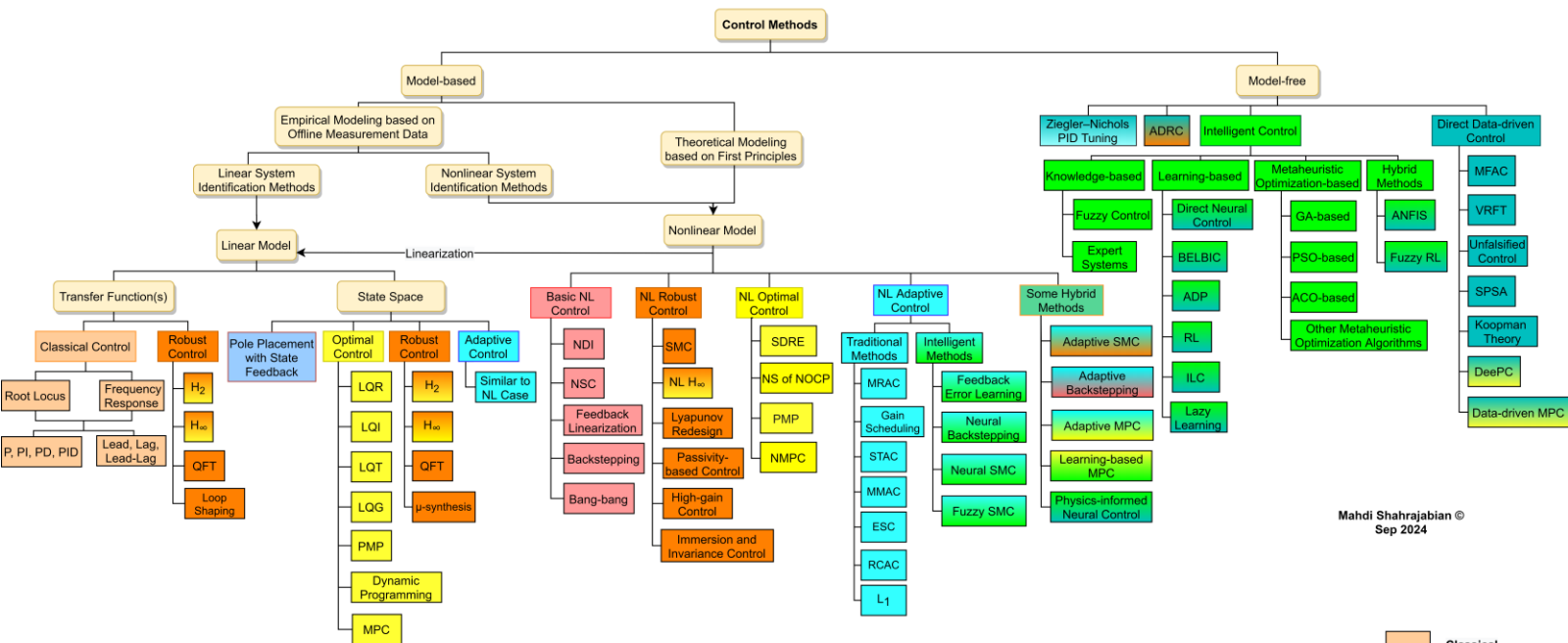


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This diagram is inspired by the concepts in: Khaki-Sedigh, Ali. *An Introduction to Data-Driven Control Systems*. John Wiley & Sons, 2023.

