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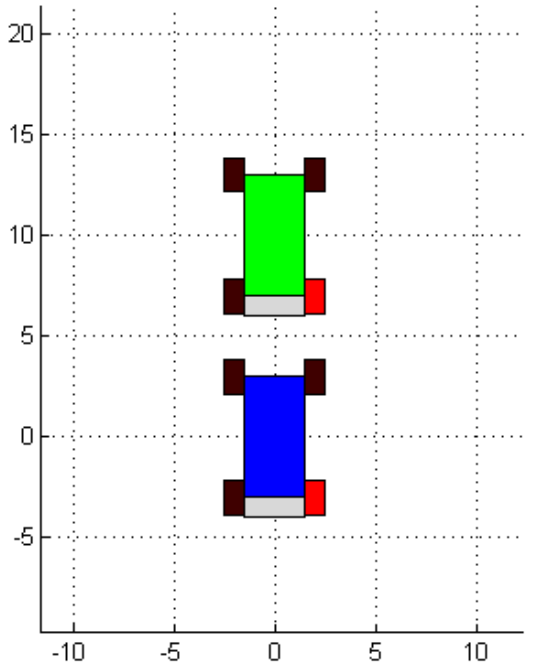
UCDAVIS

04/07/2009

Outline

- Motivation & Background
- Behavioral Schema
  - Subsumption
  - Boids
- The Automobile
- Results



"In 2006, there were an estimated 5,973,000 police-reported traffic crashes, in which 42,642 people were killed and 2,575,000 people were injured."

- NHTSA 2008 Report

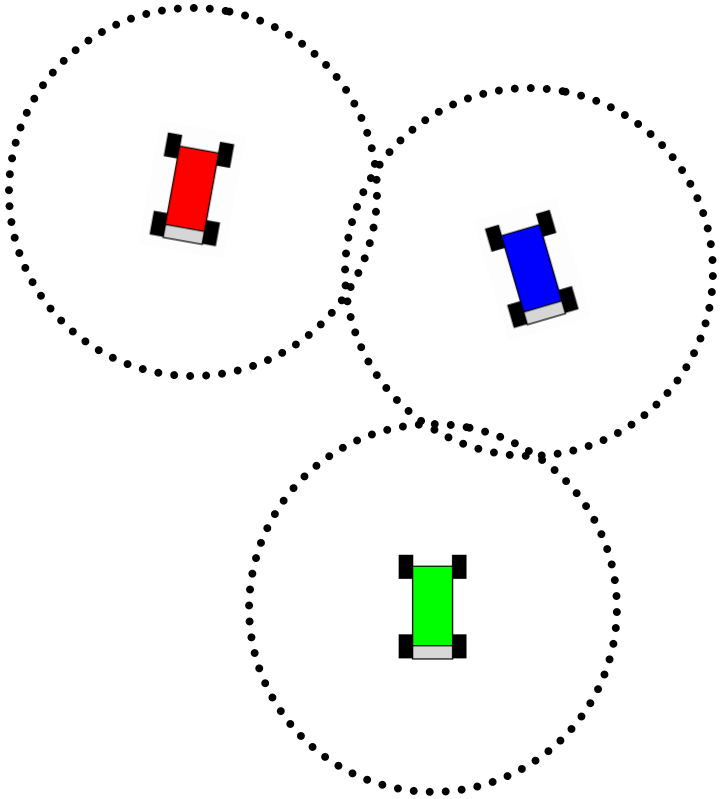
- **Societal Factors**
  - Increased average freeway speeds
  - More time spent on the road commuting
  - Rising energy costs

- **Enabling technologies**
  - OBD
  - ABS, TC, cruise/stability control
  - Increased mobile computational power

Vehicle Infrastructure Integration

Ad-hoc wireless network

- Dedicated Short-range Communications (DSRC)
- 802.11p: Wireless Access in Vehicular Environments (WAVE)



Data rate	3-27Mbps
Range	< 1 km
Mobility	> 60 mph
Channel Width	10 Mhz
Operating Band	5.86 - 5.92 GHz

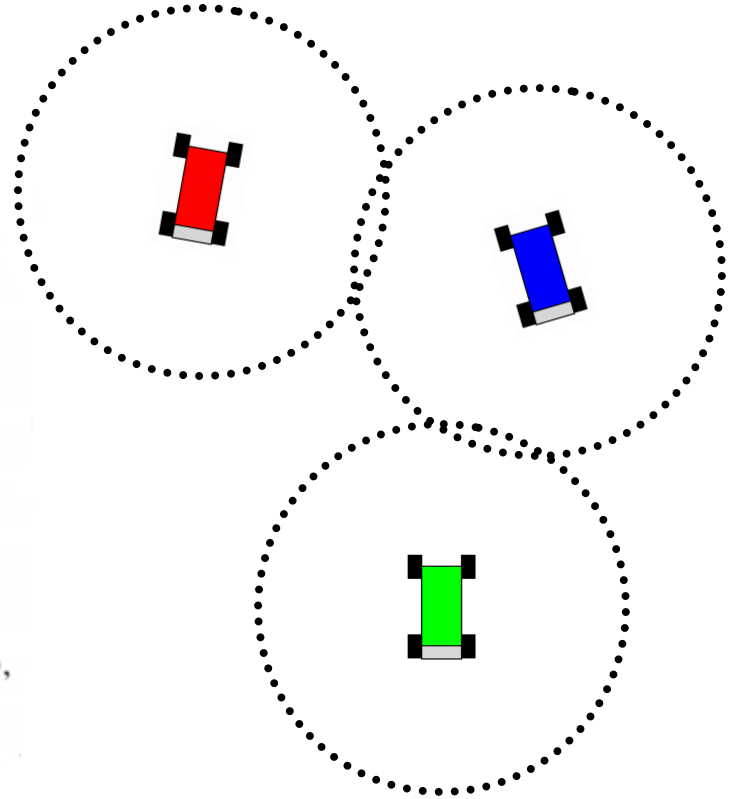
Vehicle Infrastructure Integration

protocol stack

APPLICATION	Layer 7
PRESENTATION	Layer 6
SESSION	Layer 5
TRANSPORT	Layer 4
NETWORK	Layer 3
DATA LINK	Layer 2
PHYSICAL	Layer 1

IEEE P1609
WAVE

IEEE 802.11p,
ASTM 2213
DSRC



Mercedes-Benz

Emergent Behavior

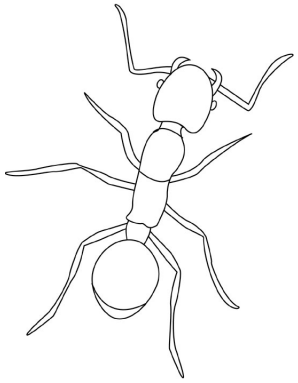
The arising of novel and coherent structures, patterns and properties in complex systems.

