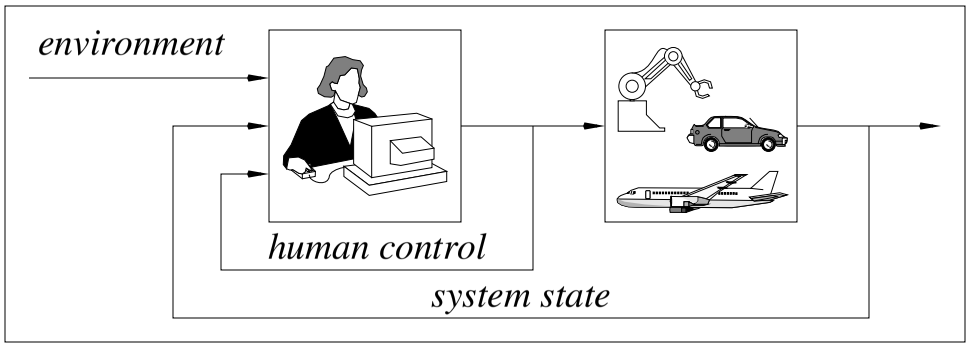
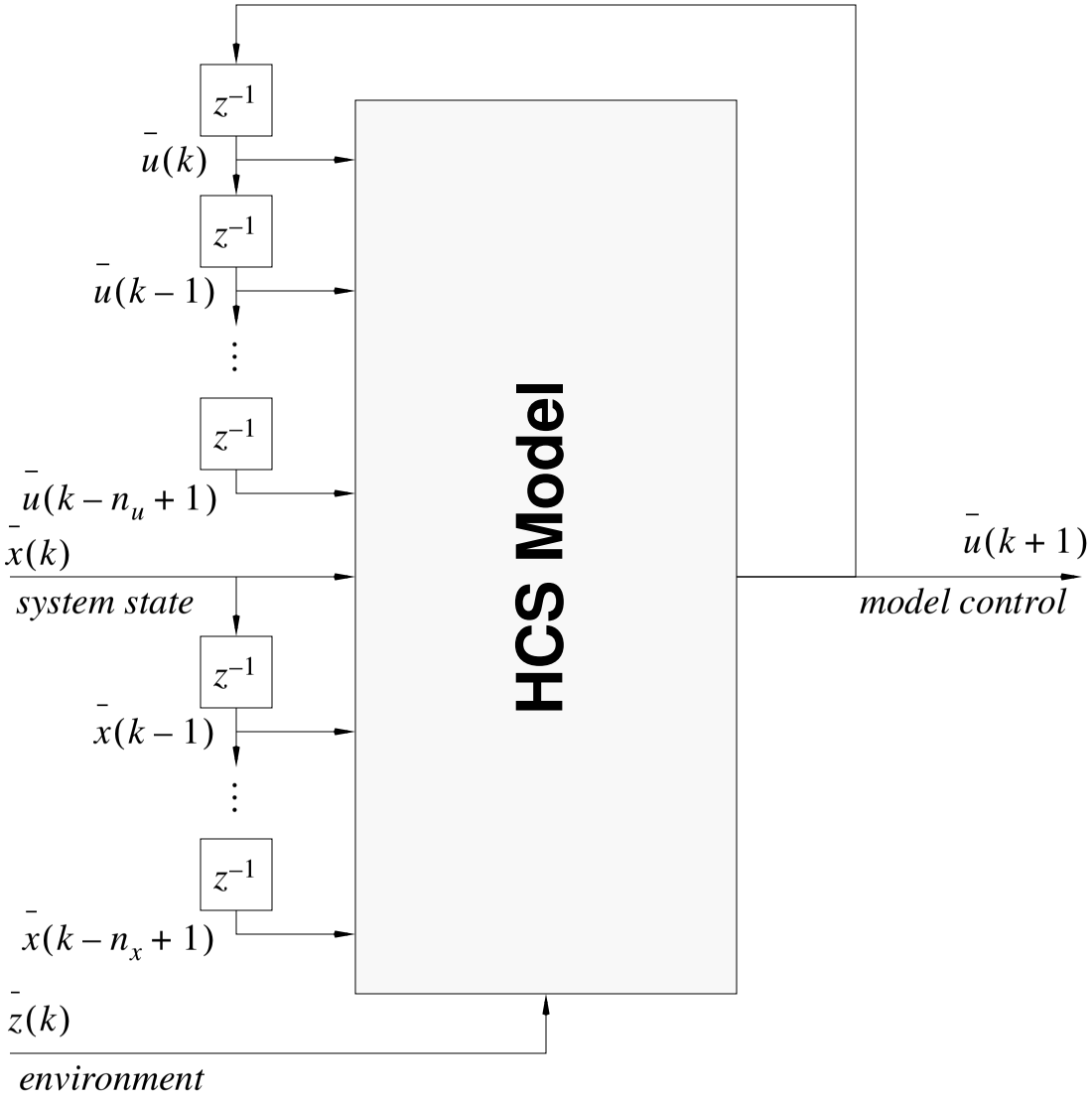
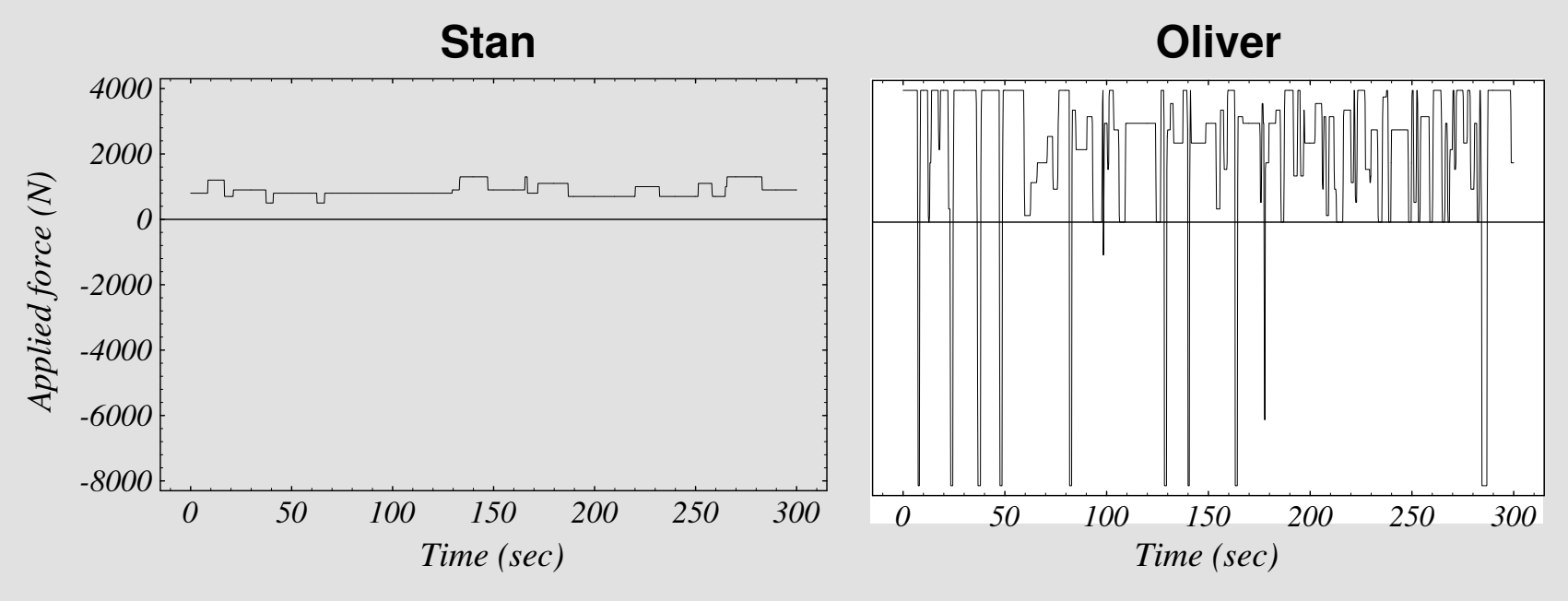
Learning human control strategies





