End-To-End Imitation Learning of Lane Following Policies Using Sum-Product Networks

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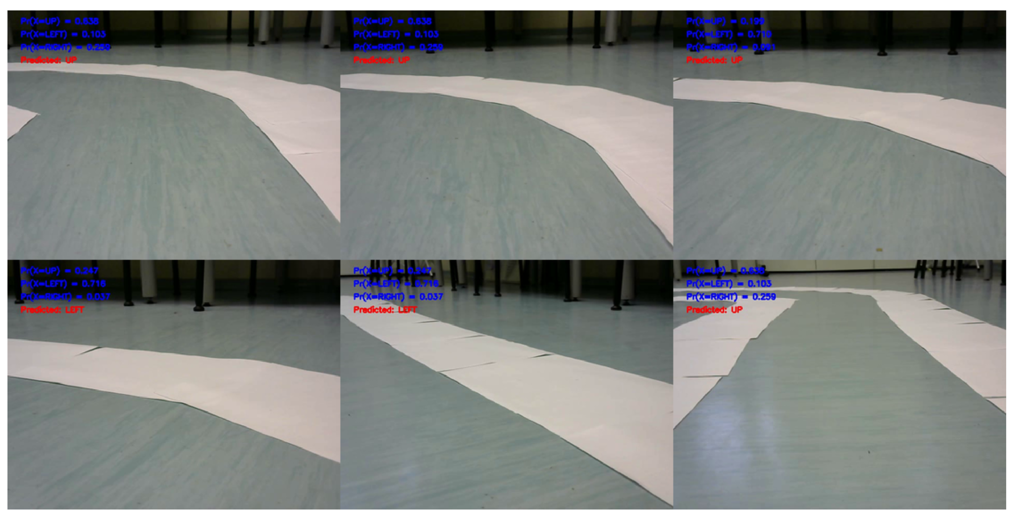
1. Task

Task: Complete whole course without going off track.

Input: Single frontal camera image.

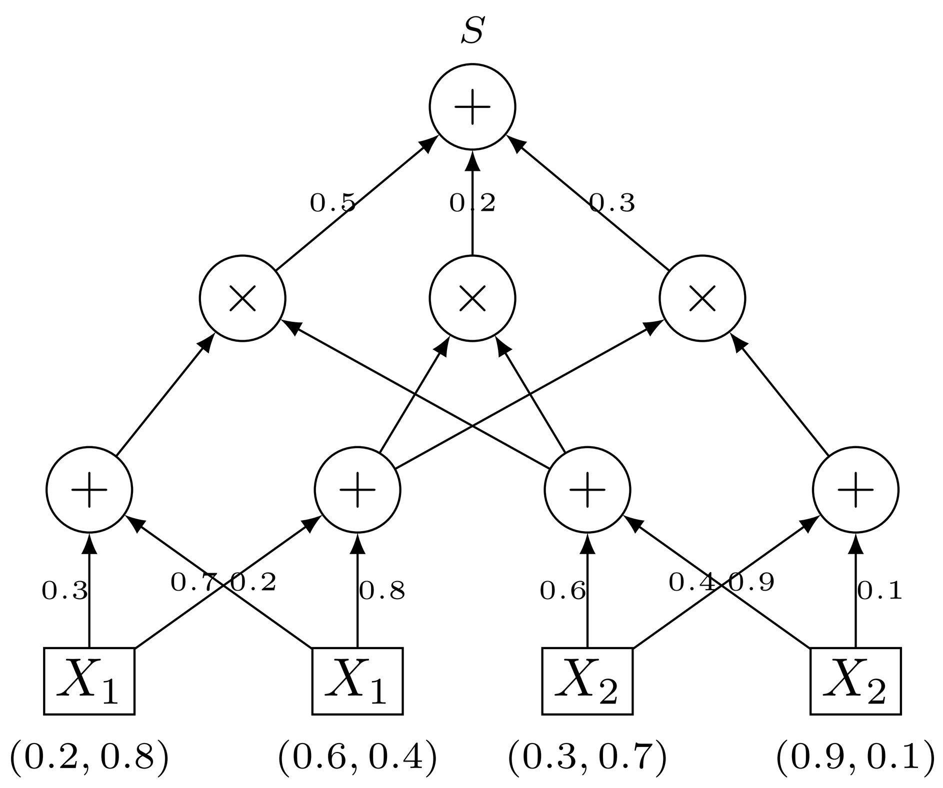
Output: Policy π with probabilities of actions.

