Automated Vehicles: Terminology and Taxonomy

Taxonomy Working Group

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Outline

- **Definitions: Autonomy and Automation**
- **Taxonomy:**
  - **Distribution of functions (intelligence)**
  - **Driving functions that could be automated**
  - **Relative roles of driver and system**
  - **Driving environments**
    - **Roadway characteristics**
    - **Traffic conditions**
    - **Weather**
    - **Operational challenges**

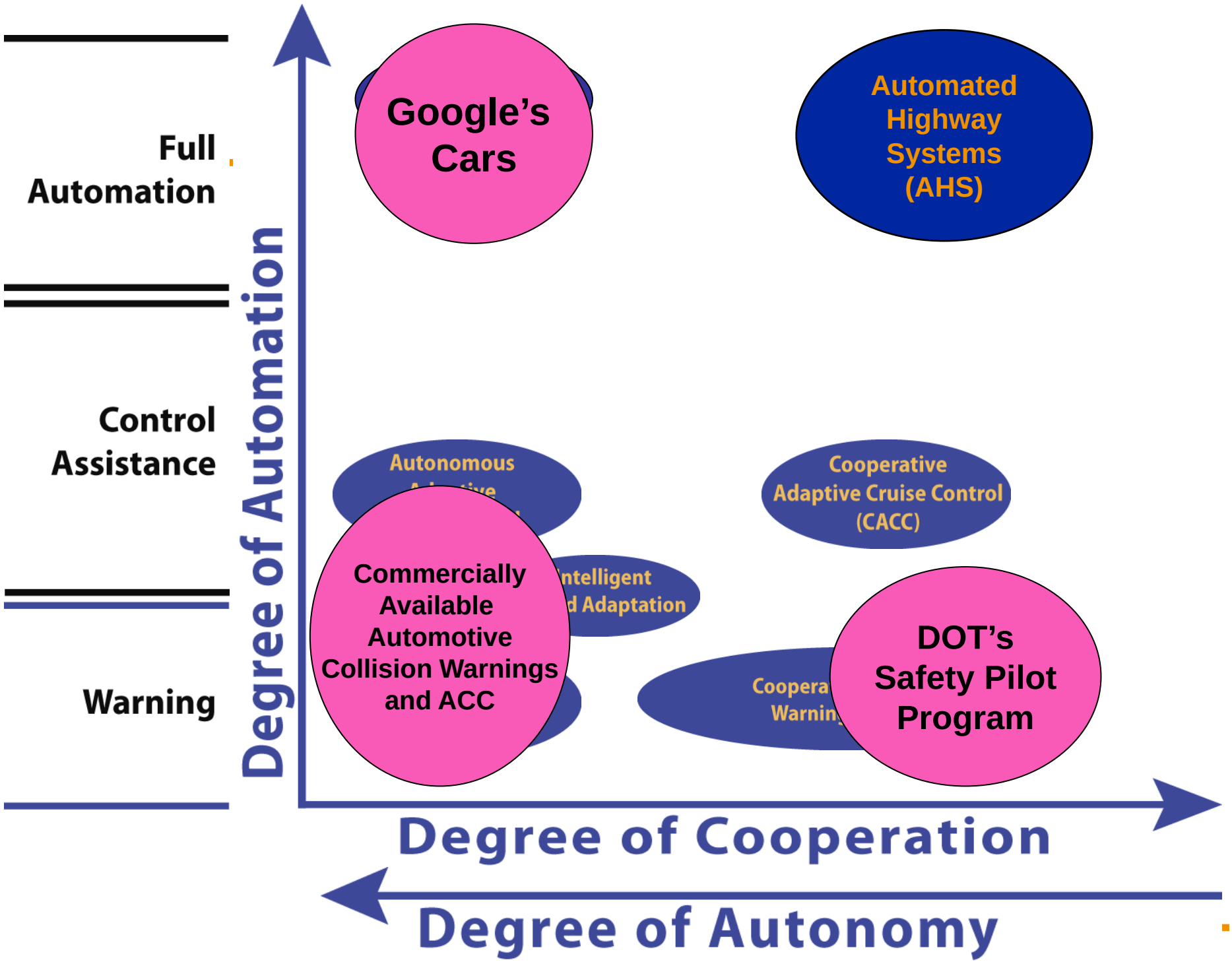
Definitions
(per Oxford English Dictionary)

- **autonomy:**
  1. *(of a state, institution, etc.)* the right of self-government, of making its own laws and administering its own affairs
  2. *(biological)* (a) the condition of being controlled only by its own laws, and not subject to any higher one; (b) organic independence
  3. a self-governing community.

  autonomous:
  1. of or pertaining to an autonomy
  2. possessed of autonomy, self governing, independent
  3. *(biological)* (a) conforming to its own laws only, and not subject to higher ones; (b) independent, i.e., not a mere form or state of some other organism.