simple local rules, applied to multiple agents

=

complex global response

Litchfield National Park, AU



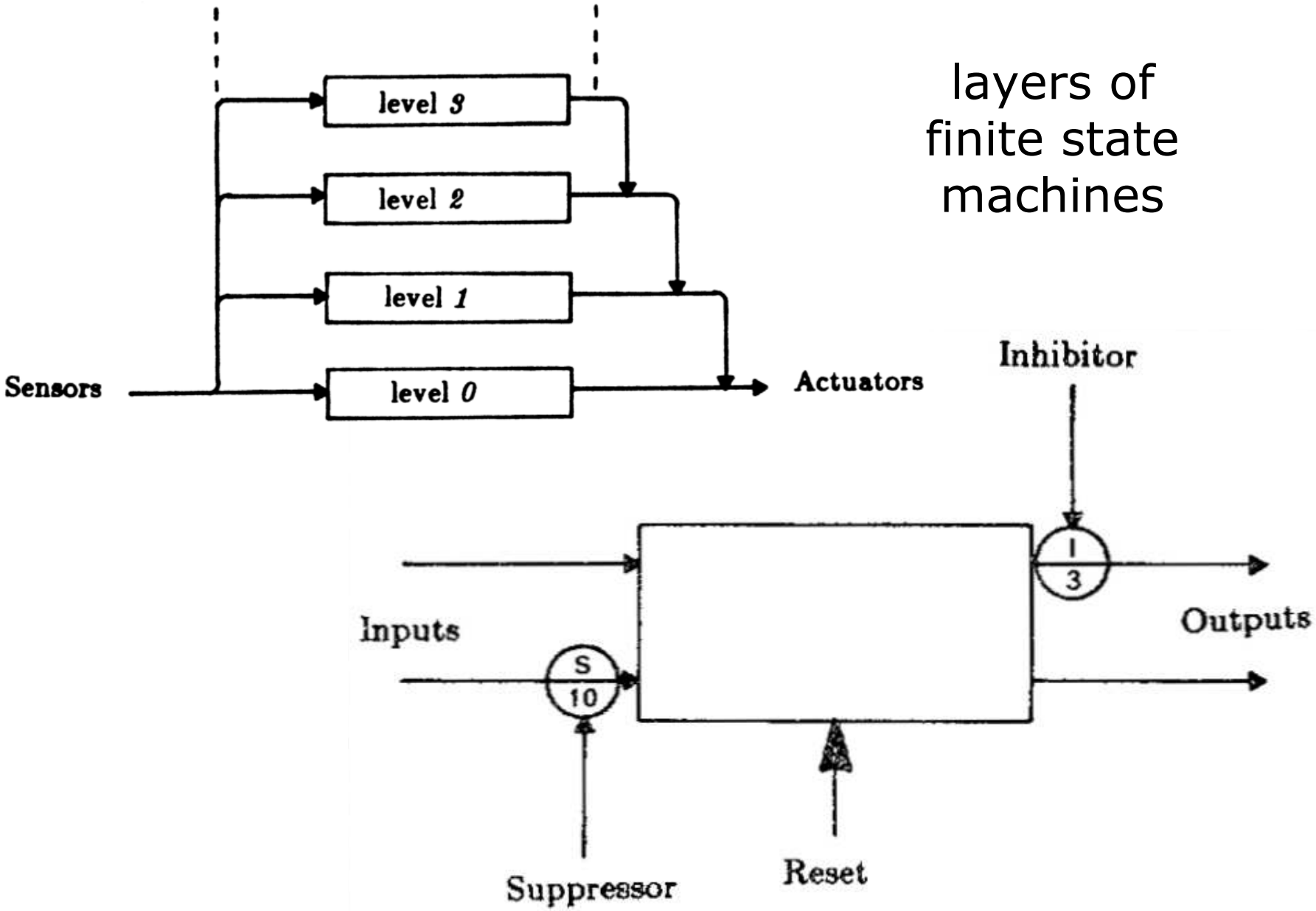
Subsumption

THE WORLD IS ITS OWN MODEL.

- Don’t try to control the robot, try to feel how the world is going to control the robot.
- Vertical task decomposition

Close connection between sensors and actuators—as opposed to a serial, deliberative approach.

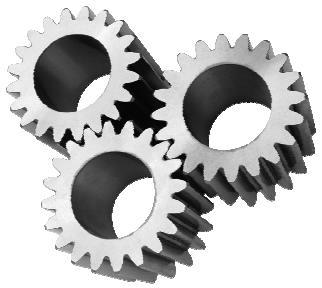
layers of finite state machines

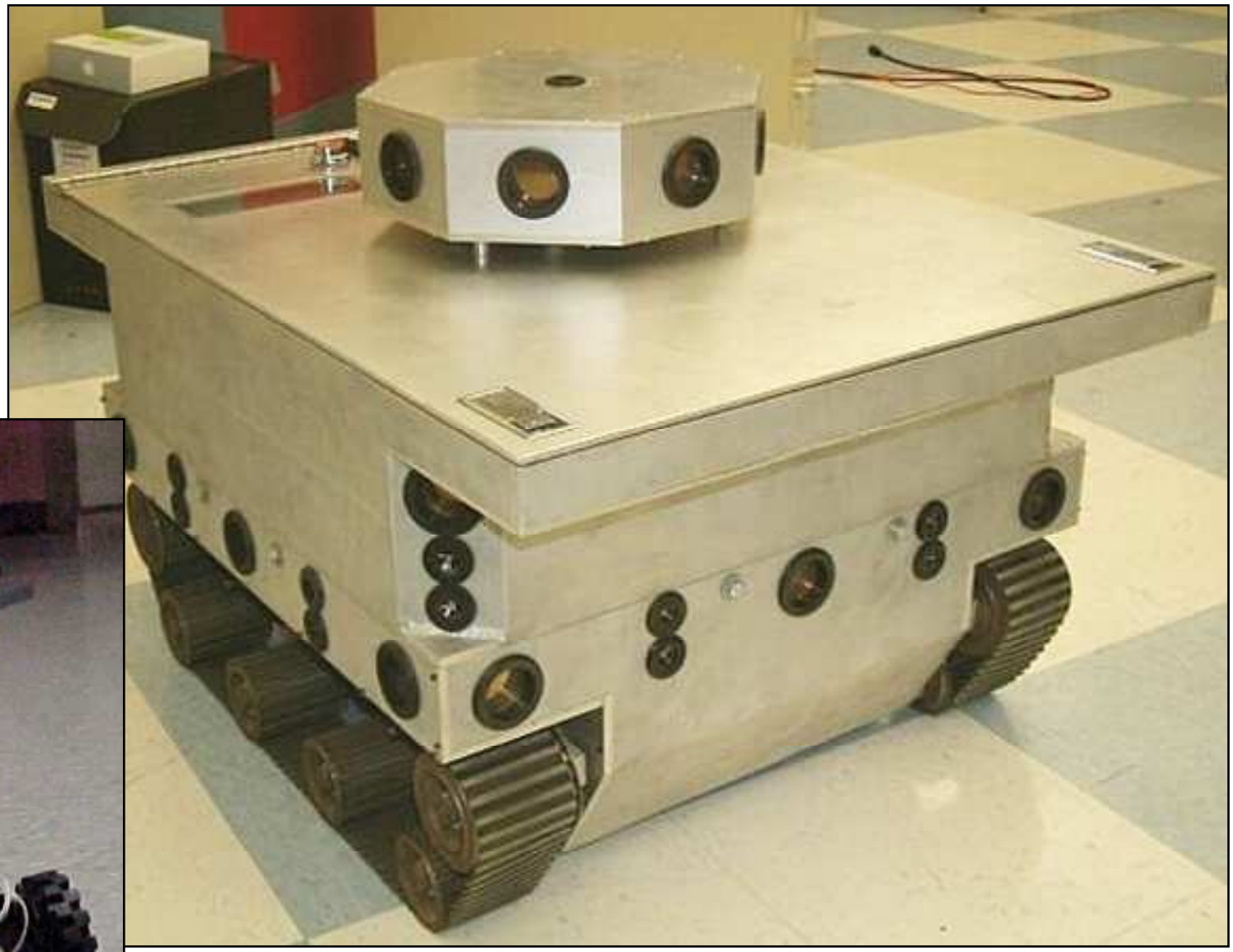


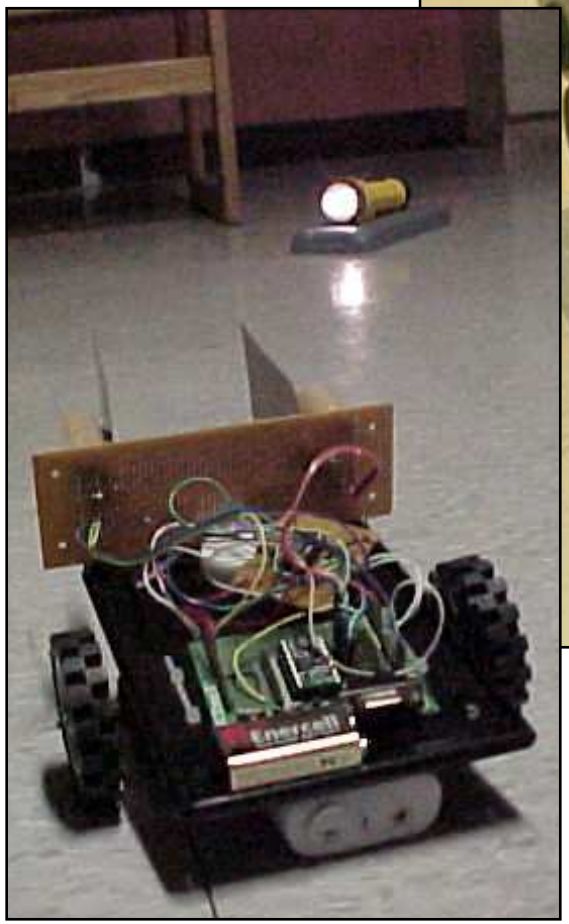
Subsumption

(subsumption is) **modularized:**
+ easier to modify, design & understand

(other architectures are) **centralized:**
+ interfacing easier, no duplicate functionality

