Meeting the Challenges of Safe Transportation in an Aging Society

Transportation Safety and Mobility for Older Adults in a Socially-Responsive Environment

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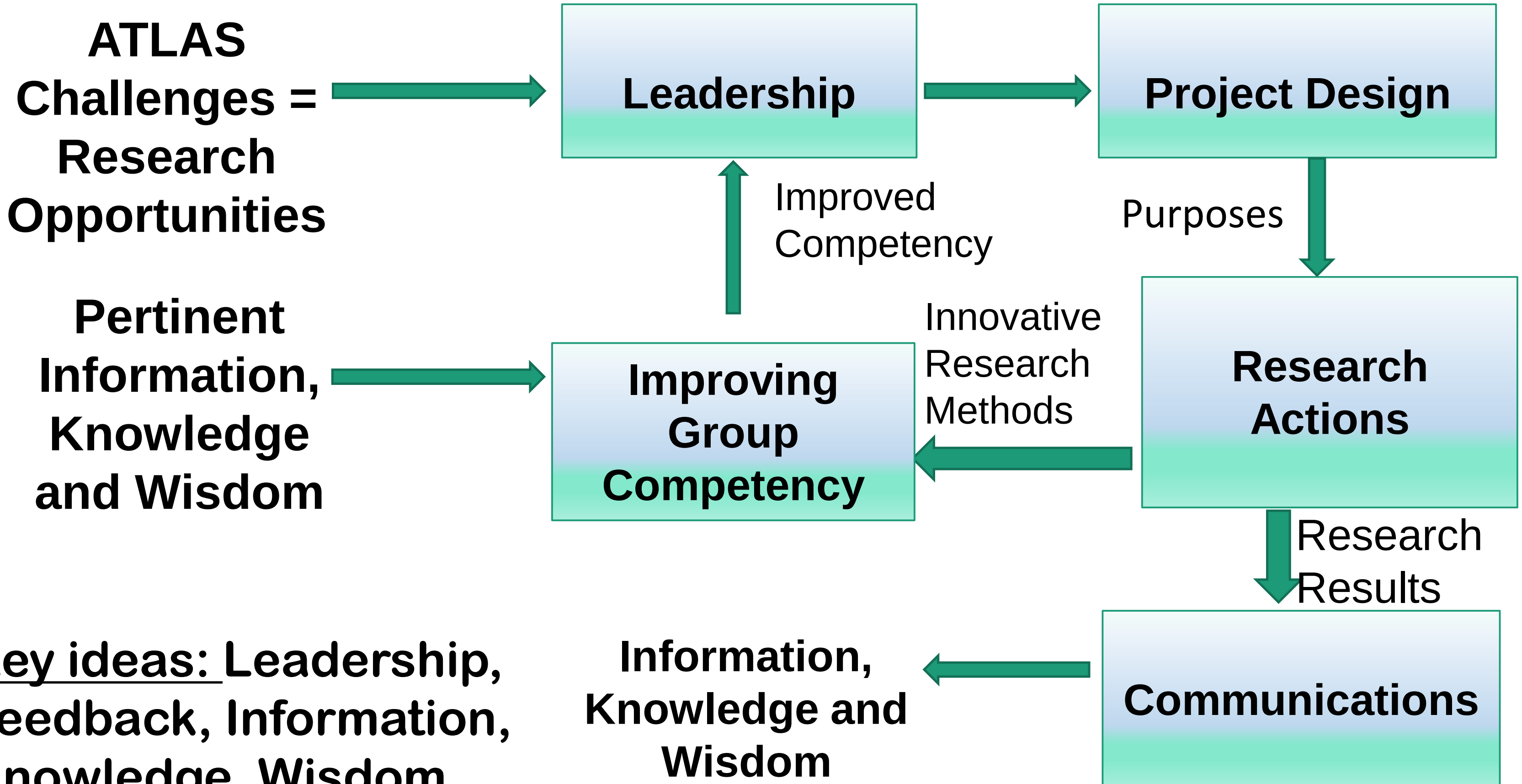
Transportation Safety and Mobility for Older Adults in a Socially-Responsive Environment

Research Group's Action Diagram



<u>Key ideas:</u> Leadership, Feedback, Information, Knowledge, Wisdom, Purposes

Transportation Safety and Mobility for Older Adults in a Socially-Responsive Environment

<u>Key ideas:</u> Improved safety and mobility, speed and velocity distinctions, Trips, functional purposes, design philosophy, guidance/wisdom, surpassing/goals

- Improving transportation safety and congestion management by matching vehicle speed to current driving situations during <u>Trips</u>.
- providing guidance for incorporating functional purposes into the design of on-board vehicle control systems
- surpassing human capabilities in perceptual awareness, decision making, and the operational aspects of driving.

✓ Practical hardware is available for enhancing information flow to and from controller units in the interests of safety, timely access to destinations, traffic flow, and energy saving.

Transportation Safety and Mobility for Older Adults in a Socially-Responsive Environment

<u>Key ideas:</u> Pertinent Information, Real-time, communication of information, STEM education (Robotics)

Demonstrations of autonomous driving by driverless cars indicate 'we' have methods for designing and developing information, communication, and control engineering (robotics) as needed to create command and control units for replacing the skills of human operators in <u>Real-Time</u> field-operational-tests.