Classification of Control Methods in Control Theory

Classification of Control Methods in Control Theory - V2.0



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Sep 2024

List of Acronyms

ACO: Ant Colony Optimization
ADP: Approximate Dynamic Programming
ADRC: Active Disturbance Rejection Control
ANFIS: Adaptive Neuro-Fuzzy Inference System
BELBIC: Brain Emotional Learning Based Intelligent Controller
DeePC: Data-Enabled Predictive Control
ESC: Extremum Seeking Control
GA: Genetic Algorithm
ILC: Iterative Learning Control
LQR: Linear Quadratic Regulator
LQI: Linear Quadratic Integral
LQT: Linear Quadratic Tracking

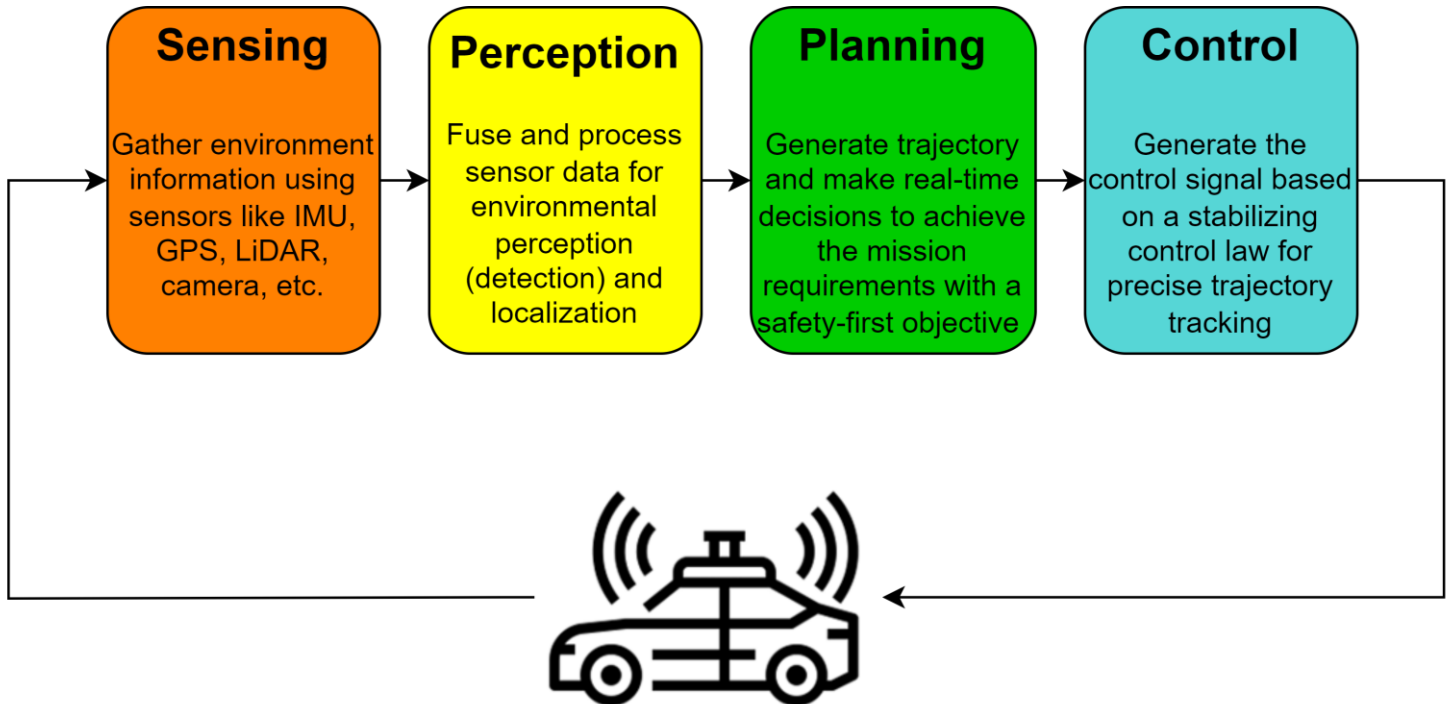
LQG: Linear Quadratic Gaussian
MFAC: Model-Free Adaptive Control
MMAC: Multiple Model Adaptive Control
MPC: Model Predictive Control
MRAC: Model-Reference Adaptive Control
NDI: Nonlinear Dynamic Inversion
NL: Nonlinear
NMPC: Nonlinear Model Predictive Control
NOCP: Nonlinear Optimal Control Problem
NS: Numerical Solution
NSC: Nested Saturation Control