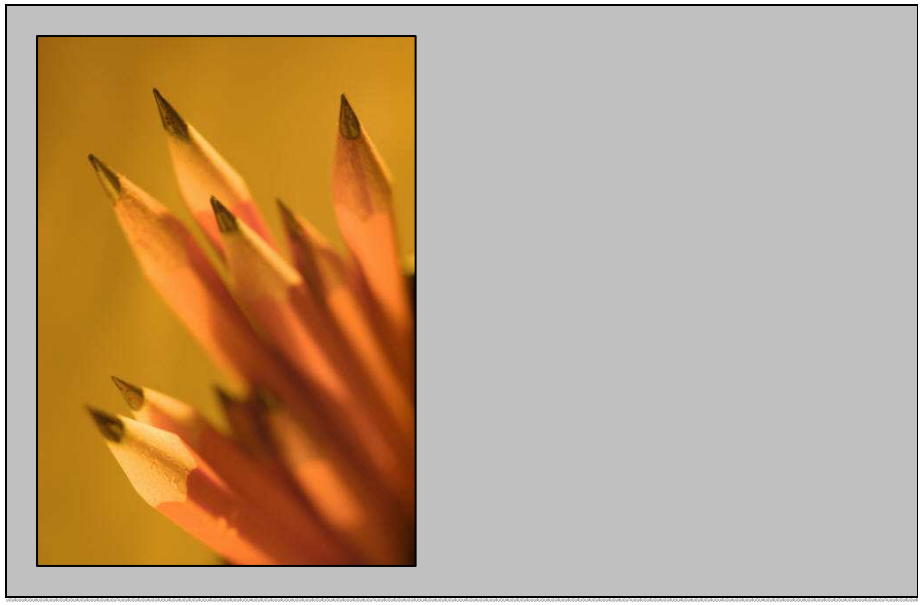






Subsumption Problems

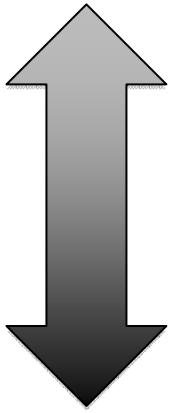
- No planning (?)
- Learning (?)
  - Fixed goals
  - Independent goals
  - Not taskable



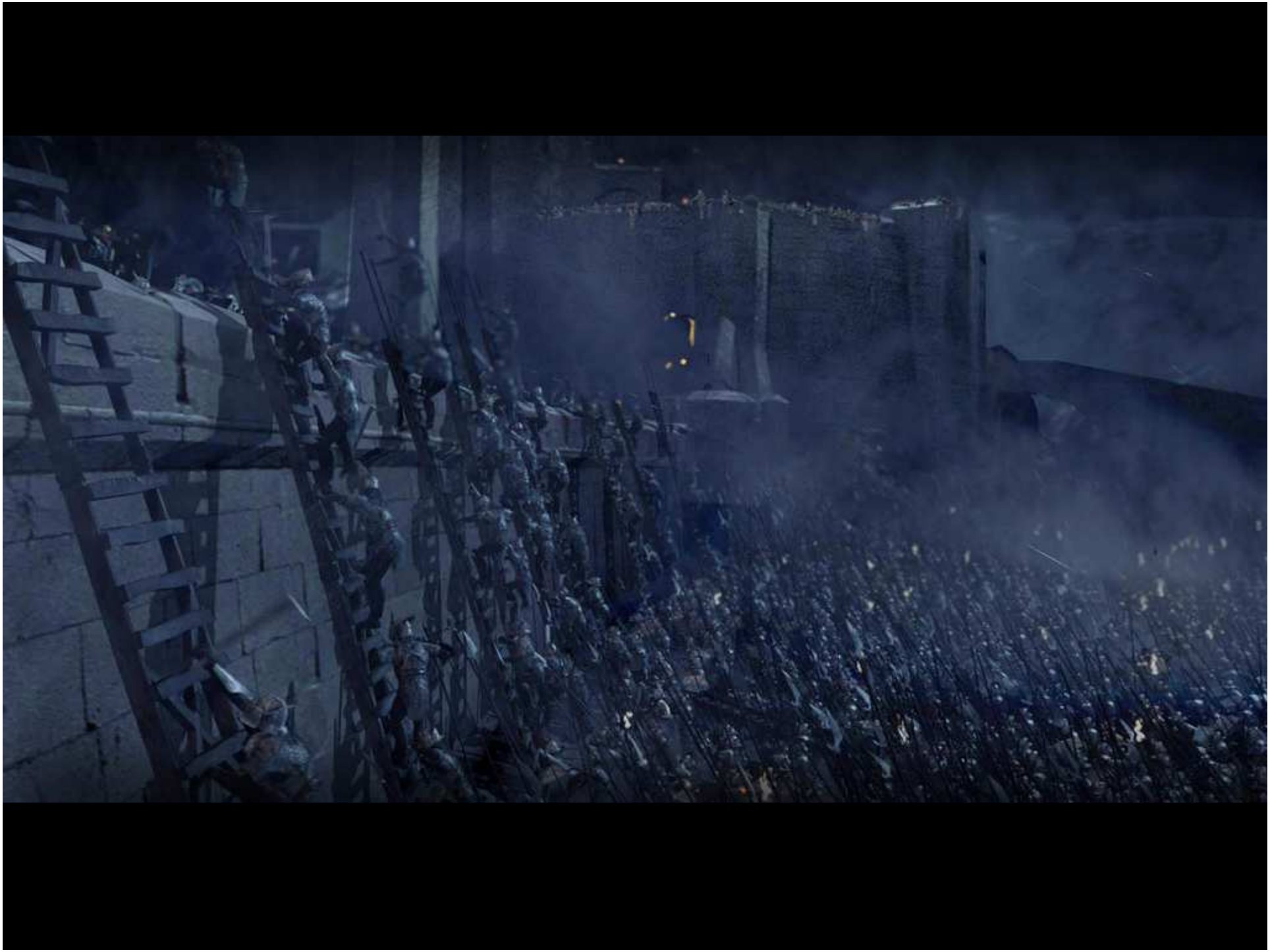
- Scaling
- Sensing barrier—as compared to animals
- Discrete nature

A Subsumption Question

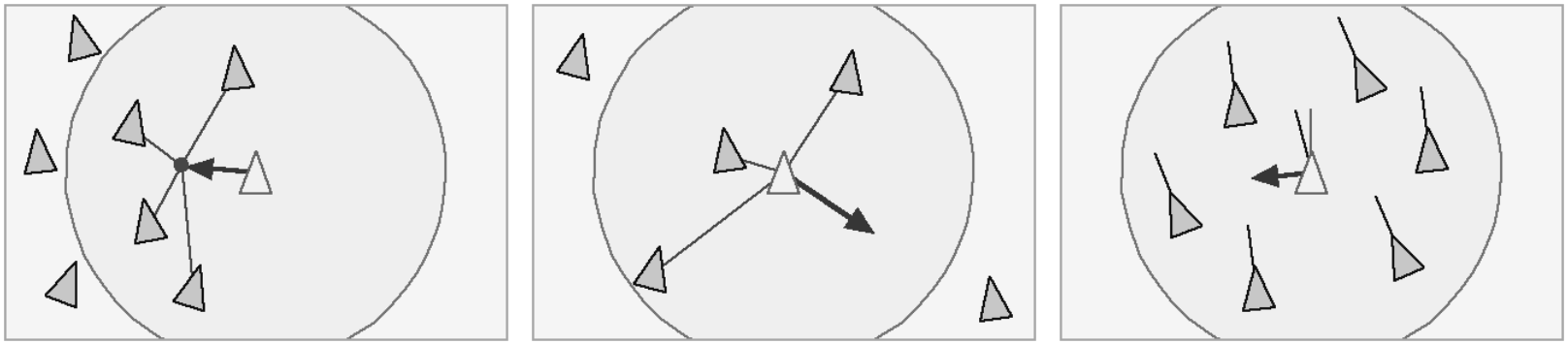
Given a particular set of rules, what global behavior emerges when agents are combined?