Wireless communication of safety and traffic information to vehicles opens opportunities for using controller units in deciding how to operate a vehicle in <u>Real Time</u> throughout a <u>Trip</u>.

Transportation Safety and Mobility for Older Adults in a Socially-Responsive Environment

Key ideas: older drivers; road system design; vehicle system design; adaptive controller units

Business Planning for Older Drivers

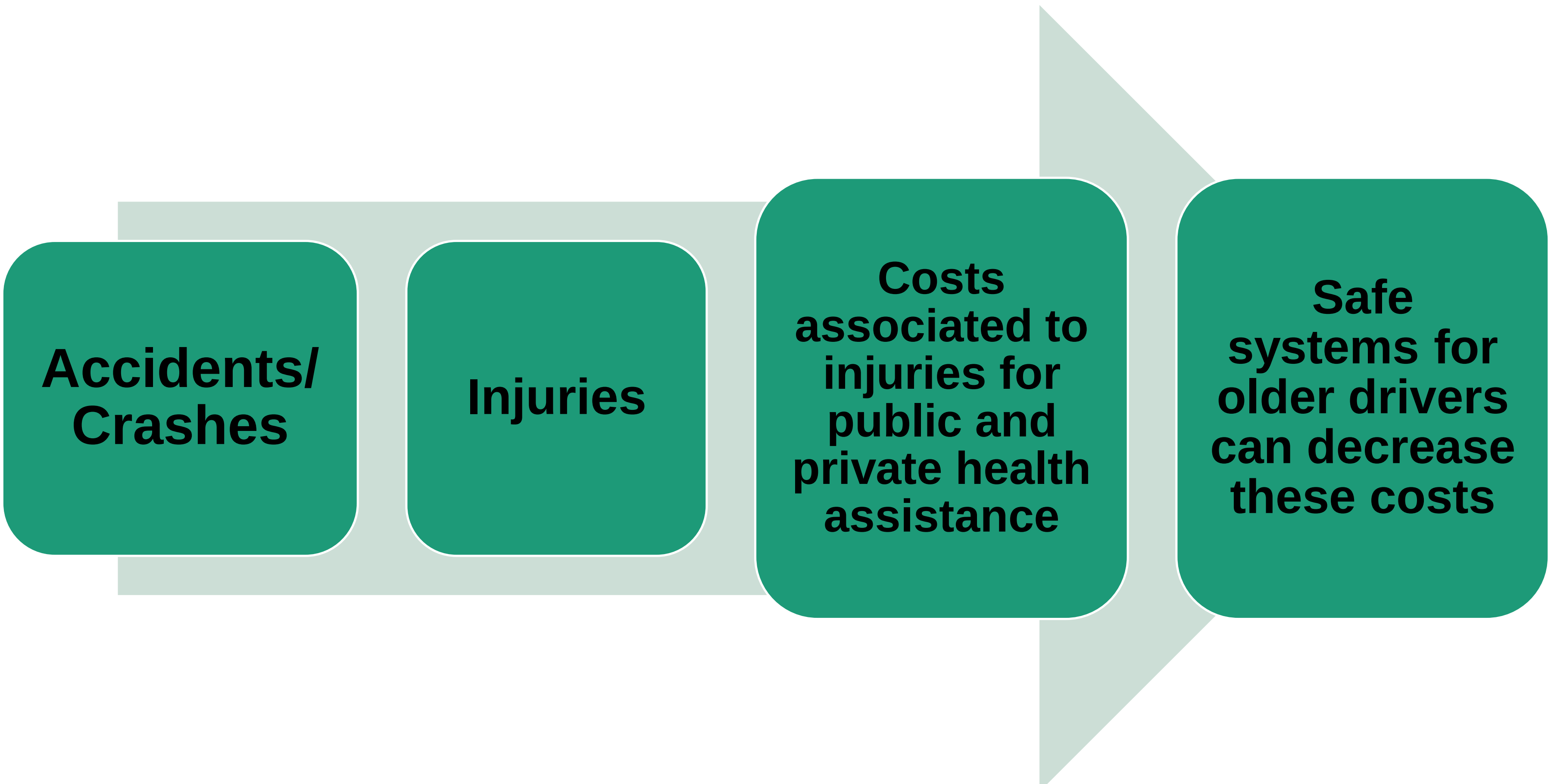
- **Safety and Mobility**
- **Highway System Factors**
- **Geometric and Informational Factors**