NN: Neural Network
PMP: Pontryagin's Minimum Principle
PSO: Particle Swarm Optimization
QFT: Quantitative Feedback Theory
RCAC: Retrospective Cost Adaptive Control
RL: Reinforcement Learning
SDRE: State-Dependent Riccati Equation
SMC: Sliding Mode Control
SPSA: Simultaneous Perturbation Stochastic Approximation
STAC: Self-Tuning Adaptive Control
VRFT: Virtual Reference Feedback Tuning

Classical
Optimal
Intelligent
Robust
Adaptive
Data-Driven

Autonomous Systems

The continuing goal of control systems is to provide **extensive flexibility** and a **high level of autonomy**.



Automation vs Autonomy

Automation

The use or introduction of automatic equipment in a manufacturing or other process or facility.

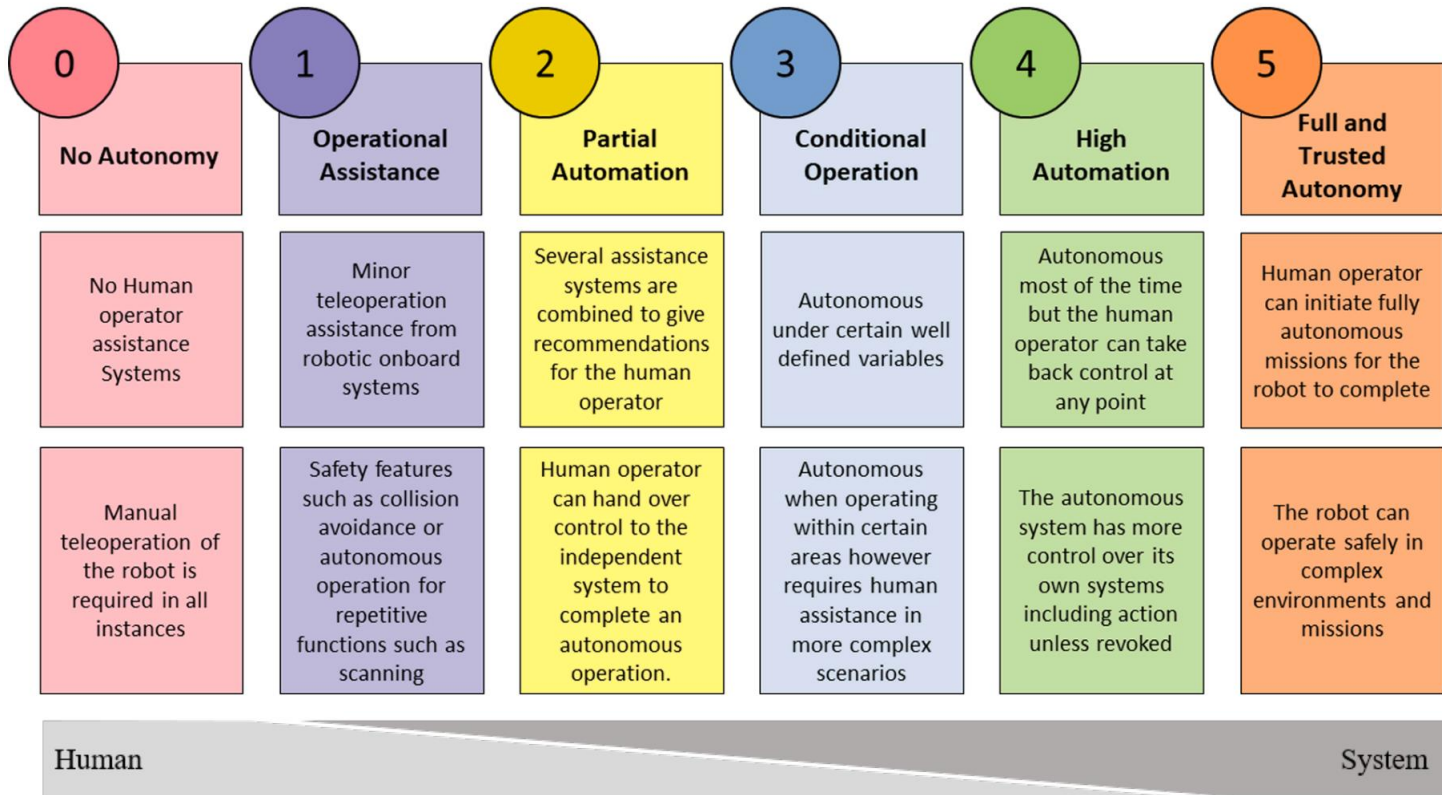
How automated a drone is always comes down to how much automatic equipment is involved and how much manual intervention it requires. An automated drone follows orders about destination and route but cannot make decisions.