- **automate: to apply automation to; to convert to largely automatic operation**

  automation: automatic control of the manufacture of a product through a number of successive stages; the application of automatic control to any branch of industry or science; by extension, the use of electronic or mechanical devices to replace human labour


Full Automation
Control Assistance
Warning
Degree of Automation
Google's Cars
Automated Highway Systems (AHS)
Autonomous
Cooperative Adaptive Cruise Control (CACC)
Commercially Available Automotive Collision Warnings and ACC
DOT's Safety Pilot Program
Degree of Cooperation
Degree of Autonomy

Distributions of Functions (Intelligence)

- **Autonomous – self-contained within the individual automated vehicle**
- **Cooperative**
  - **V2V (vehicle-vehicle cooperation)**
  - **I2V (infrastructure to vehicle)**
  - **V2I (vehicle to infrastructure)**

Driving Functions that Could Potentially be Automated

Strategic → Tactical

1. Actuation of steering, engine, brakes
2. Powertrain and chassis control (e.g., ABS, stability control – transparent to driver)
3. Real-time information collection (including driving environment perception from sensing and/or communication)
4. Hazard assessment
5. Decision making (tactical microscopic maneuvering to strategic route planning)
6. Management of vehicle flows (traffic management)
7. *Combinations (up to all of the above)*

Vehicle ↓ Mixed ↓ Infrastructure

Relative Roles of Driver and System

- **Several classification schemes already defined:**
  - **Sheridan et. al. based on general human-computer interaction concepts**
  - **TARDEC based on Army application needs**
  - **BASt (Germany) based on needs for legal analysis**
- **Imprecise terms in popular use (denigrated)**
  - **Self-driving cars**
  - **Driverless cars**
  - **Unmanned vehicles**

Ten Levels of Automation

Ref: Parasuraman, Sheridan and Wickens in *IEEE Trans. on Systems, Man and Cybernetics*, 2000

1. **No assistance**
2. **Computer offers alternatives to human (Nav. system)**
3. **Computer narrows selection to a few**
4. **Computer suggests one alternative (Route guidance or collision warning)**
5. **Computer executes suggestion if human approves**
6. **Computer allows human a limited time to veto its action**
7. **Computer acts, then informs human (ACC)**
8. **Computer informs human only if asked**
9. **Computer informs human if it wants to**
10. **Computer decides everything, ignoring human**

TARDEC Classification

- **Environmental Complexity**
- **Human Independence (and/or presence)**
- **Mission Complexity**

Definition of vehicle automation-degrees:

possible today

- **Driver Only:** Human driver executes manual driving task
- **Driver Assistance:** The driver permanently controls either longitudinal or lateral control. The other task can be automated to a certain extent by the assistance system.
- **Partial automation:** The system takes over longitudinal and lateral control, the driver shall permanently monitor the system and shall be prepared to take over control at any time.

in future

- **High automation:** The system takes over longitudinal and lateral control; the driver must no longer permanently monitor the system. In case of a take-over request, the driver must take-over control with a certain time buffer.
- **Full automation:** The system takes over longitudinal and lateral control completely and permanently. In case of a take-over request that is not carried out, the system will return to the minimal risk condition by itself.

(Note: This level can include operation with no humans onboard)

Driving Environments: Roadway (1/2)

- **Existing infrastructure, unchanged**
  - **Off-road**
  - **All roads**
  - **All paved roads**
  - **Well-marked paved roads**
  - **Urban and suburban arterials**
  - **Rural highways**
  - **Residential streets**
  - **Limited-access highways (freeways)**
  - **Parking facilities**
  - **Parks or low-speed pedestrian zones**

Driving Environments: Roadway (2/2)

- **Existing infrastructure, augmented for automation**
  - **Dedicated lanes within limited-access highway**
  - **Special markings or electronics added**
- **Separate new infrastructure**
  - **Dedicated, protected lanes on limited-access highways**
  - **Fully automated parking facilities**
  - **Physically separated guideways (PRT)**

Driving Environments: Traffic

	Density	Speed	Decorum
A	Low	Low	Mixed (residential)
B	High	Low	Well-behaved (urban)
C	Low	High	Well-behaved (rural highway)
D	High	High	Well-behaved (urban highway)
E	High	Low	Chaotic (Bangkok, Moscow)
F	High	High	Chaotic (rural, developing countries)

Driving Environment: Combinations

	Speed	Low	Low	High	High	Low	High
	Density	Low	High	Low	High	High	High
	Decorum	Mixed	Behaved	Behaved	Behaved	Chaotic	Chaotic
	Letter Code	A	B	C	D	E	F
Existing Infrastructure, Unchanged							
Off-road							
All roads							
All paved roads							
Well-marked paved roads							
Urban and suburban arterials							
Rural highways							
Residential streets							
Limited-access highways (freeways)							
Parking facility							
Parks or low-speed pedestrian zones							
Existing infrastructure, Augmented for automation							
Dedicated lanes within limited-access highway							
Special markings or electronics added							
Separate new infrastructure							
Dedicated, protected lanes on limited-access highways							
Fully automated parking facilities							
Physically separated guideways (PRT)							

Driving Environments: Weather

- Fair weather (baseline)
- Lighting conditions
  - Daylight/Night
  - Low sun angle (glare)
- Precipitation (rain, snow, sleet, etc.)
- Wind
- Visibility challenges
  - Fog
  - Dust
  - Smoke
- Pavement surface (dry, wet, snow, ice,…) and maintenance level

Driving Environments: Operational Challenges

- **Static road conditions**
  - Curves (various radii) and superelevation
  - Grades and abrupt grade changes
  - Line of sight restrictions from built environment
  - Road surface roughness
  - Roadway marking and signage condition
- **Scheduled events**
  - Special event traffic control by officers
  - Work zones
- **Dynamic or unscheduled incidents**
  - Emergency vehicles
  - Incident responders blocking traffic
  - Law enforcement actions