Hybrid Transfer Learning and Kalman Filter-Based Steering Angle Prediction for Autonomous Driving - Deep Machine Learning

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Introduction

Autonomous driving can use sensors and control methods, but this is complex and requires a lot of tuning. Newer methods rely on camera images to make decisions.

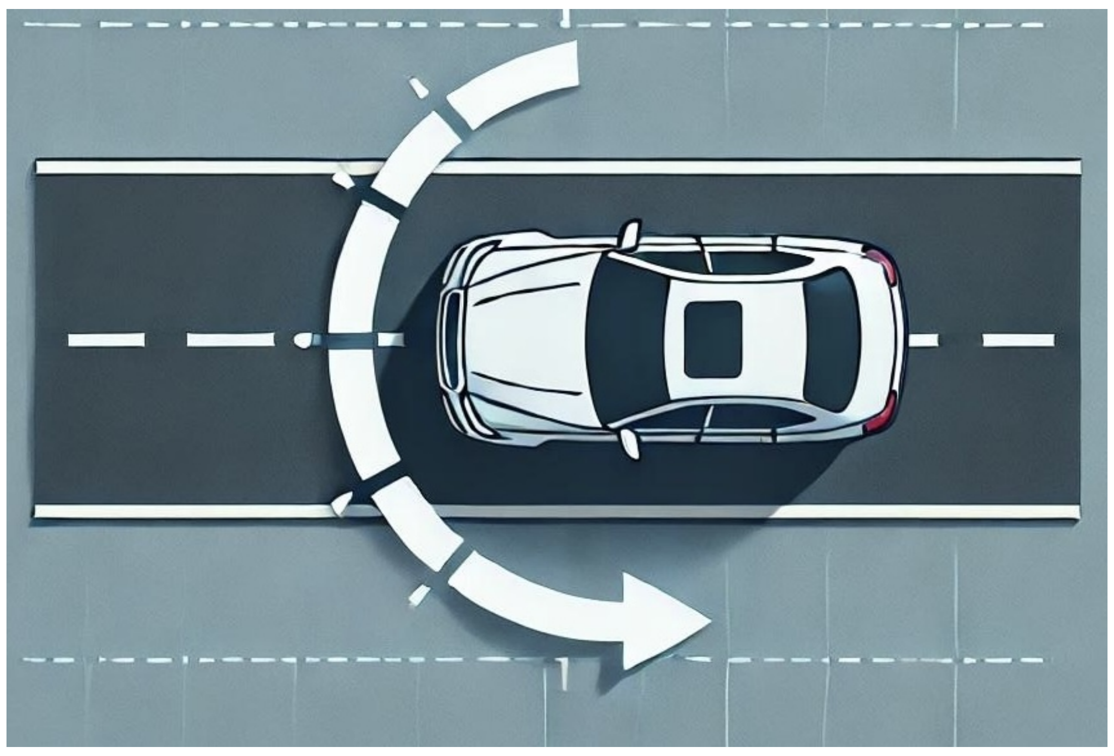


Figure 1: Car with angle prediction

What are we doing here:

- **Utilize only images from the front camera of cars** as the input data source.
- **Perform transfer learning with VGGNet19** to predict the steering angle.
- **Use LSTMs** to dynamically tune the parameters of the Kalman filter.
- **Incorporate a Kalman filter structure** to maintain accuracy even with delayed image inputs.

Engagement

Problem Formulation

- **How do we address autonomous driving traditionally?**
  We model the system and use Kalman filter estimation to design a controller for optimal control.
  Pros: Optimal observer.
  Cons: Complex setup, challenging modeling and tuning.
- **How to implement machine learning on it normally?**
  Using CNNs to predict movement, with RNNs or transformers to enhance time-based relationships.
  Pros: A black box, and it works good!
  Cons: Choosing a network is tough. CNNs alone struggle with delayed images.

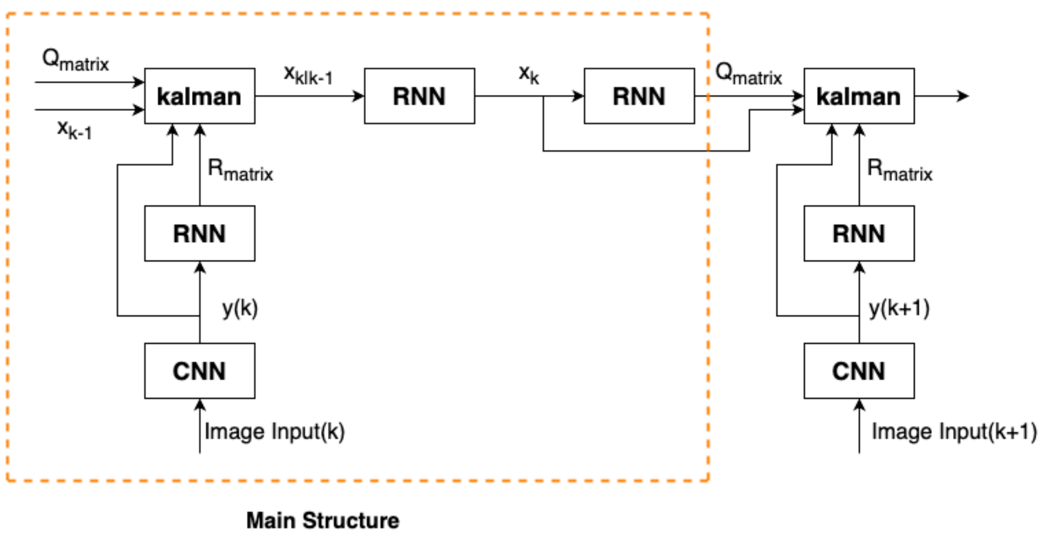


Figure 2: Model Structure

Methodology

Why not merge a Kalman filter RNN with a CNN for the best of both?