Autonomy

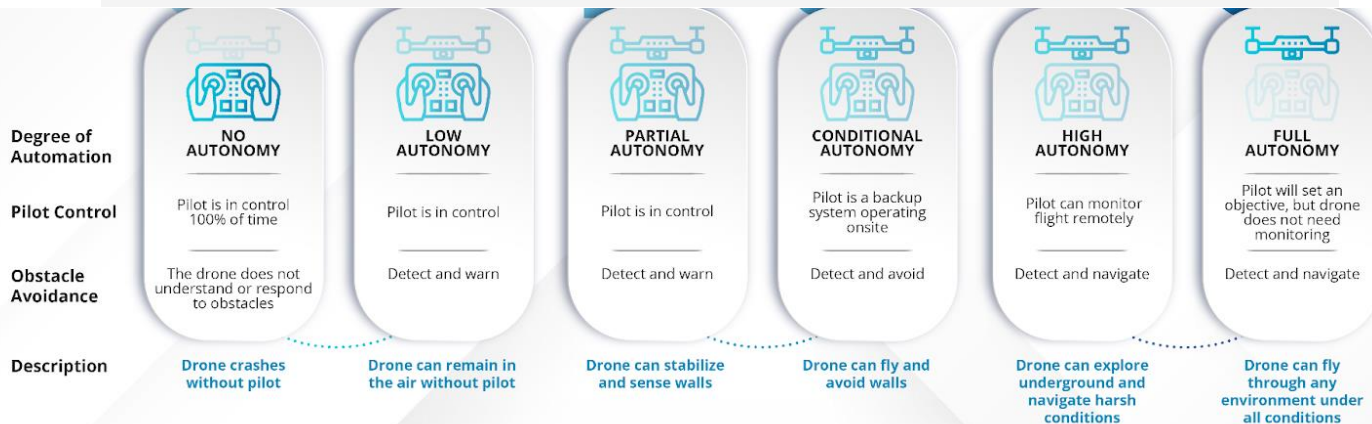
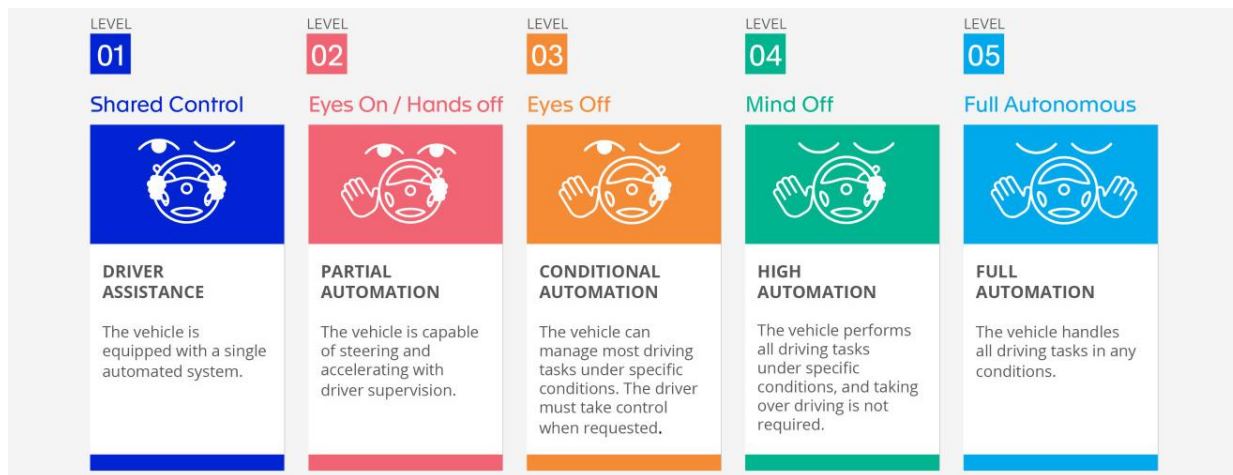
Freedom from external control or influence; independence.