Human control strategy

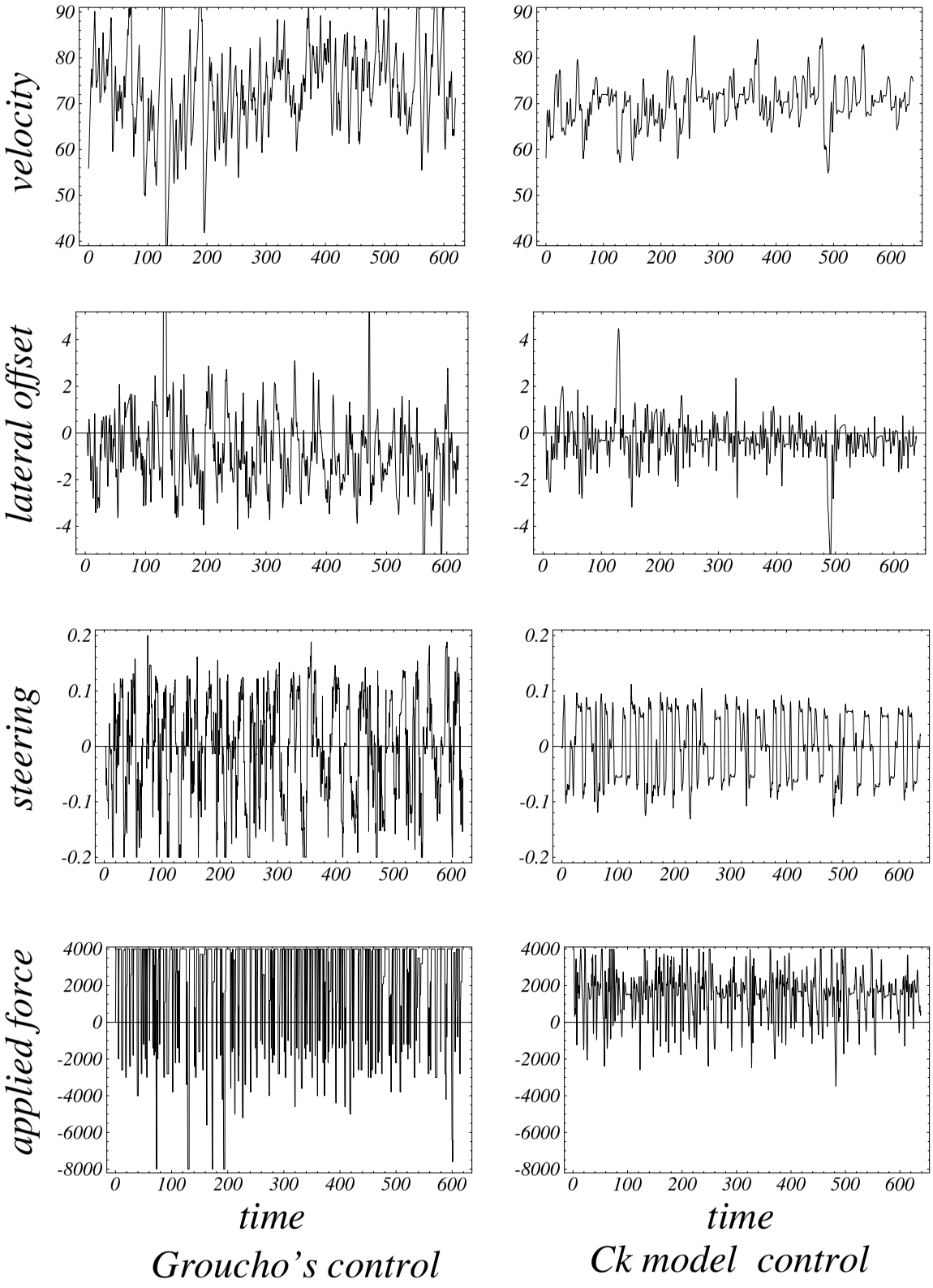
- ***Dynamic, reaction* skill, with reasonably well-defined I/O representation**
  - *Control gains*
  - *Control structure/approach*
  - *Interaction with environment/surrounding*
- **No abstract or high-level reasoning**
- **Example: human driving**