- **Design Guidance for Robotic Vehicles**
- **Adaptive Controller Units**

Business Planning for Older Drivers

Consequences of Accidents/Crashes

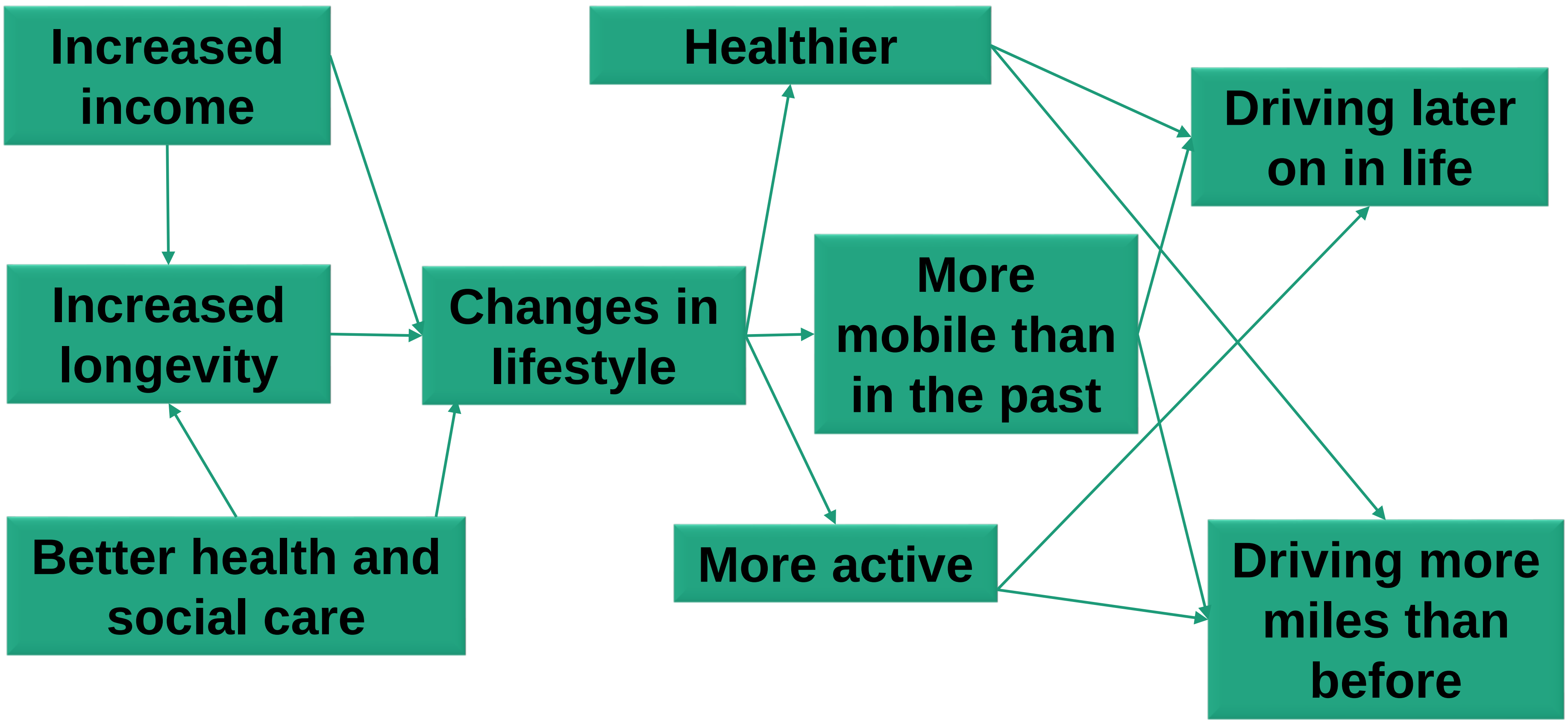
Key Idea: crash avoidance



Business Planning for Older Drivers

Older Driver Mobility Factors

Key idea: increasing number of older adults driving



(Based on Tomassini, 2004; Box *et al*., 2010)

Business Planning for Older Drivers

Consequences of Loss/Reduced Mobility

Key idea: Negative aspects of reduced mobility for older drivers

Driving loss/reduction could cause:

- Economic loss to society due to reduced spending
- Decrease in quality of life for the elderly
- Increased caregiver costs and caregiver's employer costs

(Based on Classen *et al*., 2011)

Influences of Highway System Design on Safety and Mobility

Based on AASHTO (2011) A Policy on Geometric Design of Highways and Streets

Key idea: Set speed concept

Issue: Vehicle speed setting in vehicle controller unit

- ✓Use recommended forward speeds in adverse driving conditions as the '**set speed**' to use in the controller unit
- ✓The **set speed** is the maximum speed allowed by the controller
- ✓**Set speed** changes depending upon the current location of the vehicle

Roadway factors (from map or knowledge-based information; assuming vehicle location is known)

Example		Situation		
Location	Roadway type	Traffic control	Design speed	Speed limit [Set Speed]
Exit Ramp	Rural Road	Signal	70	55

Influences of Highway System Design on Safety and Mobility

Based on AASHTO (2011) A Policy on Geometric Design of Highways and Streets

Key idea: Roadway design is a complex process

- **Lane Placement and Road Following:** continually performed both when no other traffic is present (singularly) or when it is shared with other traffic (integrated)
- **Car Following:** speed-control is involved – ACC example is helpful in the design process.
- **Passing Maneuvers:** more complex. Drivers must judge the speed and acceleration potential of their own vehicle, the speed of the lead vehicle, the speed and rate of closure of the approached vehicle, and the presence of an acceptable gap in the traffic – (robotic control challenges)
- **Sight Distances:** potentially dangerous situations must be preceded by enough sight distance for stopping or reducing speed (curves, obstacles, construction zones, intersections)

Influences of Highway System Design on Safety and Mobility

Based on AASHTO (2011) A Policy on Geometric Design of Highways and Streets

Key idea: real-time information flow between controller units and the infrastructure are needed for enhancing mobility & safety.