How does one synthesize a set of rules to accomplish a particular group task?



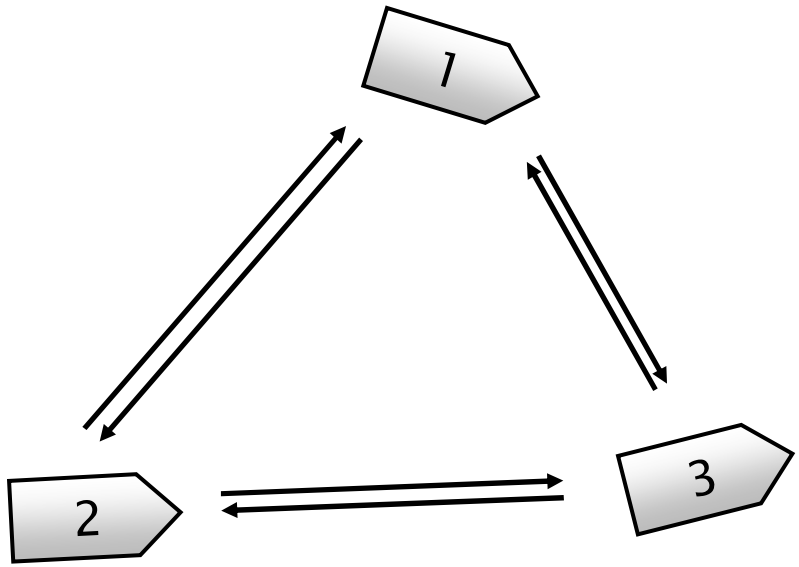
cohesion **separation** **alignment**



BOIDS: prioritized allocation

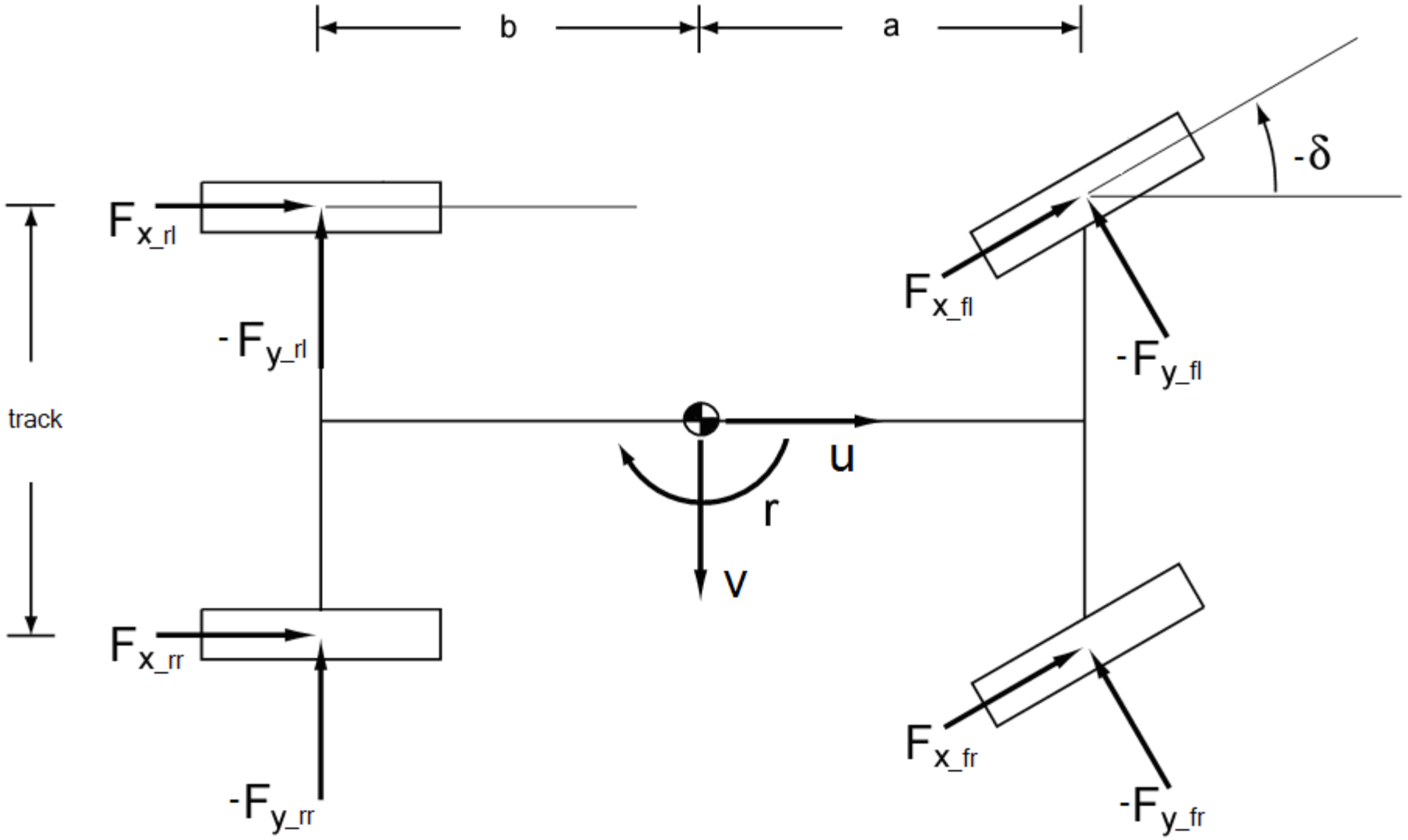
Q: Given aggregate state information, how does one enforce *road holding* & *collision avoidance*?

A: A hierarchal arrangement of passive, virtual force-generating elements.