- **Using LSTMs** to predict parameters and identify the system, avoiding tedious work [2].
- **Using a Kalman filter** to ensure accurate steering angle estimation.
- **Using a "well-trained sensor" (CNN)** to reduce noise and provide accurate measurements.

Side notes

What happens while implementing our thoughts?

- Training is tough because CNNs need shuffled images, but RNNs need them unshuffled.
  Solution: First, train the CNNs with shuffled images, then train the RNNs with unshuffled ones.
- Complex networks easily overfit the training data.
  Solution: Training the network with a large dataset which takes time.

Short example

Figure 3: Car image

Is this left turn or right turn?

- Pretty easy to tell, right?
- Well, maybe not for a computer...
- Imagine the images will even delay(due to processing time) in real world scenario... How can a computer deal with it?

The top competitor's current best approach[4].

- Transfer learning from Nvidia-CNN pretrained on car front images [3].
- Convert optical flow into three channels to train the CNN with existing weights.

It works **well with timely images** but performs **poorly** when there's a **delay between images**.

Therefore, we use a **Kalman filter-based CNN** with an **RNN** for better performance:

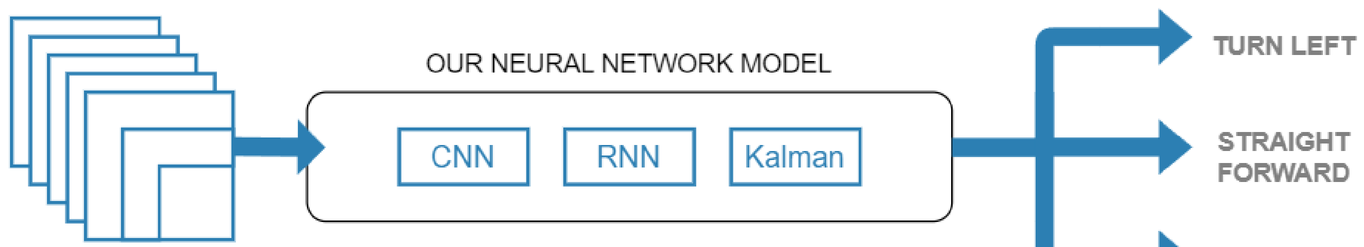
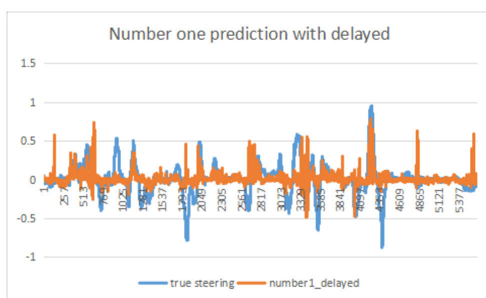
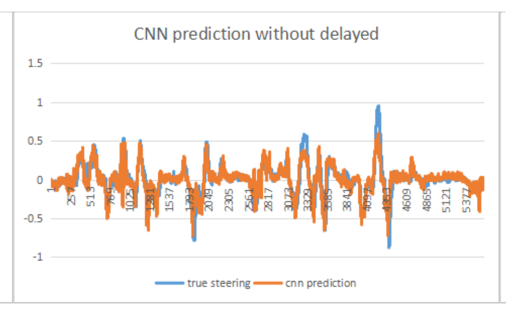


Figure 4: Our processing

- To improve CNN performance, we apply **transfer learning from VGGNet19**, as suggested in this article [1].
- The CNN's loss of **0.089** (ranked 7th on the leaderboard) is impressive given our time constraint of **2 weeks compared to 2 months**.
- The original CNN performs better without delays with loss 0.036, but with delays, the loss increases to 0.20. **Our modified version stays at 0.14 even with delays!**





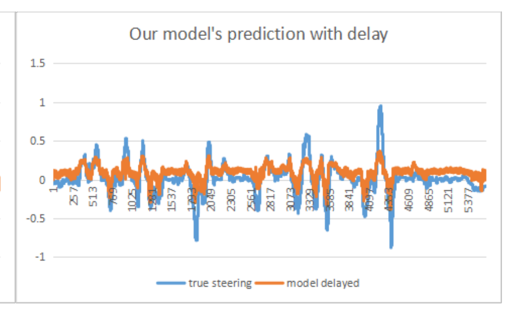


Figure 5: Number one prediction with delay. Figure 6: Our CNN prediction without delay. Figure 7: Our whole model's prediction with delay.

References

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[2] R. D. N. N. F. T. Huseyin Coskun, Felix Achilles. Long short-term memory kalman filters: Recurrent neural estimators for pose regularization, Aug 2017.

[3] D. D. B. F. B. F. P. G. L. D. J. M. M. U. M. J. Z. X. Z. J. Z. K. Z. Mariusz Bojarski, Davide Del Testa. End to end learning for self-driving cars, Apr 2016.

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