Based on "Traffic Control with Connected Vehicles", Prof. Henry Liu Copyright 2015-2016 University of Michigan, see Section titled "Application—INFLO".

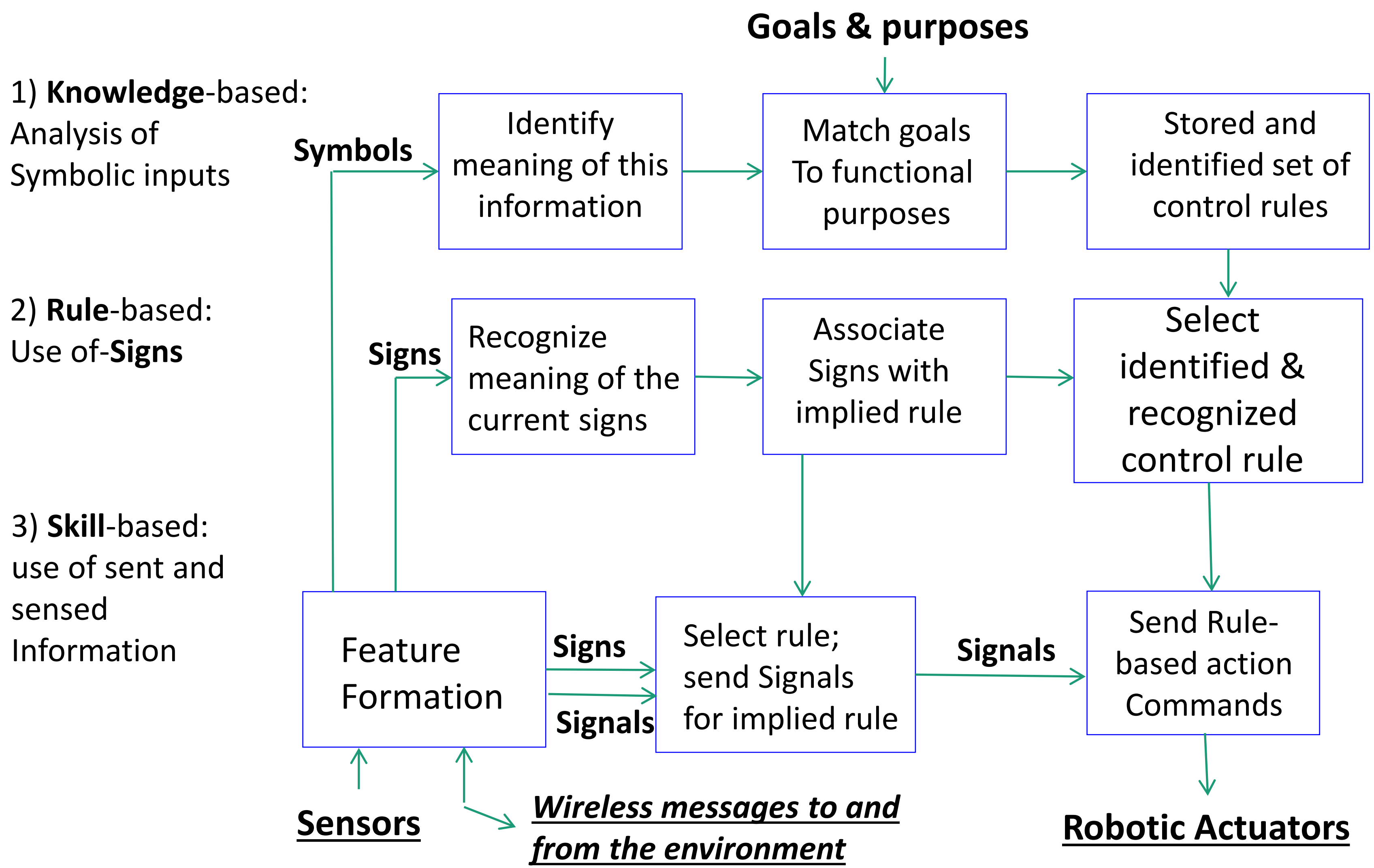
- INFLO involves information a driver cannot or does not observe independently. It describes an opportunity for improving the safety and mobility of the driving process through use of communication between the vehicle and the infrastructure.
- A vehicle equipped with a robotic controller-unit needs to know:

(1) pertinent real-time information from the infrastructure to aid in making complex safety and mobility related decisions and (2) it needs to transmit pertinent information on its location etc. to the infrastructure's communication receiver (in real-time, perhaps 10 communication cycles per second).