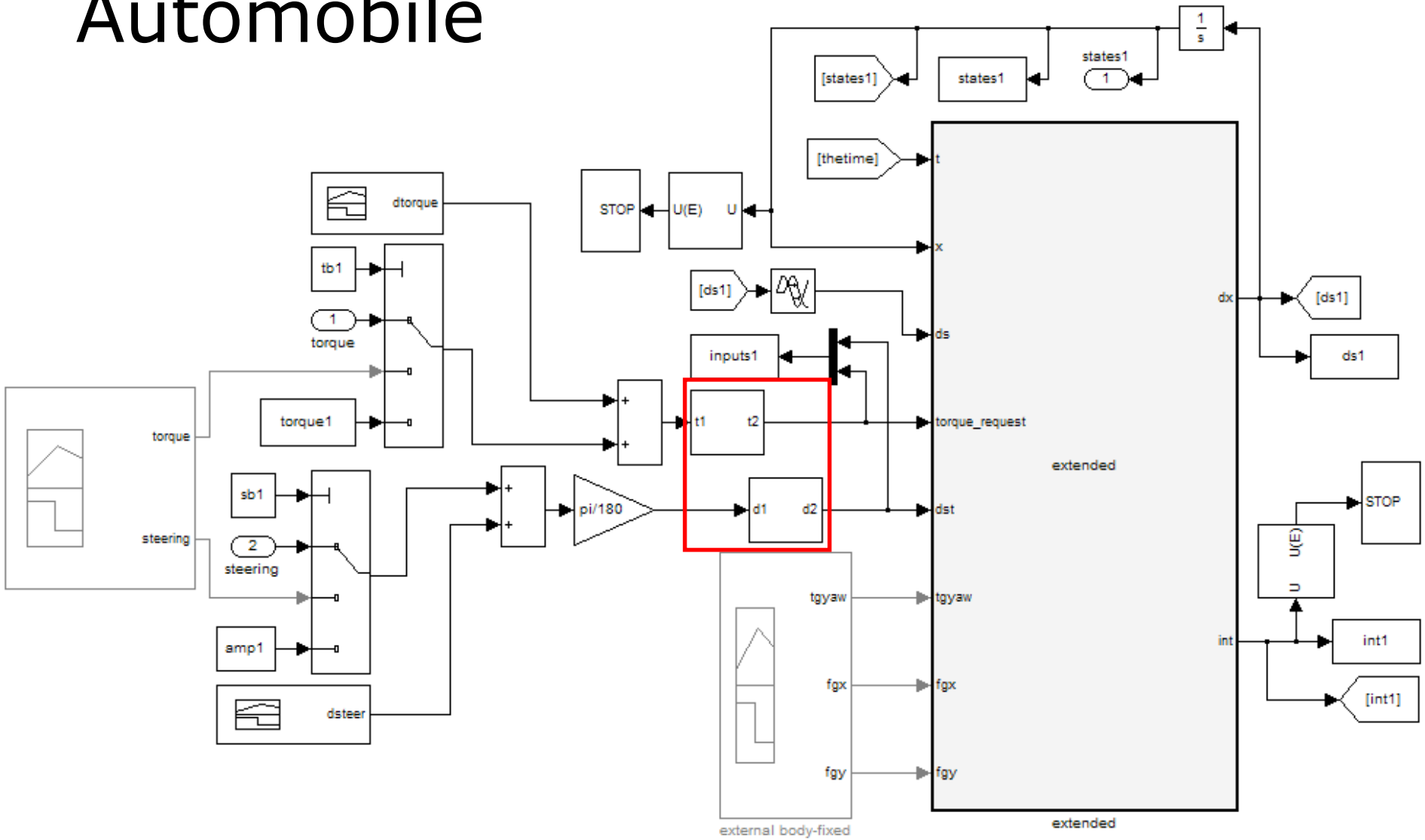
Objectives

- Identify *effective error signals*
  - Generalized (no heuristics, binning or logic)
  - State-based
- Address platform & energy limitations
- Account for heterogeneous agents

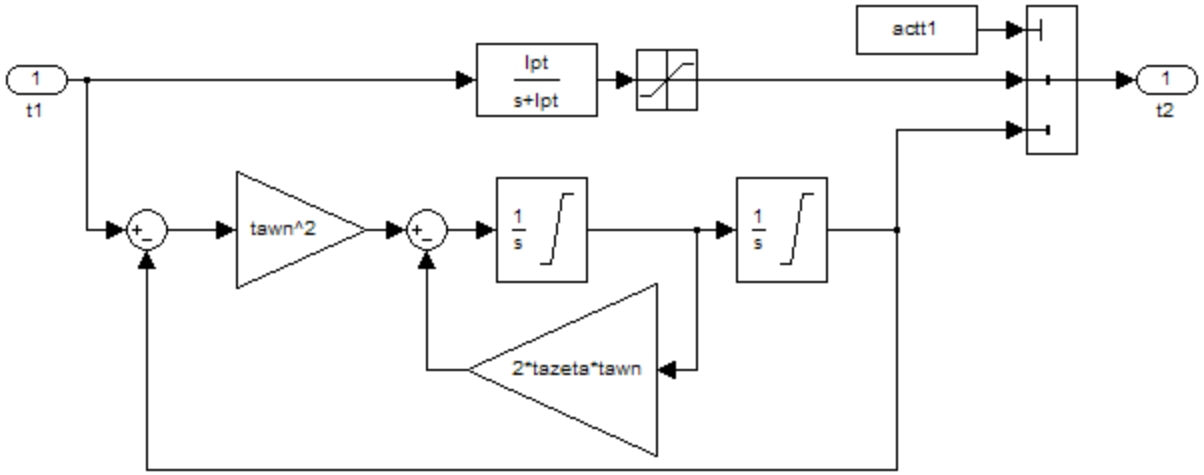


$$\vec{x} = \begin{bmatrix} u & v & \Psi & r & X & Y & \omega_{fl} & \omega_{fr} & \omega_{rl} & \omega_{rr} \end{bmatrix}^{\mathrm{T}}$$

Automobile


1
s
states1
1
[states1]
states1
[thetime]
t
STOP
U(E)
U
x
dtorque
tb1
1
torque
[ds1]
ds
dx
[ds1]
inputs1
ds1
torque
torque1
t1
t2
torque_request
extended
sb1
2
steering
pi/180
d1
d2
dst
STOP
U(E)
U
tgyaw
tgyaw
amp1
int
int1
fgx
fgx
[int1]
dsteer
fgy
fgy
external body-fixed
extended

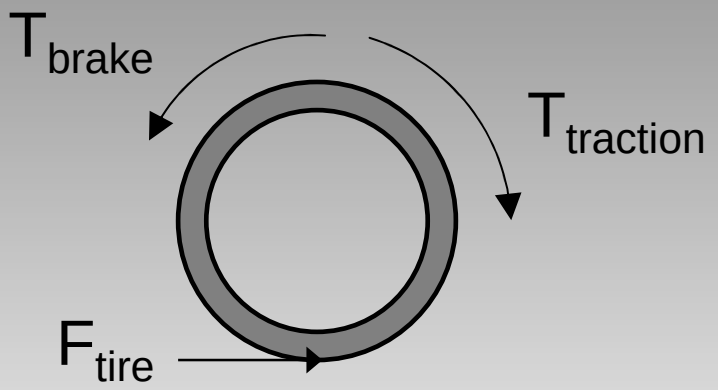
Actuator



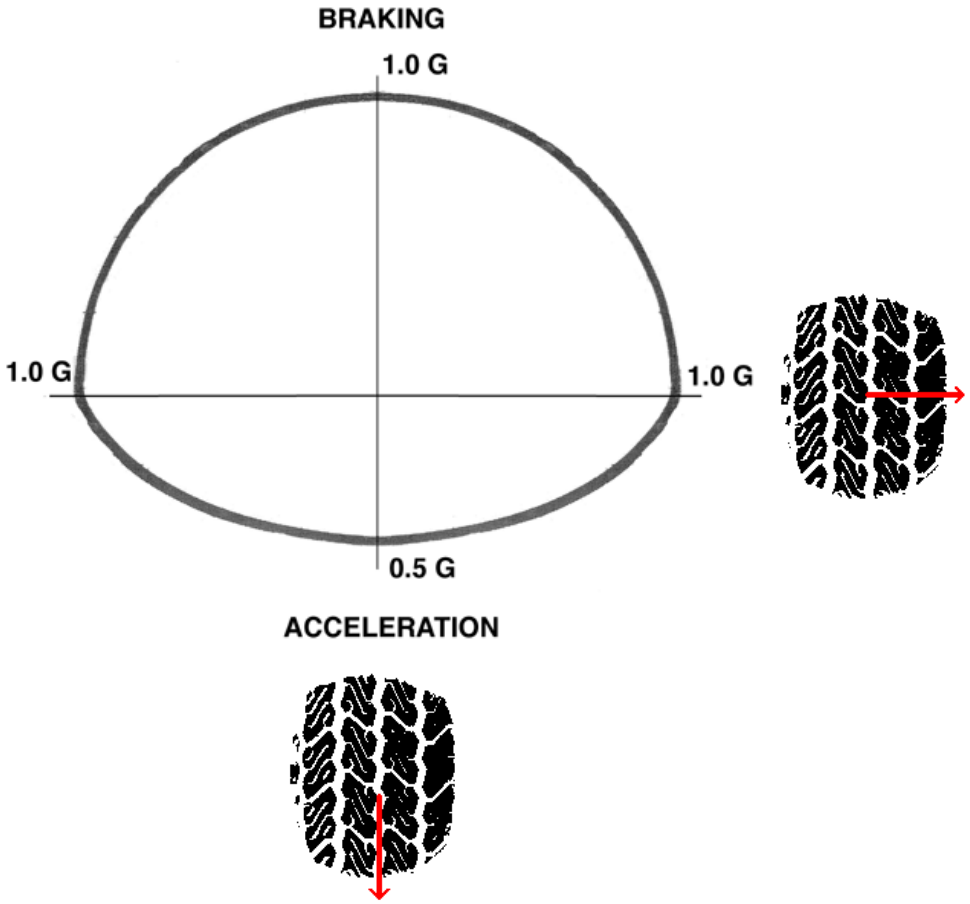
$$\frac{\delta}{\delta_c}(s) = \frac{K\omega_n^{\,2}}{s^2 + 2\zeta\omega_n s + \omega_n^{\,2}}$$