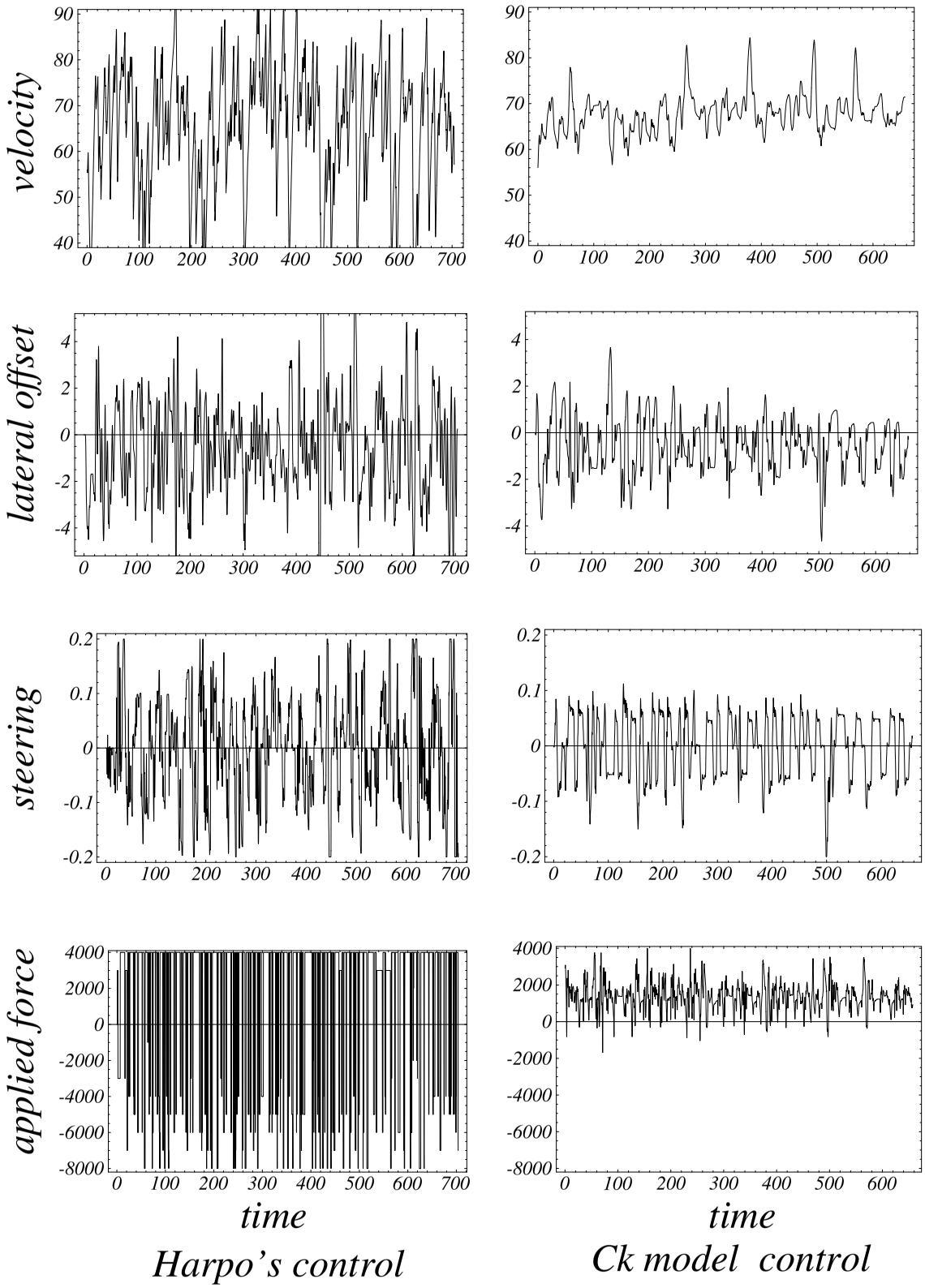
Learning human control strategy

- **Difficult to model human control strategy *analytically*.**
- **Unknown individual controller properties**
  - *Structure*
  - *Order*
- **Human control strategy modeling complications**
  - *Dynamic*
  - *Stochastic — errors and inconsistencies*
  - *Possibly discontinuous*
  - *Possibly nonlinear*
- **Continuous learning approach: neural networks**