Guidance for Designing Controllers for Robotic Vehicles

Reference: Skills, Rules, and Knowledge; Signals, Signs, and Symbols; and Other Distinctions in Human Performance Models, Rasmussen , 1983, IEEE Transactions

[Apply Jens Rasmussen’s design philosophy to controllers for robotic systems]
---substitute “robotic controller” for “human” in the reference title



Guidance for Designing Controllers for Robotic Vehicles

Example: Adaptive Cruise Control System

Based on Fancher 2012 reference

FP, statement of functional purpose: e = R – Th V = 0

VA, vehicle/actuator dynamics model: Tv dV/dt + V = Vc

HT, here to there: Te de/dt + e = 0 (where e = R – Th V)

CR, control rule where R, dR/dt, and V are measured:

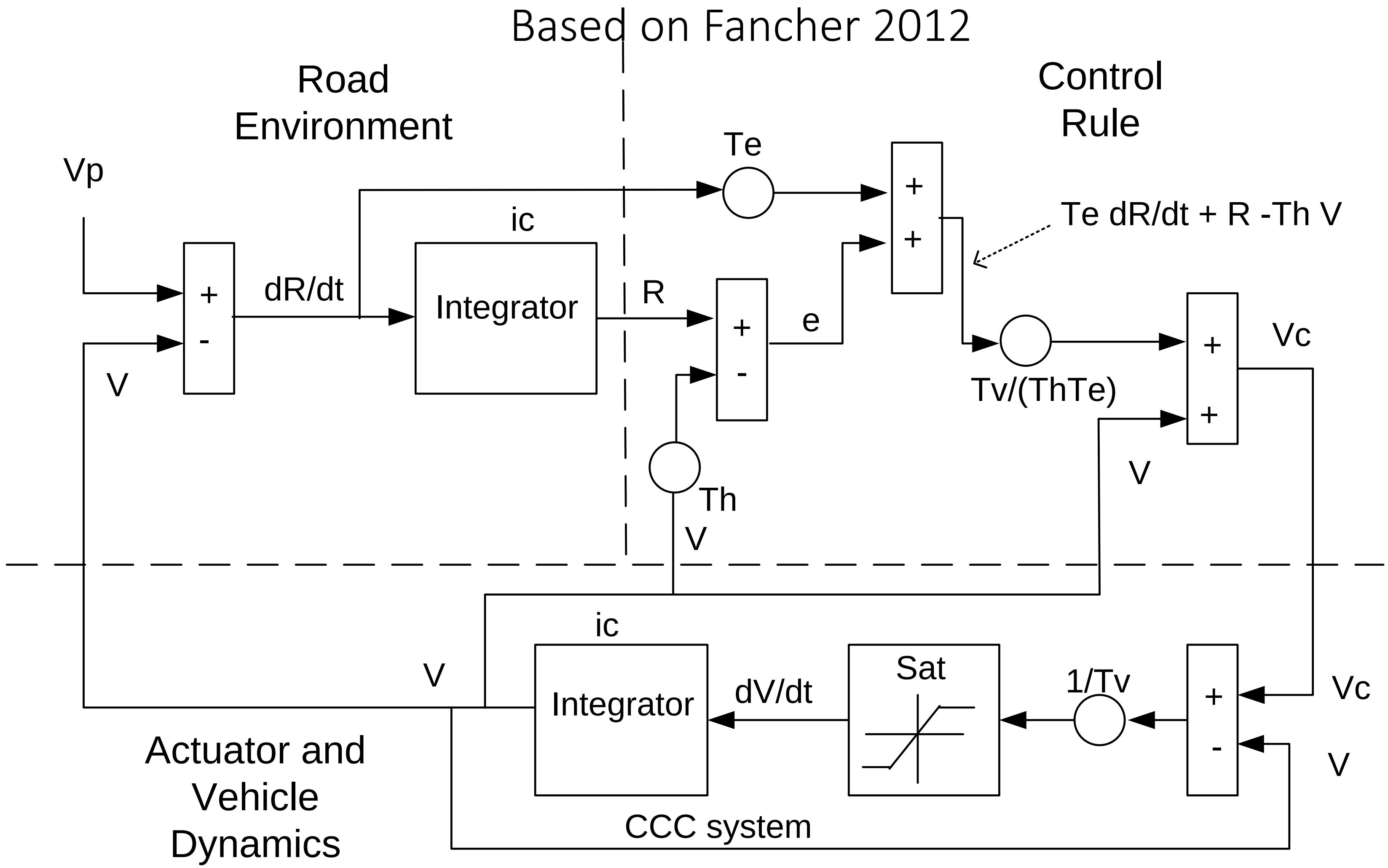
$$V_c = V + \left(\frac{T_v}{T_h T_e} \right) \left[T_e \dot{R} + R - T_h V \right]$$

RE, driving/road environment: $\dot{R} = V_p - V$

Guidance for Designing Controllers for Robotic Vehicles

Example: Adaptive Cruise Control System
--preceding vehicle velocity Vp less than Set speed = Vs

Based on Fancher 2012



Reference:

Guidance for Designing Controllers for Robotic Vehicles

Example: Adaptive Cruise Control System

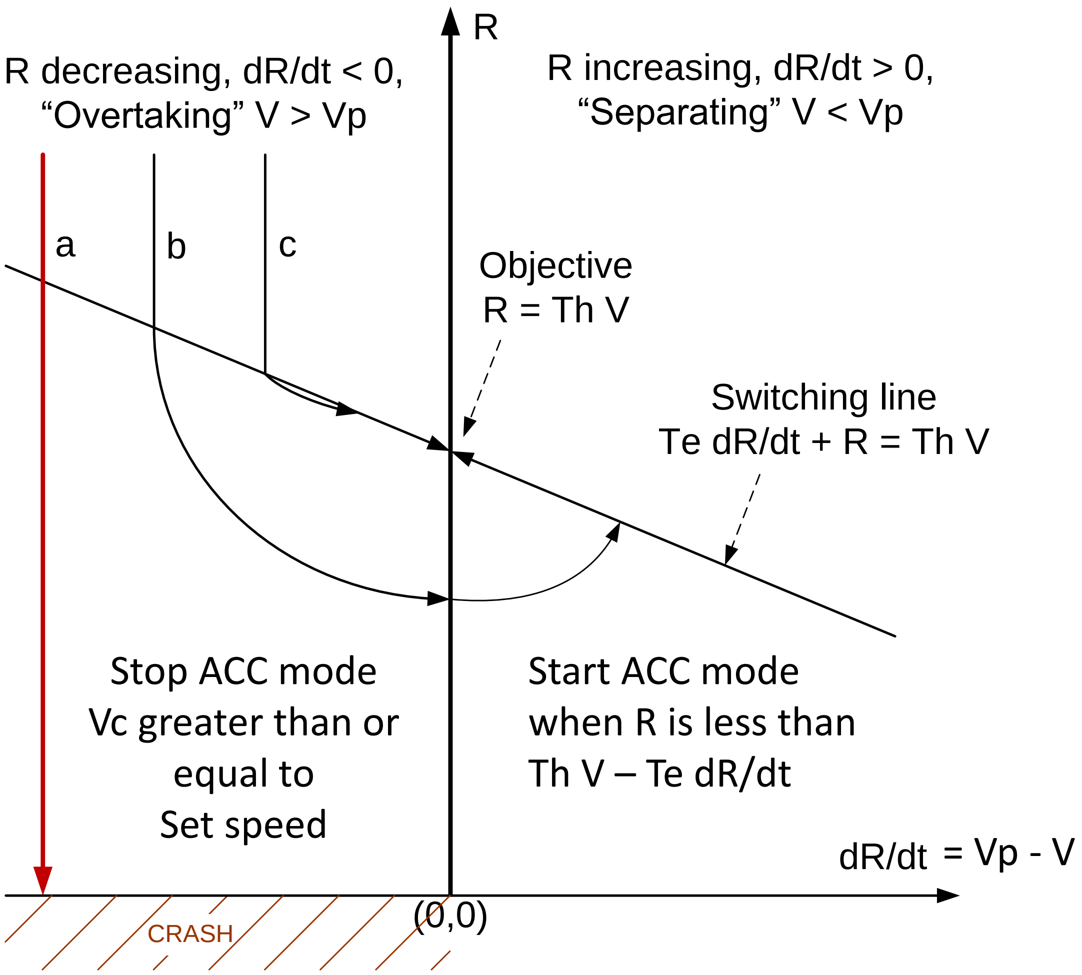
Based on Fancher 2012

Wisdom based on generalizing Slotine and Li, "Applied Nonlinear Control" 1991, Prentice-Hall; "Nonlinear Control Systems Design";

+ Feedback Linearization

+ Sliding Control

+ Adaptive Control



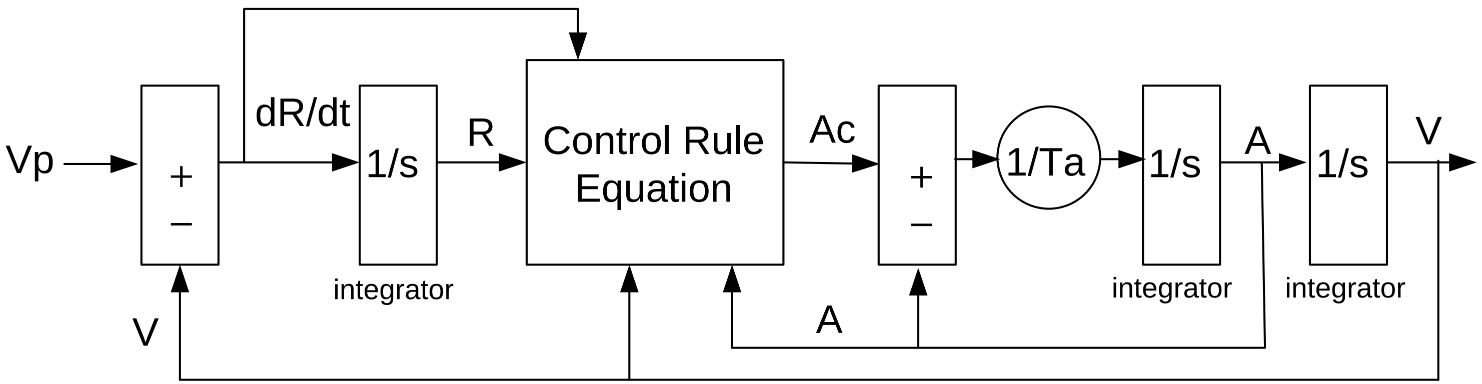
Guidance for Designing Controllers for Robotic Vehicles

Example: Adaptive Cruise Control System

Based on Fancher 2012

Vehicle String performance == no overshoot from vehicle to vehicle in the string.
--Means mitigating stop and go driving