Wheels

$$\frac{d\omega}{dt} = \frac{1}{I_t}\left(\frac{T_t}{2} - \frac{T_b}{2} - F_{tire}R_{tire}\right)$$

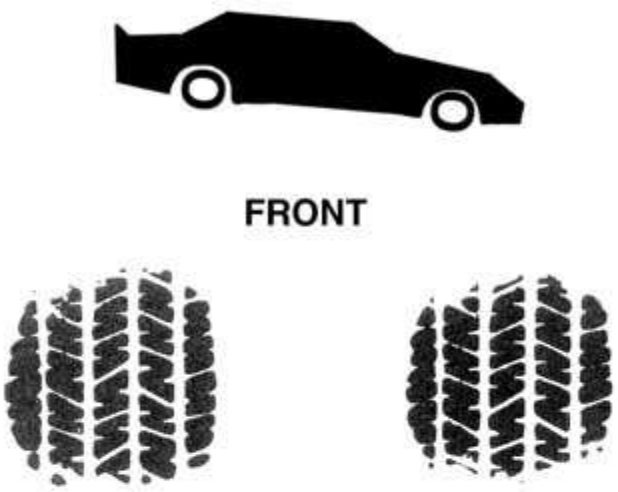


Friction Ellipse

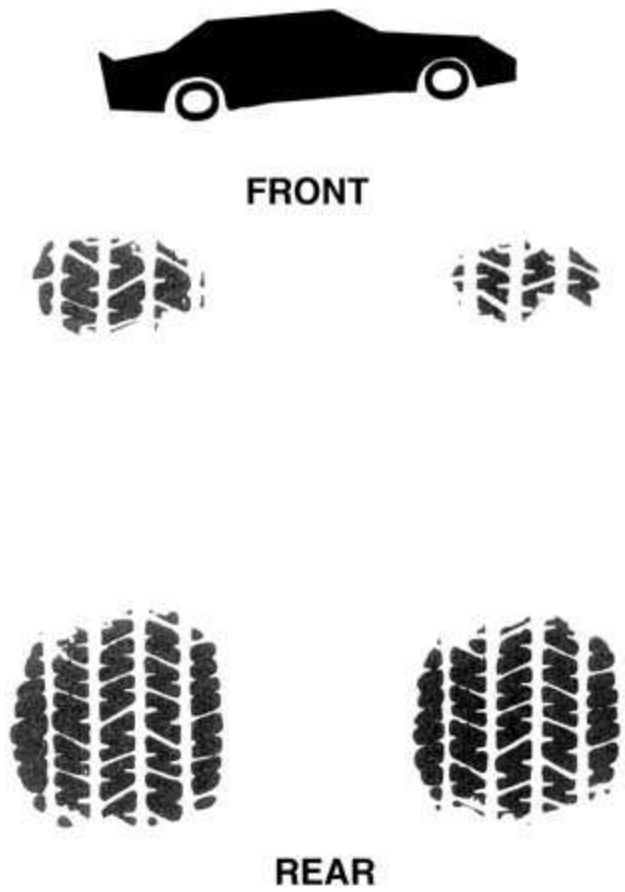


STATIC

BRAKING



ACCELERATION

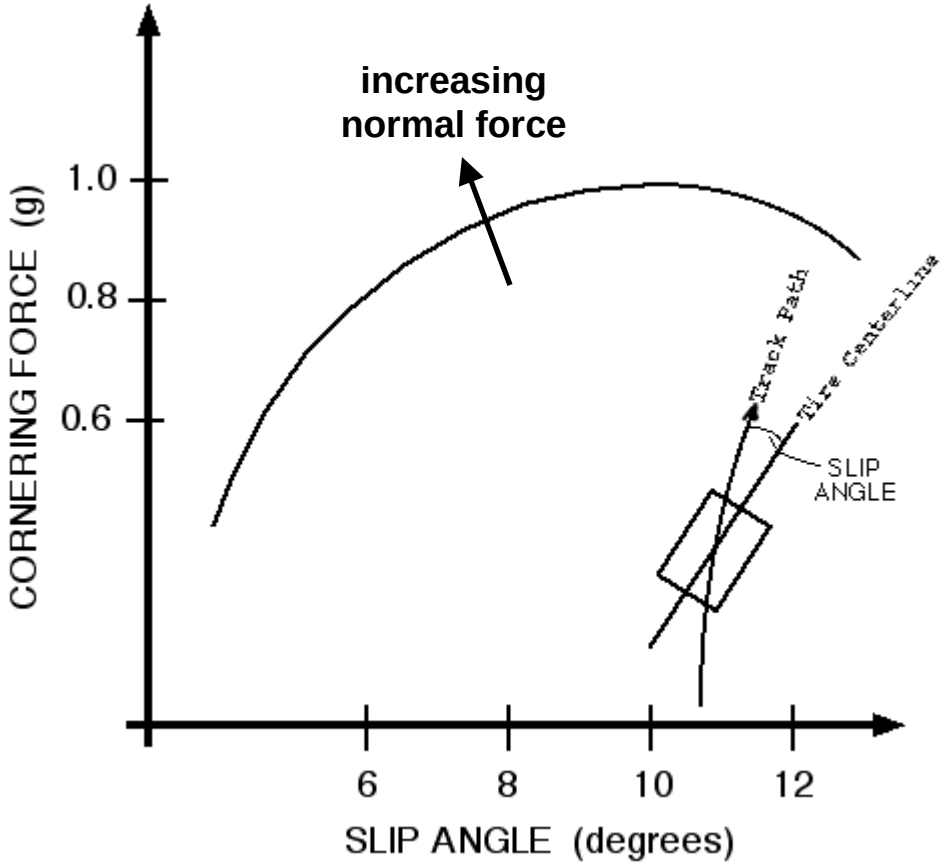


RIGHT TURN

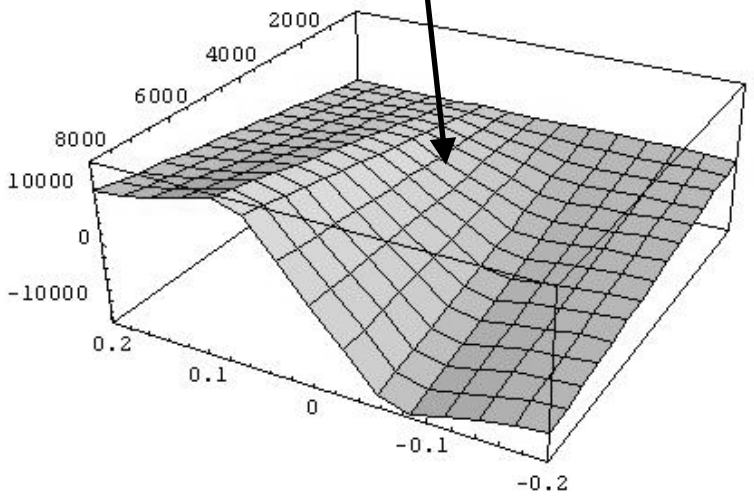
FRONT

REAR

Magic formula



OMG--no empirical model exists to reproduce this.