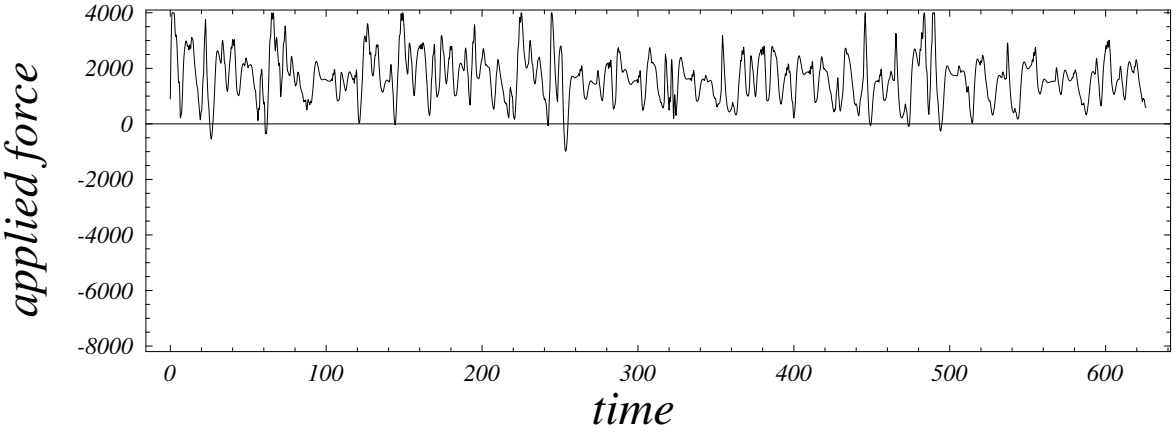
HCS model example: *Ck*



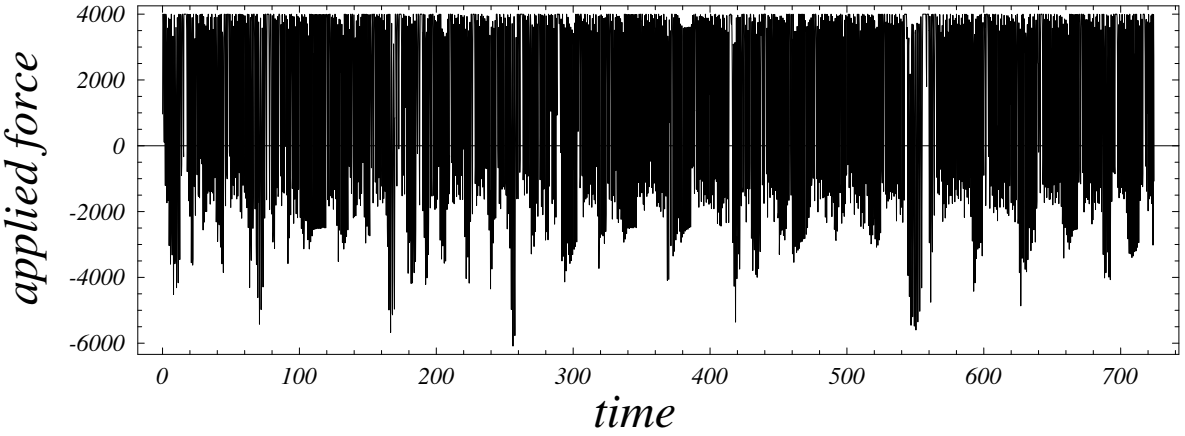
HCS model example #2: *Ck*



Additional hidden units in *neural network*



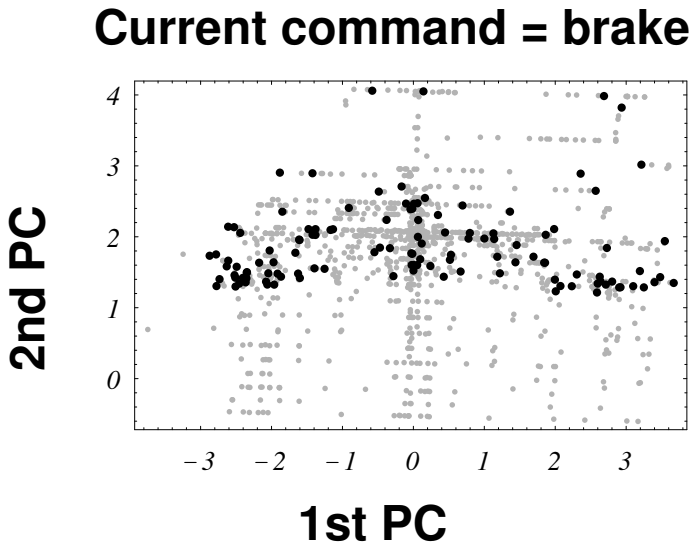
linear model

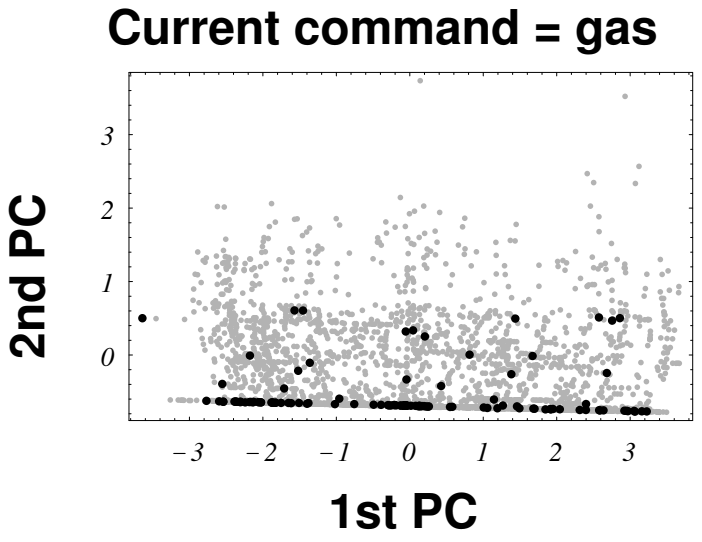


one additional hidden unit

Need for discontinuous learning

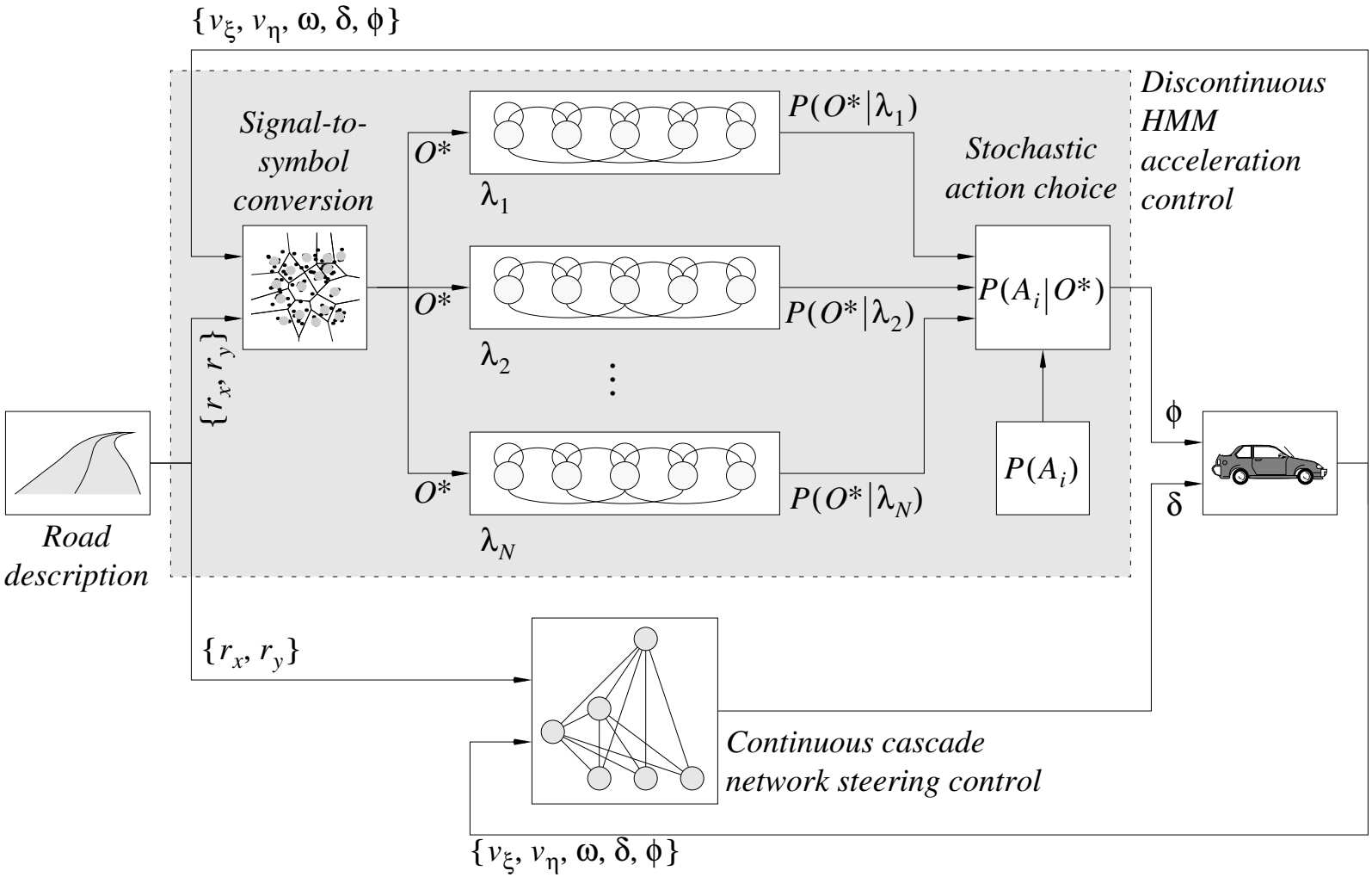
- *Cq*, *Ck* models are convergent (stable) strategies, but are not "similar."
- In reduced dimensional plot, "switches" overlap "nonswitches."





- Continuous neural network may have difficulty modeling discontinuous (e.g. switching) control strategies.