How autonomous a drone is must always be a measurement of how independent the platform and its workflow are. A truly autonomous drone would *decide* on destination and route as well as control in the air.

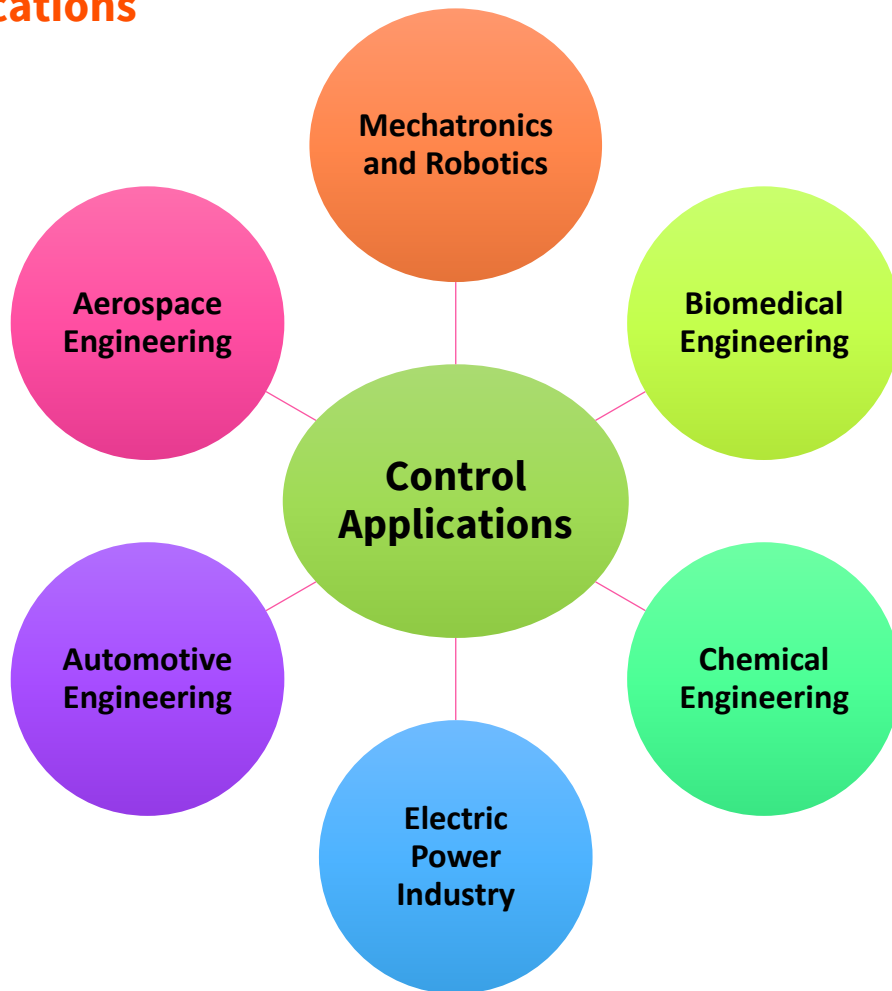
Levels of Autonomy



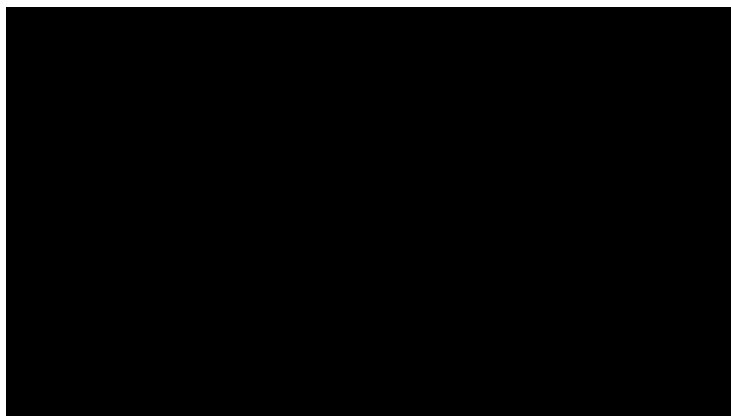
Levels of Autonomy