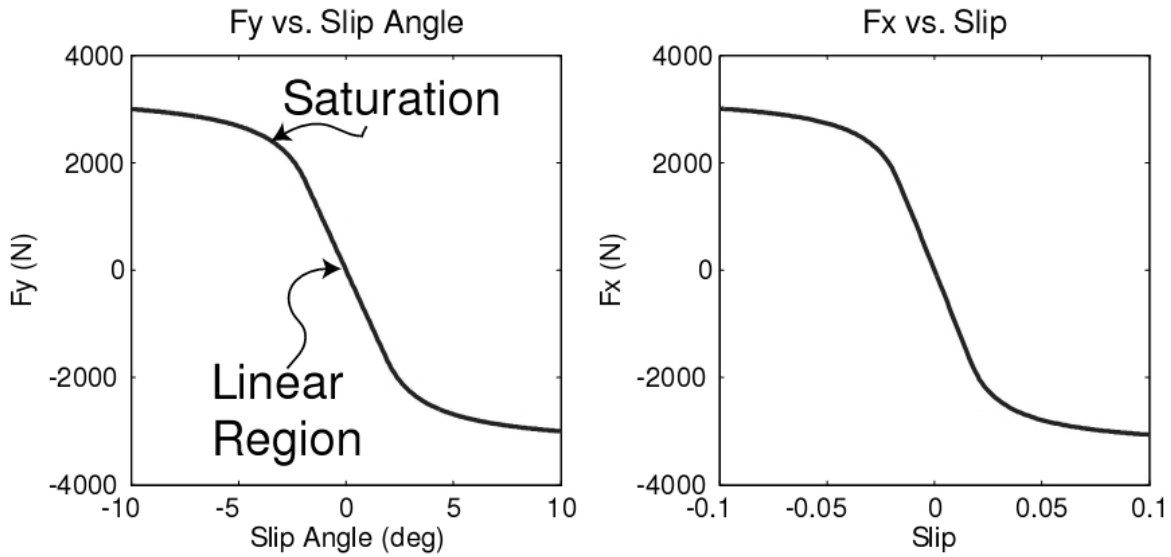
No force can be generated without wheel slip and/or slip angle.

Tires

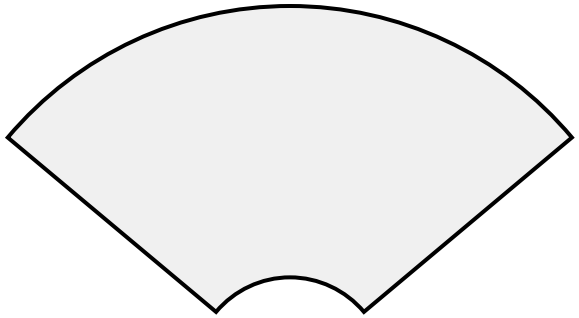
inputs:
tire stiffness
normal load
slip angle
wheel slip

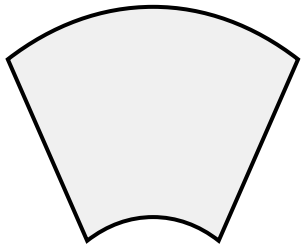
Non-linear Dugoff Tire Model

outputs:
F_x and F_y



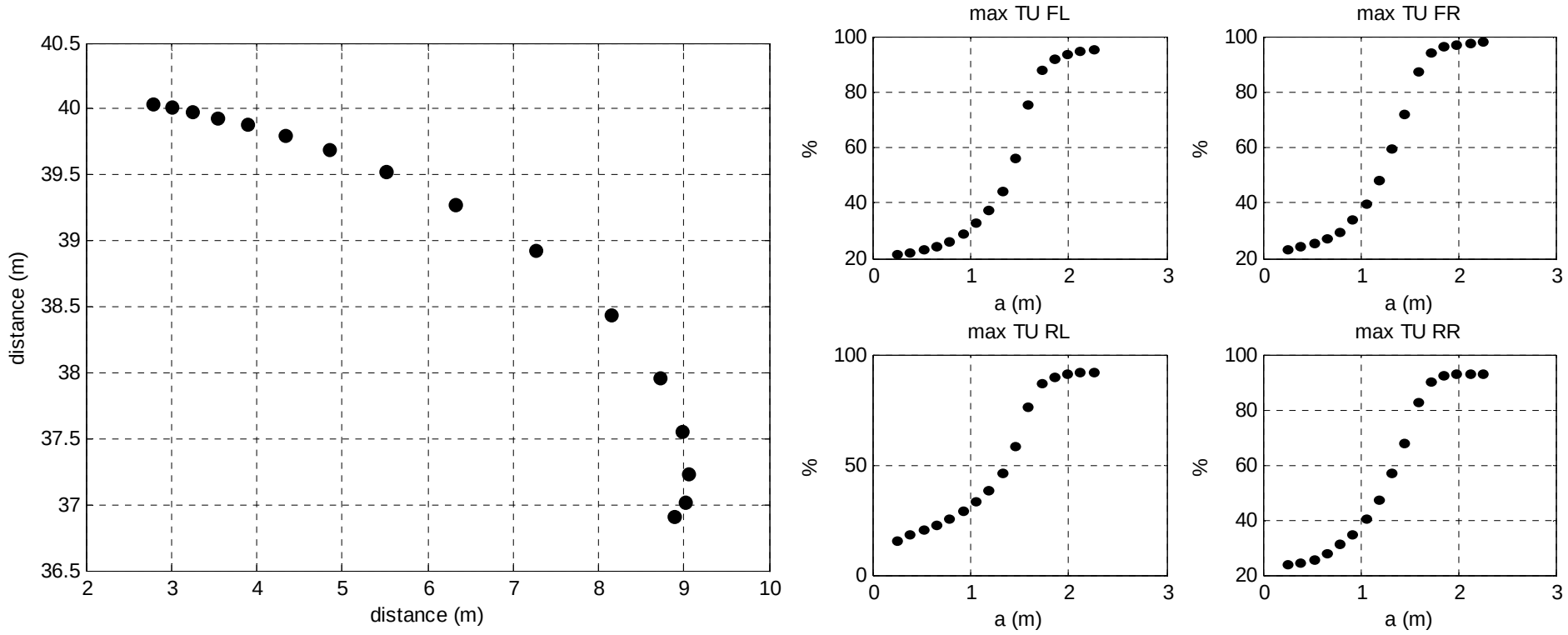
Let’s call it ‘capability’

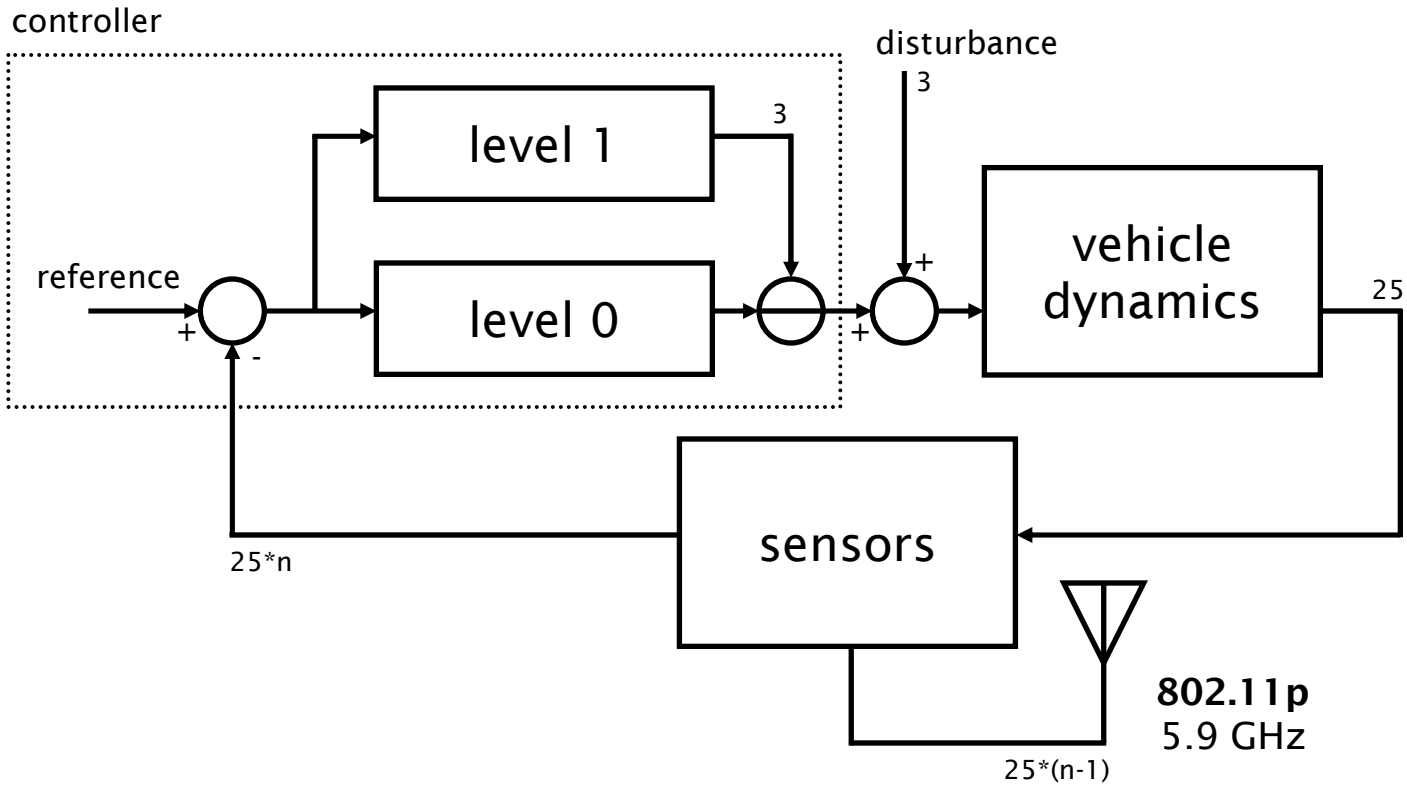




Effect of Weight Distribution

2-second map: 20 m/s, 30º steered input (wheel)
a = [10%, 80%] of wheelbase in 15 steps