Actions: Turn left, right or go straight.



2. Sum-Product Networks

Sum-product networks (SPNs) are deep tractable density estimators with a neural network-like structure subject to only sums and products as activation functions.



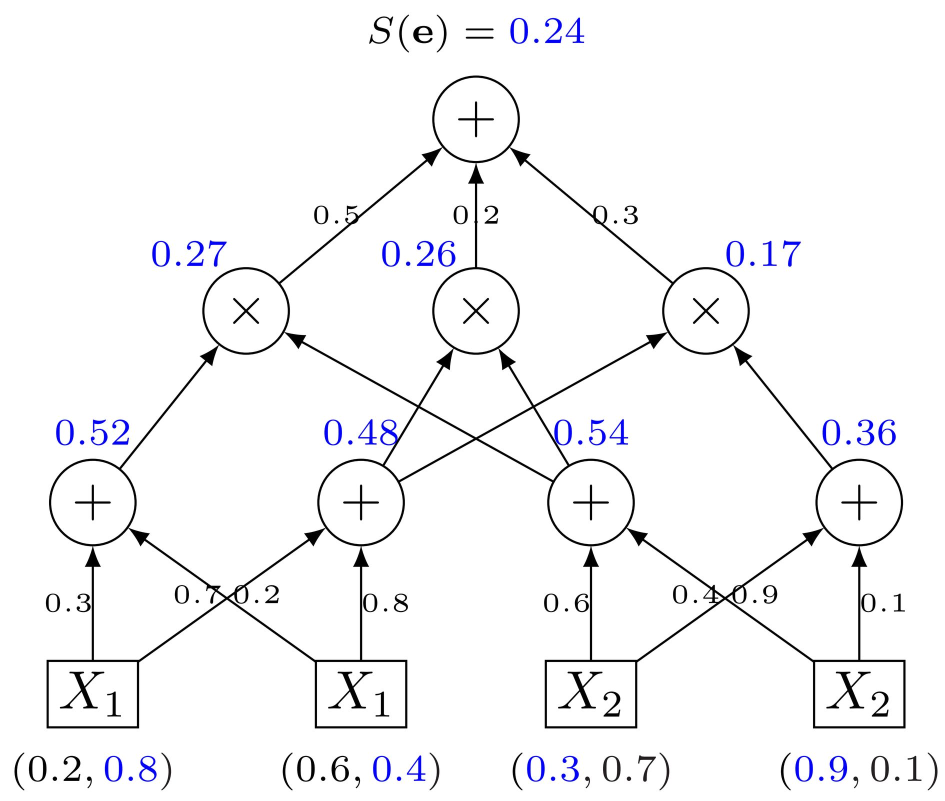
In the above example, leaves are binomial distributions over each RV X_i.

3. Inference in SPNs

The probability of evidence of

$$\mathbf{e} = \{X_1 = 1, X_2 = 0\}$$

is the value of the SPN's root.



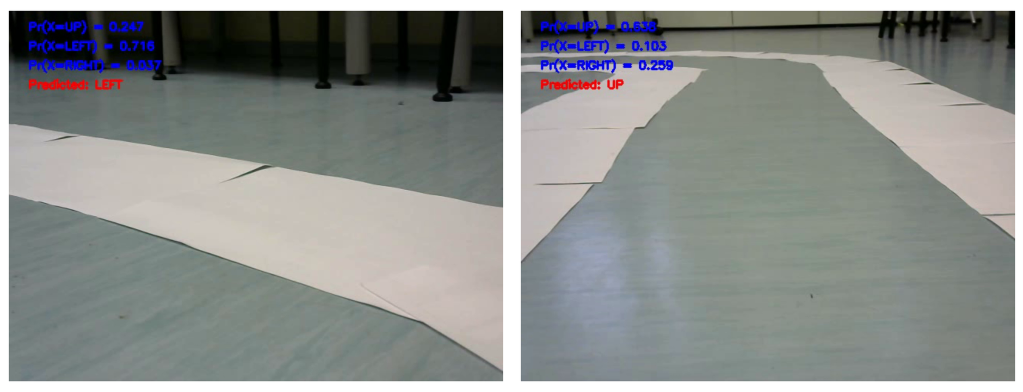
$$P(\mathbf{e} = \{X_1 = 1, X_2 = 0\}) = S(\mathbf{e}) = 0.24$$