Hybrid continuous/discontinuous control



Actions

- **Applied force > 0 (gas is currently active):**
  - A_1 *: do nothing.*
  - A_2 *: increase applied force.*
  - A_3 *: decrease applied force, but keep > 0.*
  - A_4 *: switch to braking*

- **Applied force < 0 (brake is currently active):**
  - A_5 *: do nothing*
  - A_6 *: increase braking force*
  - A_7 *: decrease braking force*
  - A_8 *: switch to accelerator*

Statistical model and priors

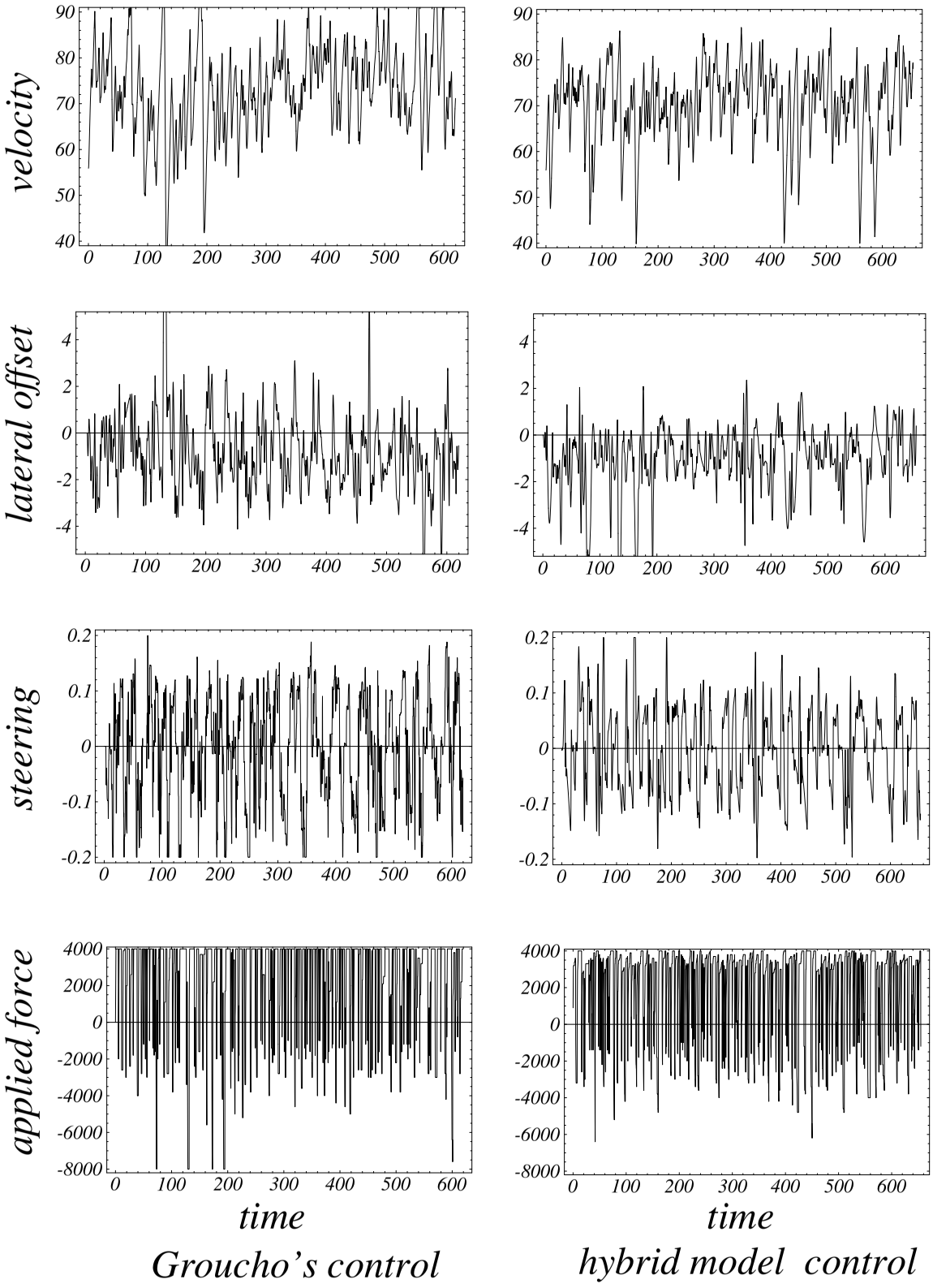
- **Single-state HMMs (encode arbitrary statistical distribution of inputs).**

