Automated Sim Coaching

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1 Introduction

We are given the following data:

- Expert/Coach driving behavior for one lap, $\mathcal{C}(s)$
- Student driving behavior for one lap, $\mathcal{S}(s)$

where s is the distance along the track center line with $s = 0$ denoting the start line. Note that generally the racing line is not the track center and we need to have a procedure to map every car position on the track to an s value. This can be done by an orthogonal projection as shown in figure 1 below.

Let's make the notion of "driving behavior" mentioned above more precise. Both $\mathcal{C}(s)$ and $\mathcal{S}(s)$ represent metrics at each point s. Some examples of these metrics are:

- Throttle, $T(s)$
- Brake pressure, $B(s)$
- Steering angle $\theta(s)$
- Some measure of jitter in steering angle. E.g. $\frac{d\theta}{ds}$. In practice, this would be computed through finite difference i.e. $\frac{d\theta}{ds} \approx \frac{\theta(s_{t+1})-\theta(s_t)}{s_{t+1}-s_t}$ where s_t refers to the s-value at time t, assuming discrete time measurements.
- For more complex situations, quantities like instantaneous brake balance.

Note that there are some variations for each quantity. These are:

- Instantaneous quantity, e.g. throttle at that particular s-value.
- Time-averaged quantity, e.g. throttle value averaged over previous K time-steps. This would give a smoother value.
- First derivatives of quantity (like the steering angle jitter mentioned above)
- Second derivatives of quantity

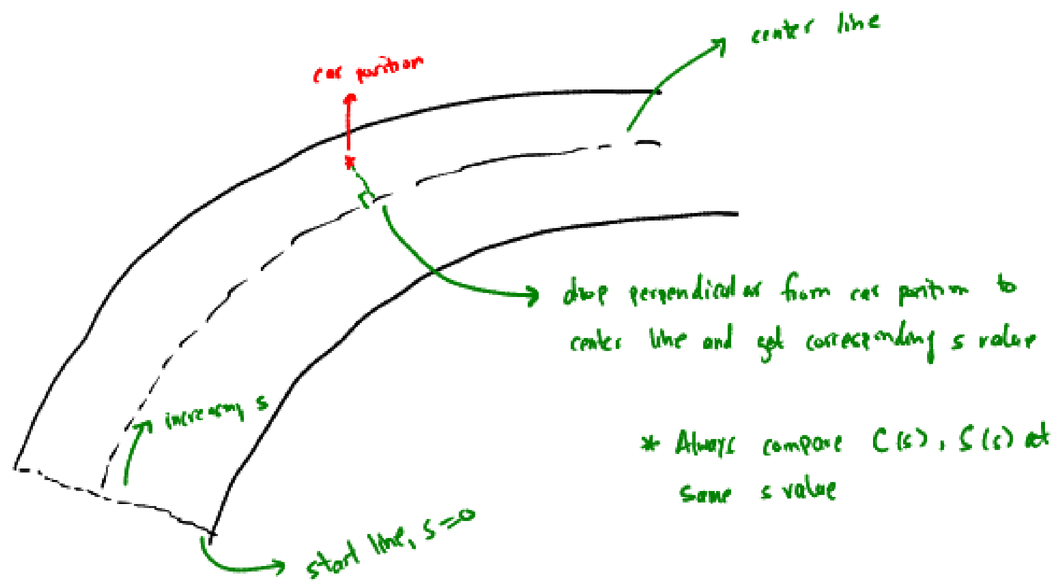

Figure 1: Caption

- Cross-correlations of two quantities over some time-window i.e. previous K time-steps

The idea is that $\mathcal{C}(s)$ and $\mathcal{S}(s)$ capture multiple metrics and trace a curve in some high-dimensional space. As s increases, one moves along this curve for the coach and the student.

One way to suggest changes to the student is to identify points, s_t where $\mathcal{C}(s_t)$ and $\mathcal{S}(s_t)$ are very different. Formally this could be done by ranking s_t values according to the metric $(\mathcal{C}(s_t) - \mathcal{S}(s_t))^2$. Note that since $\mathcal{C}/\mathcal{S}(s)$ are vector quantities i.e.

$$\mathcal{C}/\mathcal{S}(s) = (T(s), B(s), \theta(s), \ldots)$$

we would have to normalize the scale of each quantity to be between some limits (e.g. between 0 and 1) and then compute the metric as a sum/average of squared differences for each quantity.

Once we have identified the points where a student's trajectory is most different from the coach's trajectory, we can rank the quantities and point out the ones that are most different. More precisely, suppose that $\mathcal{C}(s_*)$ and $\mathcal{S}(s_*)$ have a large difference. Then, one could compare:

$\mathcal{C}(s_*) = (T_c(s_*), B_c(s_*), \theta_c(s_*), \ldots)$

and

$\mathcal{S}(s_*) = (T_s(s_*), B_s(s_*), \theta_s(s_*), \ldots)$

and rank each quantity by the size of their respective differences: $(T_c(s_*) - T_s(s_*))^2$, $(B_c(s_*) - B_s(s_*))^2$, $(\theta_c(s_*) - \theta_s(s_*))^2$ etc.

This could also be turned into text for the student with suggestions like: "your throttle is too high, slow down", "you are braking too early, stay on the throttle" etc.

This part is a bit hand-crafted but we can test it against two drivers and hopefully significantly improve the student's lap times.

Note that everything above assumes that the car condition and setup and track conditions are almost identical for the coach and the student. In the future, these suggestions could be used to train a model that can generalize to unseen conditions and setups (haven't thought carefully about this part yet :))