Controlling steering with Energy-Based Models

Mykyta Baliesnyi, Ardi Tampuu, Tambet Matiisen
Autonomous Driving Lab, University of Tartu, Estonia

We tested **energy-based** models at rally road-following with a **real car**.

Take a picture to:
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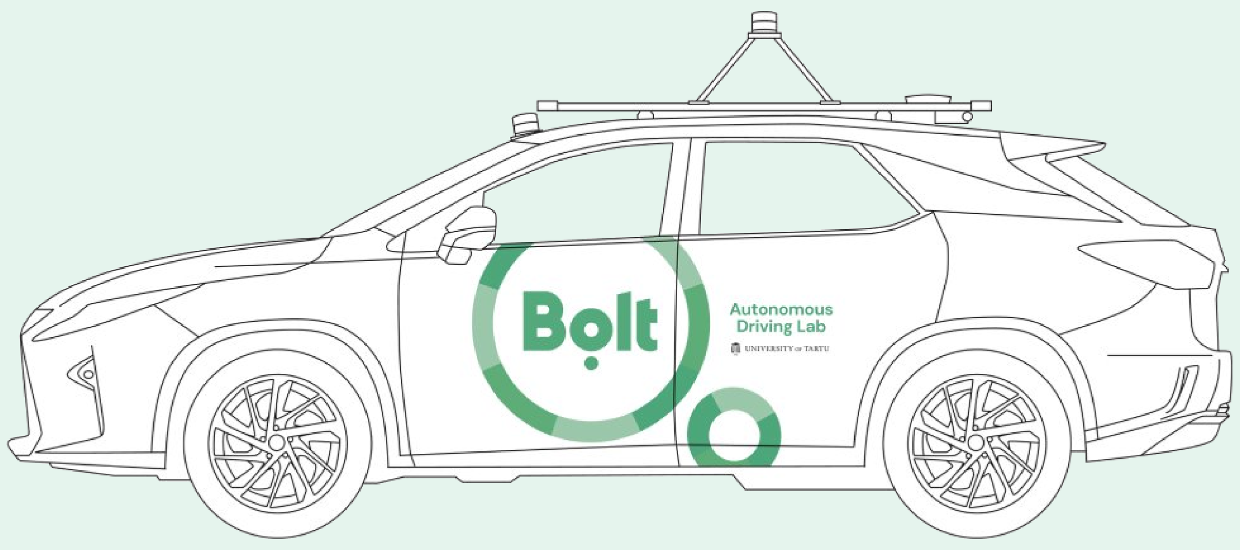
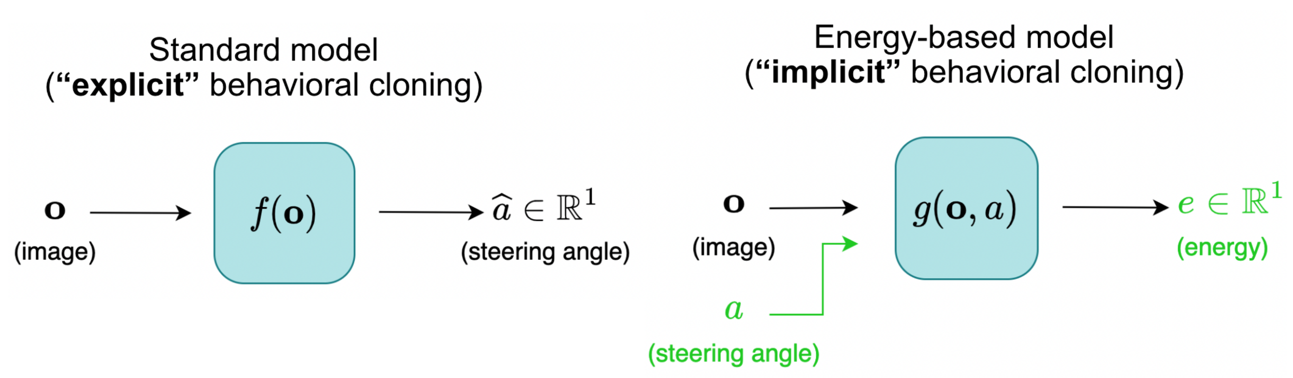