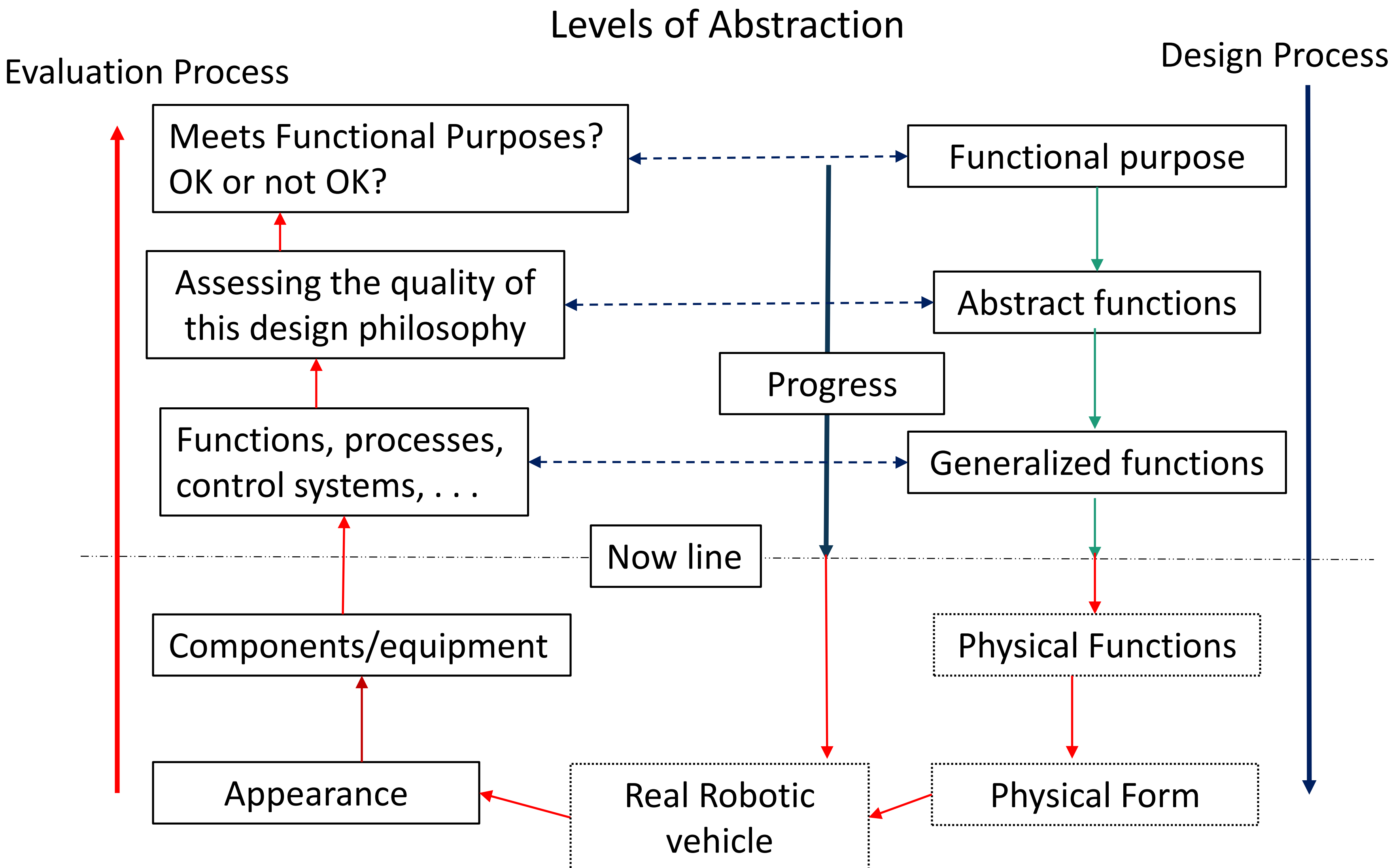
For $e = (R - Th\,V - K\,A)$ [Note: K A term]
and $de/dt = dR/dt - Th\,A - K\,(Ac - A)/Ta$
with the Control Policy $Te\,de/dt + e = 0$,
the Control Rule is: $Ac = A + (Ta/K)\,[dR/dt - Th\,A + e/Te]$



The result is: $Vp/V = 1/(Ks^2 + Th\,s + 1)$ and for no undershoot performance, we choose $K = Th^2/4$

Guidance for Designing Controllers for Robotic Vehicles

Based on generalizing Rasmussen's concepts of abstraction levels.



Concluding Statements

<u>Summary of Progress</u>: Information, Knowledge, and Wisdom; pursued through abstractions above Physical Functions and Forms. Resulted in “Guidance for Designing Controllers for Robotic Vehicles”. where the <u>actuators</u> of the robotic vehicle employ feed-back control and real-time sensor data.

<u>Next Steps</u>: **+** #1) the number of control rules as needed for avoiding crashes on trips. Apply our generalized design-philosophy to develop “Signs” indicating the control rule to use in specific situations. Expand control modes to cover directional plus translational dynamics. Simulate the overall driving process to evaluate and improve the design for each control mode. **+** #2) Extend Business Planning to treat the influence of Economic Factors on the Development of Autonomous Vehicles. **+** #3) Further examine knowledge pertaining to roadway information/data.