Control Applications



Control Applications



Learning Minimum Time Flight in Cluttered Environments

Robert Penicka, Yunlong Song,
Elia Kaufmann, Davide Scaramuzza

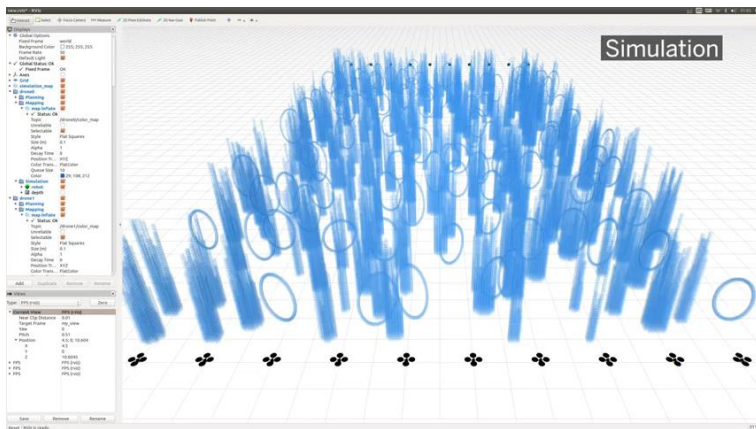
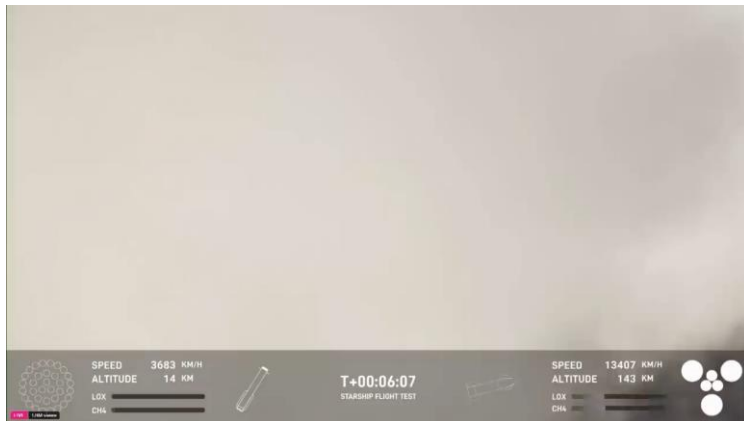


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Control Applications



Any Question?