$$P(O^* | A_i) \equiv P(O^* | \lambda_i)$$

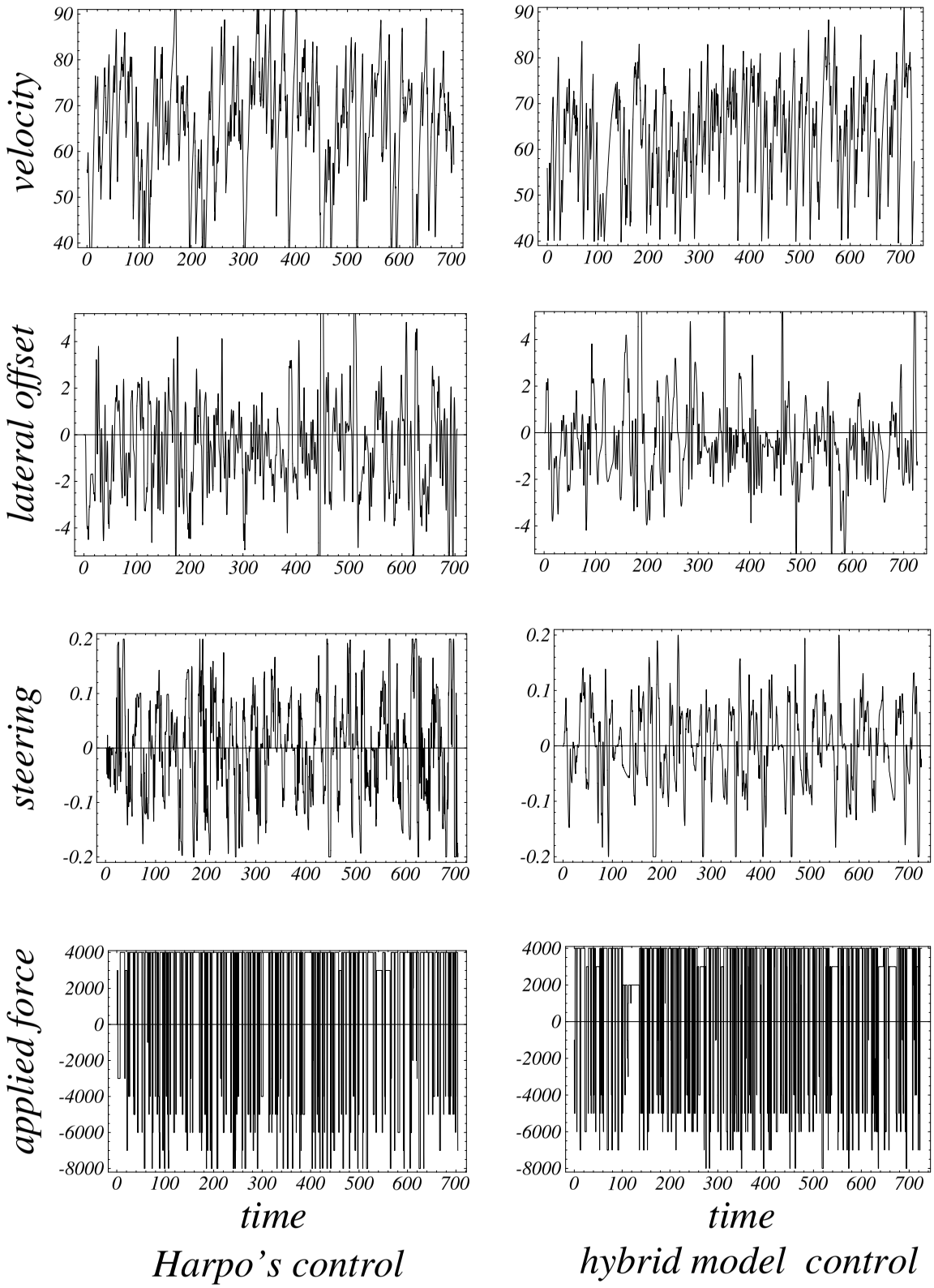
- **Priors: frequency of occurrence for action A_i in human data set**