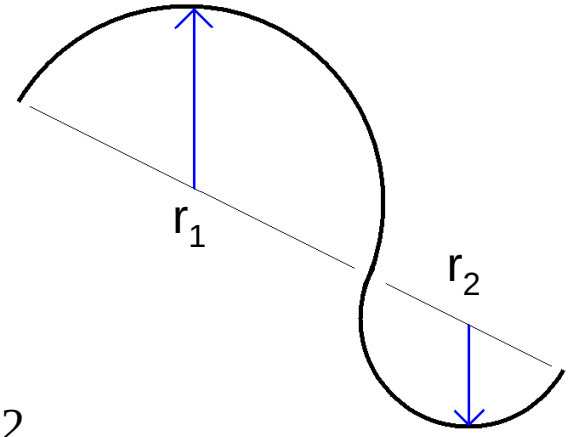




level 0: vehicle-road
level 1: vehicle-vehicle

Primary behavior (level 0)

- Vehicle-road interactions
  - curve over speed control
  - lane departure mitigation

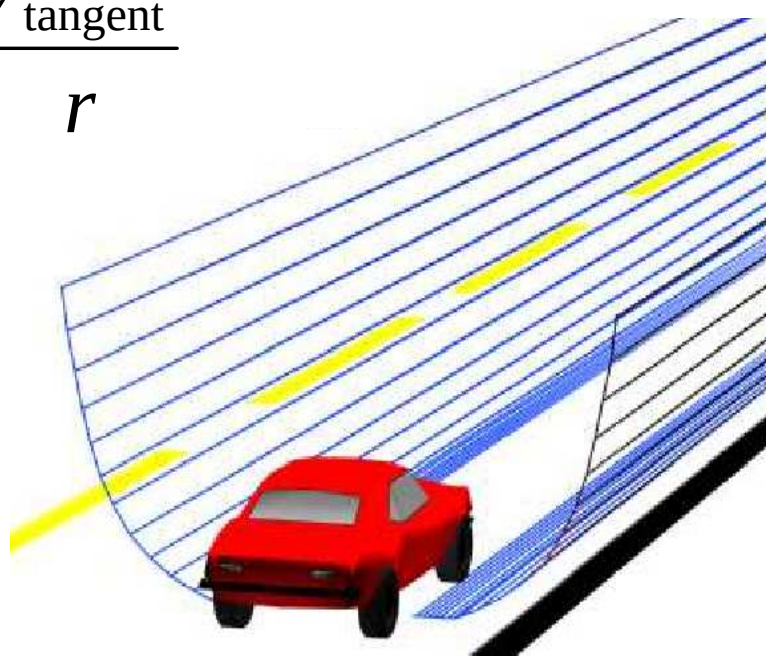


$$v_f^2 = v_i^2 + 2ad$$

$$v_f = v_i + at$$

$$d = \frac{1}{2}at^2 + v_i t + d_0$$

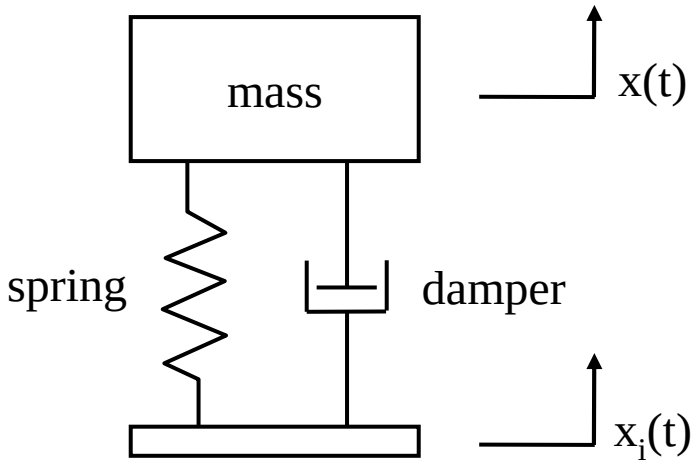
$$a_{lateral} \stackrel{?}{=} \frac{v_{\text{tangent}}^2}{r}$$



Secondary behavior (level 1)

- Vehicle-vehicle interactions
  - virtual springs and dampers form network
  - physical interpretation resembles distributed system
  - free-length/low-energy configuration exists
  - intrinsically stable

nodes → cars
edges (directed) → virtual forces
layers → behavior levels



Functional details

Level 1 utilizing 'real' spring-dampers

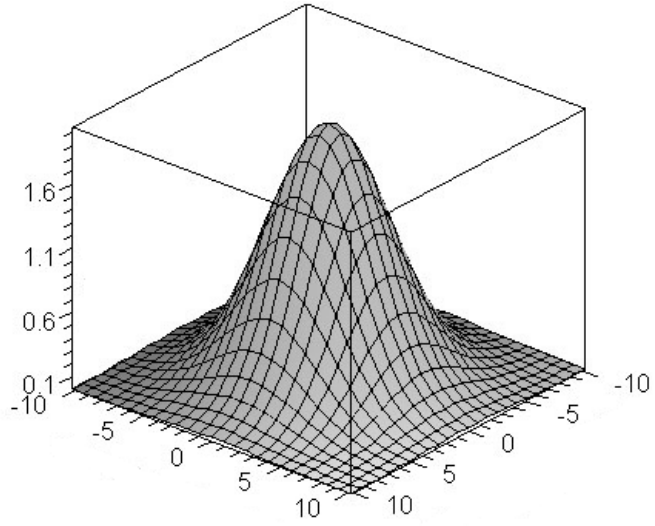
0	F_{12}	...	F_{1n}
F_{21}	0	F_{23}	...
...	F_{32}	0	$F_{(n-1)n}$
F_{n1}	...	$F_{n(n-1)}$	0

procedure:

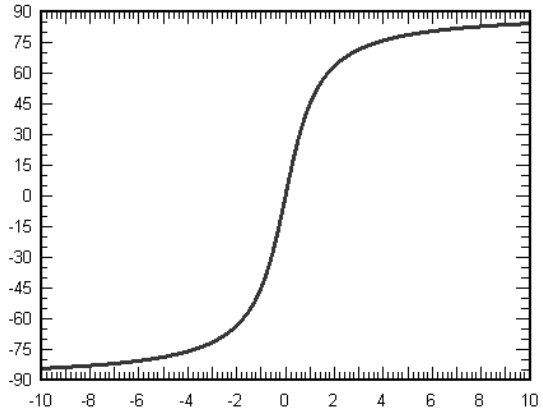
1. compute distance → constitutive law
2. compute relative angles → geometry
3. populate force adjacency matrix
4. use coordinate transformation to resolve forces into body-fixed coordinates
5. use automatic control to develop inputs that drive these forces to zero

Level 1 fields

- Alternate field formats
  - Gauss Function
  - Inverse Tangent



- How is stability classified?
- What signals can be used to establish traffic disturbances?



some film

thank you!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Emergent Behavior

1. radical novelty (features not previously observed in systems)
2. coherence or correlation (meaning integrated wholes that maintain themselves over some period of time)
3. a global or macro "level" (i.e. there is some property of "wholeness")
4. it is the product of a dynamical process (it evolves)
5. it is "ostensive“ and “ - it can be perceived