Pertinent Information Sources + References

Business Planning; sources of wisdom **+** References**: (**see footnotes at bottom of slides)

Knowledge and wisdom on roadway design policy **+** Reference: **"**A Policy on Geometric Design of Highways and Streets", 2011, 6th Edition, ISBN: 978-1-56051-508-1

ACC System; Vehicle Control Knowledge and wisdom **+** References: #1) Directional and longitudinal control; ["Road and Off-Road Vehicle System Dynamics Handbook",edited by G. Mastinu and M. Ploechl, copyright 2014, ISBN: 13:978-0-8493-3322-4]—(Chapters 39 and 40 pertain to Automatic lateral control and Longitudinal Control.) **+ #**2) ACC field operational testing; ["Intelligent Cruise Control (ICC) Field Operational Test, P. Fancher et al., UMTRI, Tech. Rept. DOT-HS-808-849, 1998]—Contains data analysis for 108 drivers.

Knowledge and wisdom on Implementing Mobility Transformation Systems; **+** References: #1) ["Dynamics of Heavy Duty Trucks" - lecture 22, "Implementing the Purpose" - "Knowledge-Based Functional Control of Highway Vehicles"], UMTRI: Mechanics of Heavy-Duty Trucks, The University of Michigan Center for Professional Development, Ann Arbor, June 4-7, 2012, Copyright 2012 Regents of the University of Michigan (021512) - (provides wisdom and knowledge on ACC system design), #2) ["Connected and Automated Vehicles Course for Automotive Engineers", Integrative Systems + Design, College of Engineering, University of Michigan, Oct. 19-22, 2015],--Copyrighted Handbook contains a comprehensive set of knowledge for engineering CAVs—email isd.engin.umich.edu/cav for information.

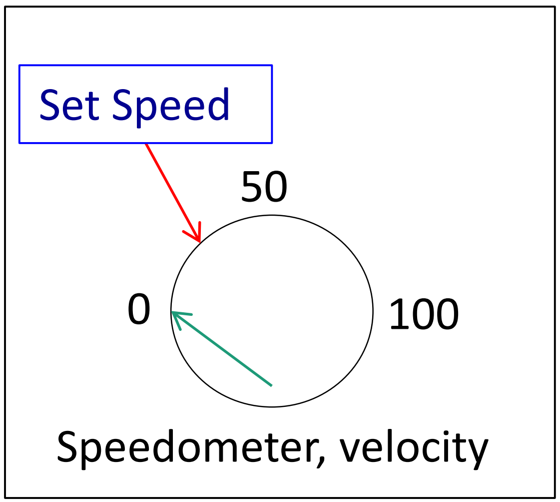
Knowledge and wisdom concerning communication between vehicles and the infrastructure system **+** Henry Liu, INFLO; (see reference on slide)

Knowledge and wisdom applied to maneuvering at limit performance to avoid crashes **+** Slotine and Li, "Applied Nonlinear Control"; (see reference on slide)

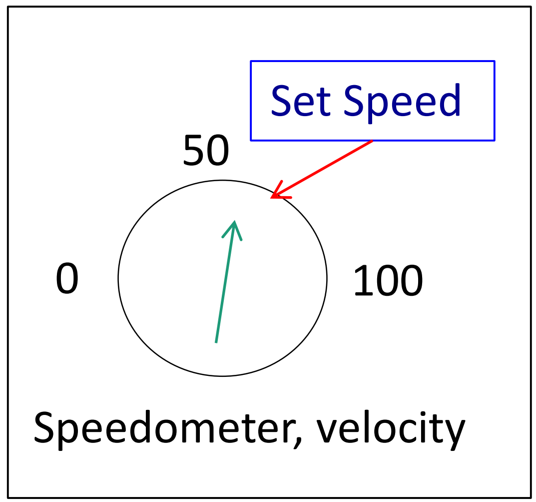
End for Now

Guidance for Designing Controllers for Robotic Vehicles

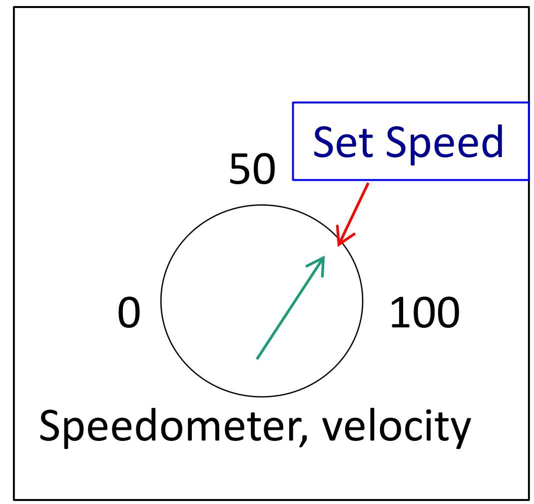
Based on Rasmussen



Start up velocities, accelerating



Closing in on a leader traveling slower than your vehicle's Set Speed or decelerating for safety and mobility reasons



Traveling at a safe velocity