$$P(A_i | O^*) \propto P(O^* | \lambda_i) P(A_i)$$

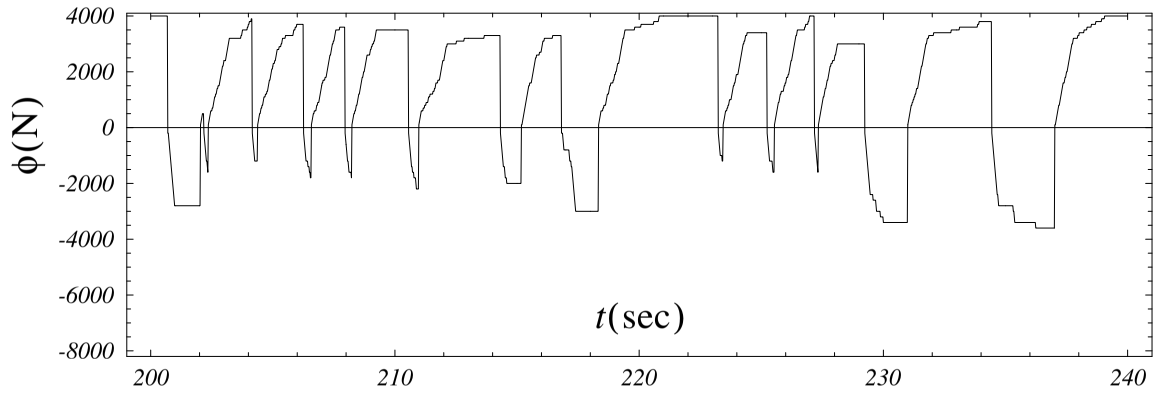
HCS model example: hybrid



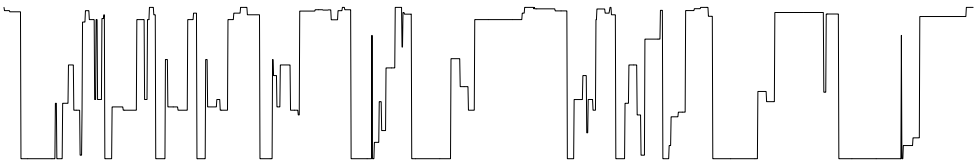
HCS model example #2: hybrid



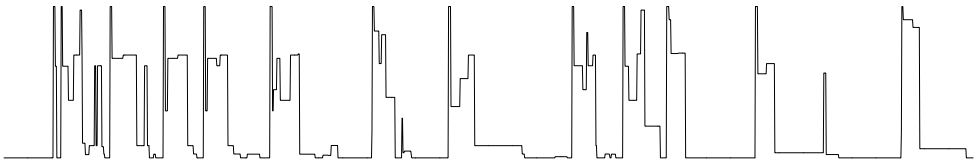
A closer look



$P(A_1|O)$

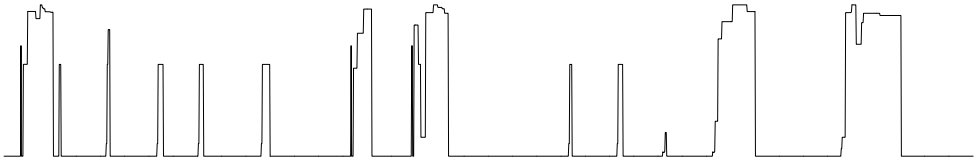


$P(A_2|O)$

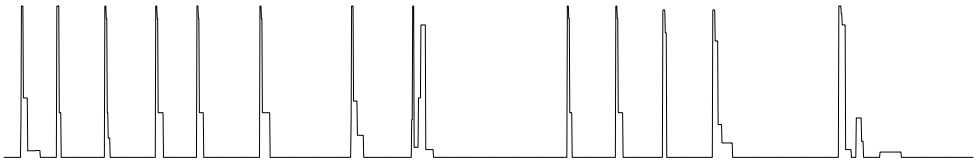


$P(A_4|O)$ *switch (gas to brake)*

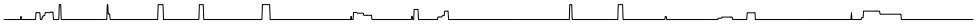
$P(A_5|O)$



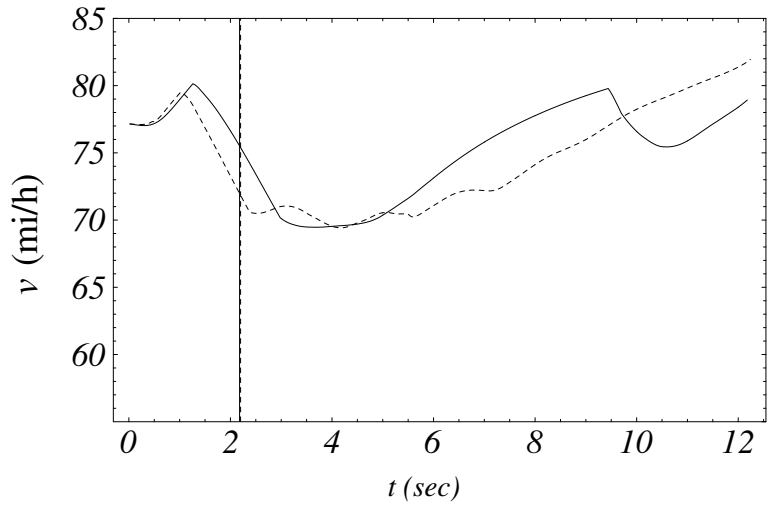
$P(A_6|O)$

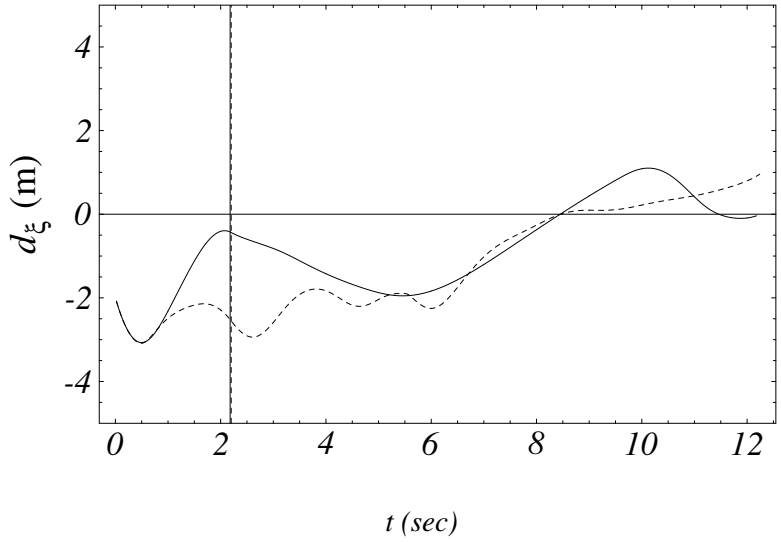


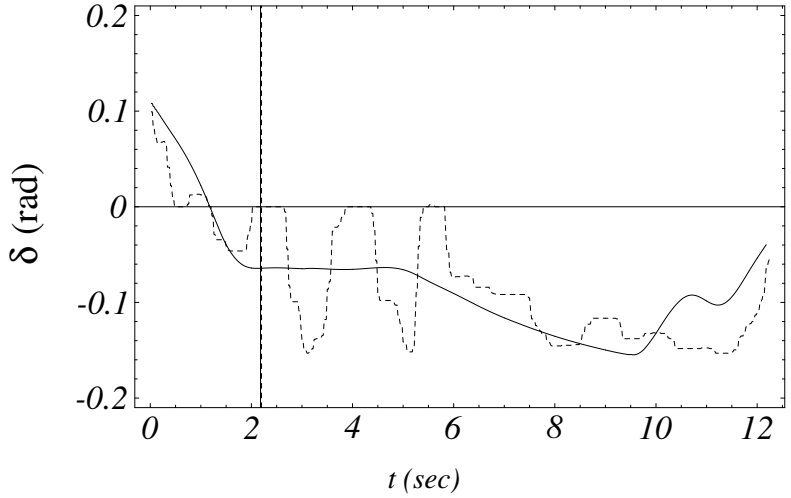
$P(A_8|O)$ *switch (brake to gas)*

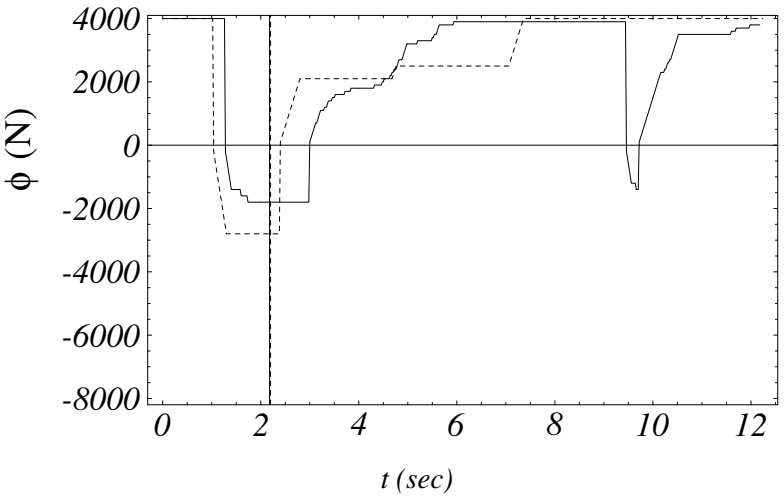


Sample Groucho turning maneuver