What are Energy-Based Models (EBMs)



$$\hat{a} = f(\mathbf{o}) \qquad \hat{a} = \arg\min_{a} g(\mathbf{o}, a)$$

Figure 1 - Energy-based vs standard model

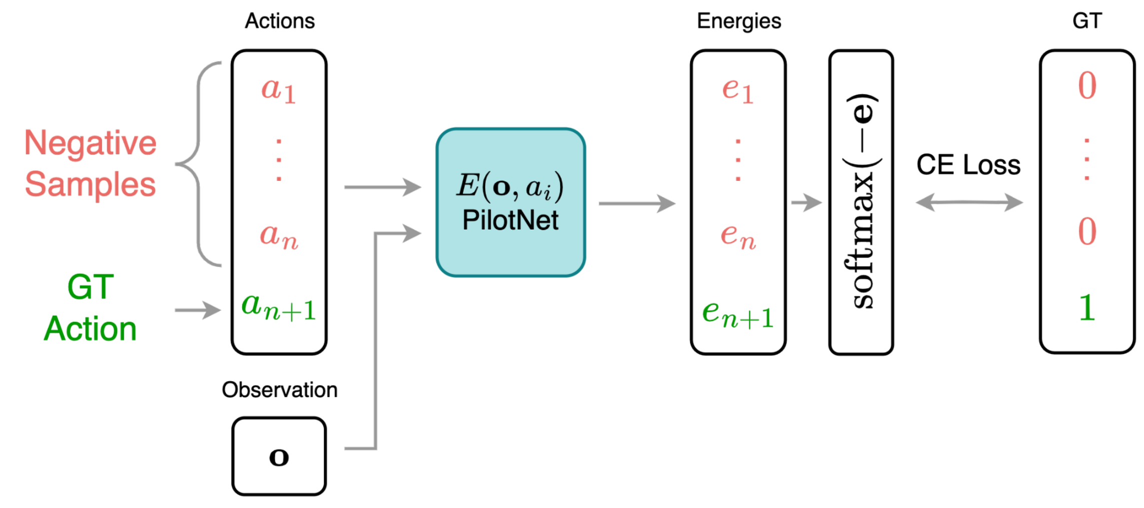


Figure 2 - EBM training process

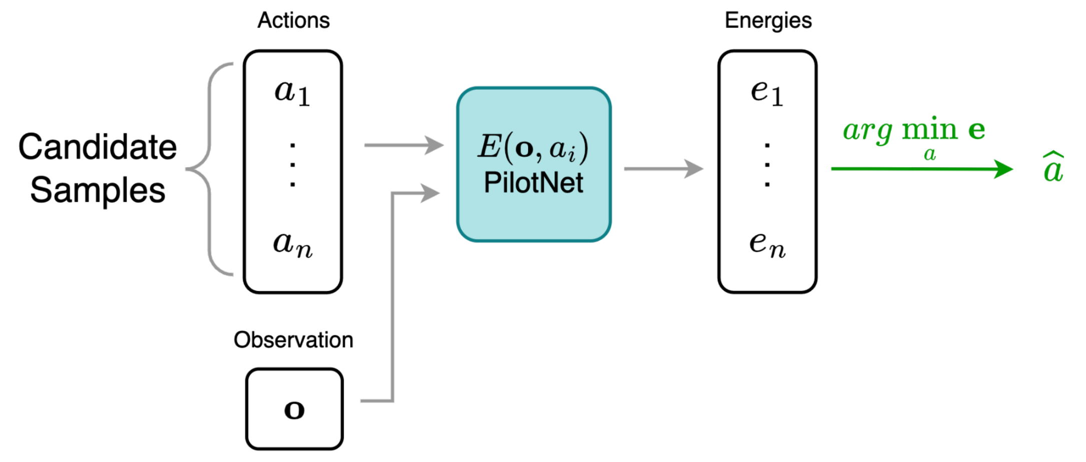


Figure 3 - EBM inference process

Why are EBMs interesting?