4. Lane Following as Classification

Actions the agent can take are turning left, right or going straight.

LEFT FORWARD RIGHT

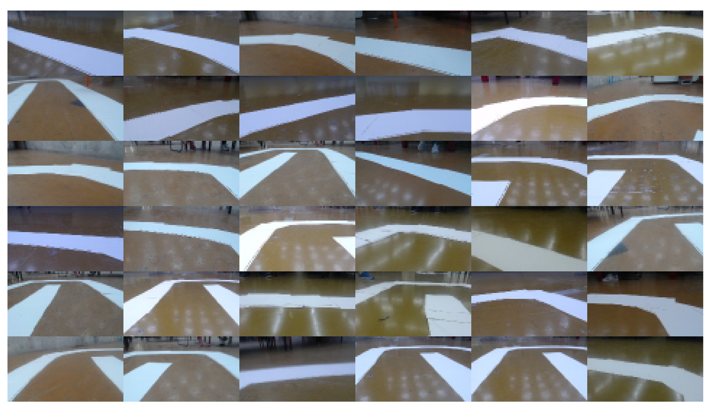
The SPN models a stochastic policy π that attributes the probabilities of each action given the robot's front camera image feed.

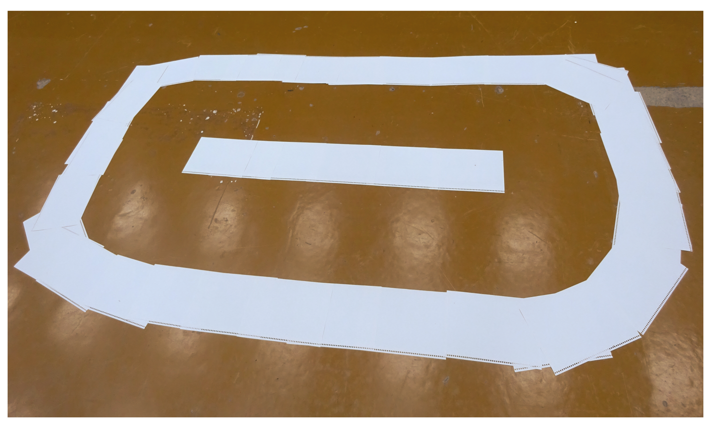


This is achieved by classifying each frame as either `LEFT`, `FORWARD` or `RIGHT`.