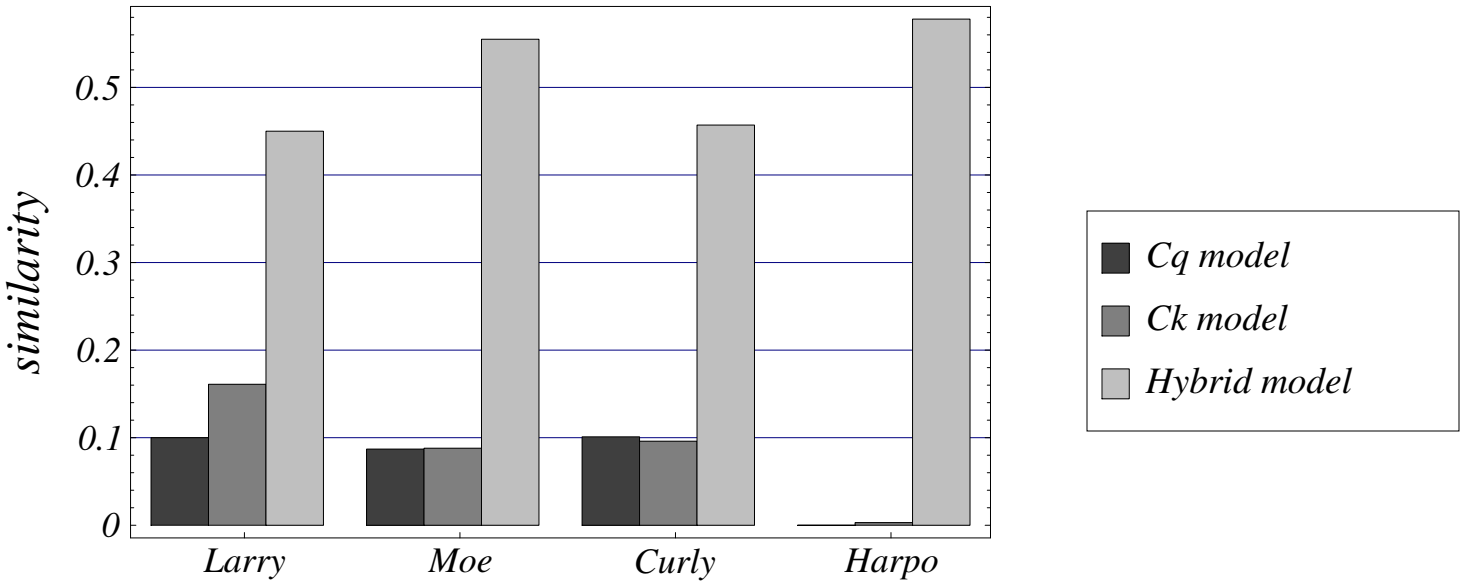






Human-to-model validation

- **Quantify qualitative observations**



- **Hybrid model exhibits greater similarity than either of the purely NN-based modeling approaches.**

Model-to-human classification

Table 1: Hybrid model-to-human matching

σ	*Larry*	*Moe*	*Groucho*	*Harpo*
Larry's model	**0.450**	0.329	0.315	0.069
Moe's model	0.126	**0.555**	0.338	0.217
Groucho's model	0.152	0.377	**0.457**	0.206
Harpo's model	0.013	0.134	0.127	**0.578**

Table 2: *Ck* model-to-human matching

σ	*Larry*	*Moe*	*Groucho*	*Harpo*
Larry's model	0.161	**0.166**	0.118	0.157
Moe's model	0.056	**0.088**	0.063	0.041
Groucho's model	0.056	0.066	**0.096**	0.040
Harpo's model	0.006	0.008	**0.012**	0.003