1 EBMs can represent **multimodal** policies

2 Impressive out-of-distribution generalization & fast learning

3 Easy to convert most architectures to EBMs

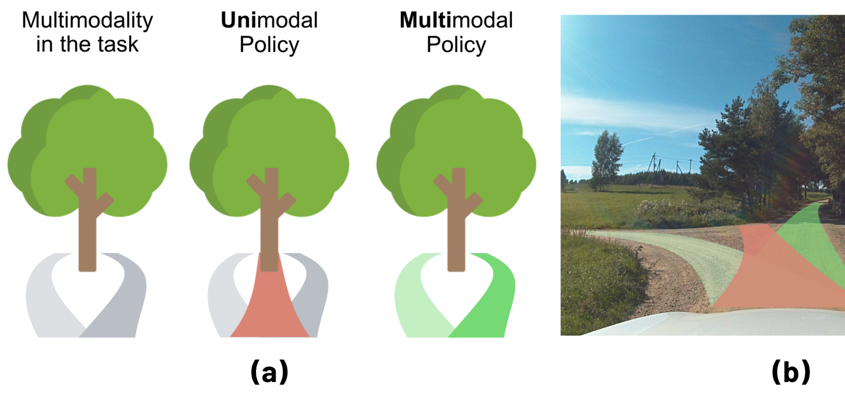


Figure 4 - Unimodal vs Multimodal policies

What we thought (see Figure 4a)

1 Standard PilotNet would **"drive into the tree"**

2 EBM PilotNet would **"pick one path around the tree"**

3 EBM -> fewer interventions

What happened (see Figure 4b)

1 Standard PilotNet **swerved towards left (89% of time)**

2 EBM **drove straight without swerving (61% of time)**

3 EBM -> ~same # interventions

4 EBM -> less smooth

Models we compared

EBMs

1 Energy-based PilotNet

2 Energy-based PilotNet with Soft targets in the CE loss

3 Energy-based PilotNet with Temporal smoothing

$$L_{temp} = \alpha \left\| \mathbf{e}_t - \mathbf{e}_{t+1} \right\|,$$

$\mathbf{e}_t$: energies of all possible angles at time t

α : smoothing strength (e.g. *1.0*)