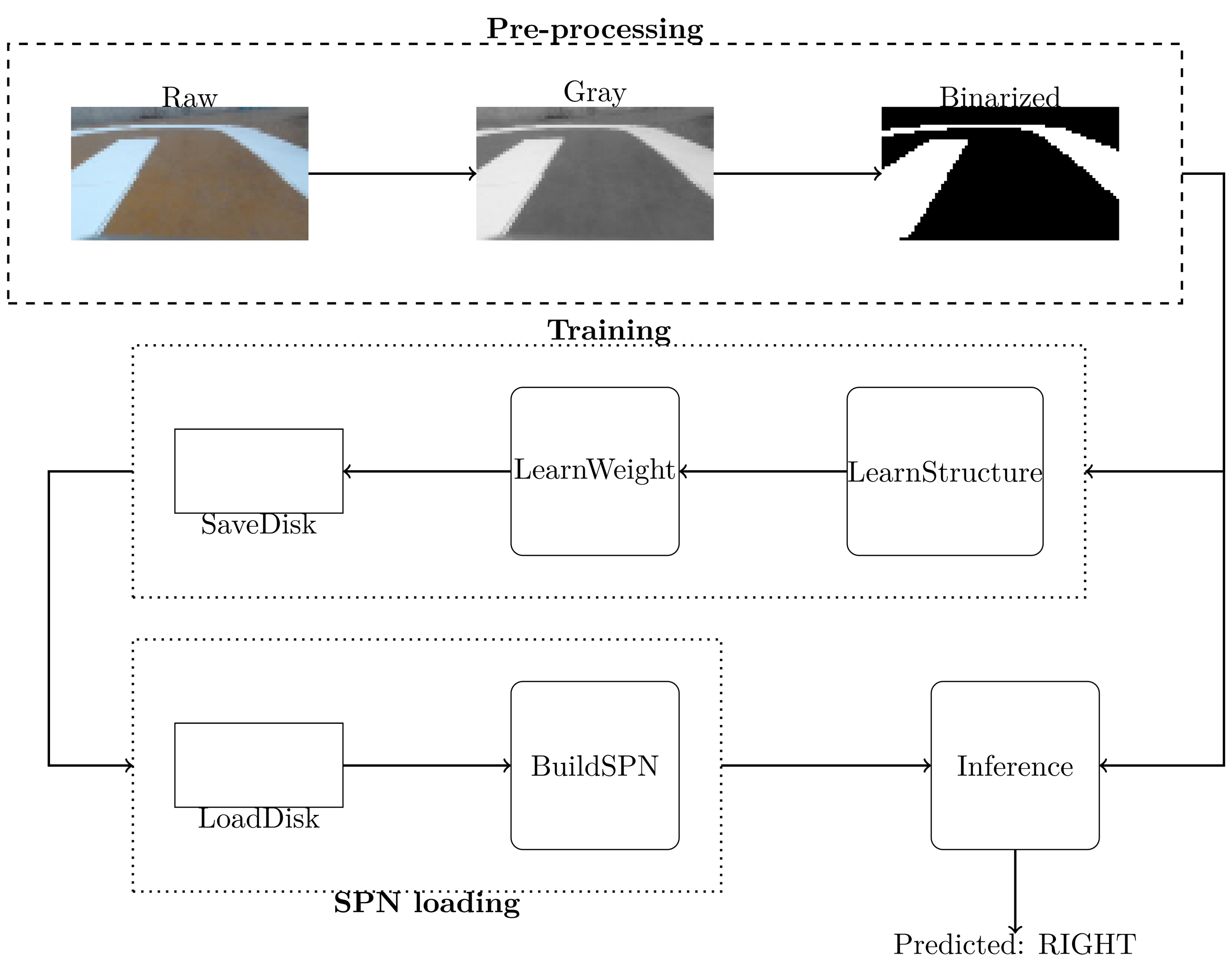
5. Results

Models were trained on single-track data obtained by [4].





A pre-processing step was applied, either binarization, quantization or histogram equalization.



Models were evaluated on three different test tracks, with different lighting and floor conditions.

Compared to neural networks, SPNs achieved slightly lower accuracy, but were degrees of scale faster on prediction.

Model	Accuracy (%)	Speed (seconds)
DFN	81.3	≈1.35
CNN	80.6	≈1.35
1: Q_4, GD-SPN+d	78.2	≈0.70
2: Q_6, GD-SPN+d	74.4	≈0.15
3: GD-SPN+d	62.4	≈0.07

- DFNs and CNNs were more accurate, but too slow;
- All SPN models were much faster compared to neural networks;
- Timely decisions are more important than accurate ones.

Video of each model in each track can be found through the following QR code or URL link.

`https://youtu.be/vhpWQDX2cQU`

6. References and Acknowledgements

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[2] R. Gens and D. Pedro. Learning the structure of sum-product networks. In *ICML*, 2013.

[3] A. Dennis and D. Ventura. Learning the architecture of sum-product networks using clustering on variables. In *NIPS*, 2012.

[4] P. Moraes and F. Salvatore. Self-driving pi car. `https://github.com/felipessalvatore/self_driving_pi_car`, 2018.

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