Baselines

4 Standard PilotNet (MAE regression)

5 Classification PilotNet (softmax on a discretization)

6 Mixture Density PilotNet (5 Gaussians)

Conclusions

1 EBMs *do* handle multimodal situations better

2 This did not result in overall better performance in a road-following task

3 More rich, multimodal tasks are needed to bring out the EBM benefits

Extra figures

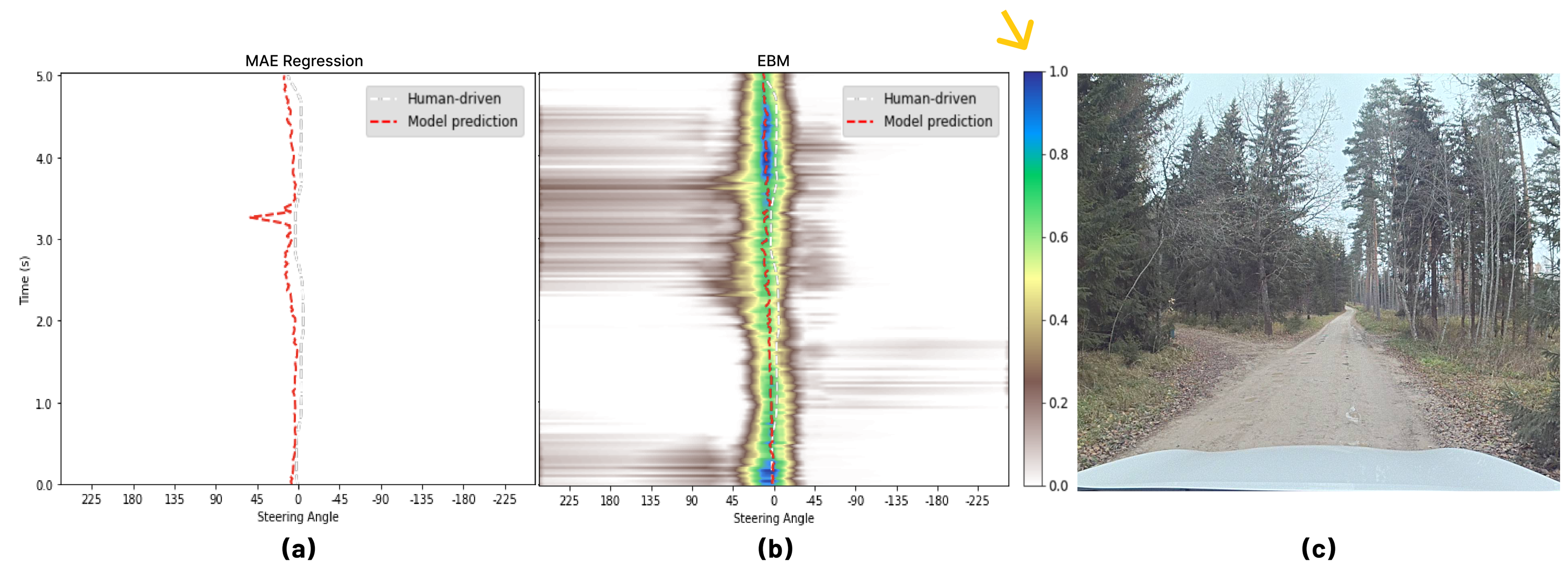


Figure 5 - Model predictions over a 5-sec intersection.

(a) Standard (MAE regression) PilotNet makes a swerve to follow an average path (between left and straight) @3.5s because it is unimodal.

(b) Energy-Based PilotNet represents the multimodality and follows the most likely (straight) path.

(c) View of the intersection @2s.

Table 1 - Driving ability over three real-world and three VISTA drives per model

Model	Real world		VISTA	
	Interventions	Whiteness	Crashes	Whiteness
EBM	4	176.93°/s	2	114.33°/s
	1	96.94°/s	1	121.57°/s
	2	223.59°/s	2	121.67°/s
mean:	2.33	165.82°/s	1.67	119.19°/s
EBM Temp. Smoothing	5	119.39°/s	3	58.70°/s
	2	137.22°/s	2	60.37°/s
	3	77.28°/s	2	48.86°/s
mean:	3.33	111.30°/s	2.33	55.98°/s
EBM Soft Targets	5	56.33°/s	3	85.72°/s
	5	57.15°/s	3	74.97°/s
	4	56.86°/s	3	81.87°/s
mean:	4.66	56.78°/s	3	80.85°/s
Regression (MAE)	2	37.84°/s	0	24.39°/s
	2	75.34°/s	0	24.75°/s
	1	33.10°/s	0	24.25°/s
mean:	1.66	48.76°/s	0	24.47°/s
Classification	1	182.39°/s	1	123.69°/s
	7	287.14°/s	1	105.13°/s
	1	162.27°/s	1	104.31°/s
mean:	3.00	210.60°/s	1	111.04°/s
MDN	1	33.62°/s	3	37.22°/s
	5	35.46°/s	3	35.74°/s
	5	37.39°/s	3	35.84°/s
mean:	3.66	35.49°/s	3	36.27°/s

Replicate our results!

OR use this as a benchmark
OR to select models you deploy

THE VISTA SIMULATOR

Code to evaluate models on our real-world track in the VISTA Driving Simulator