KENWORTH TRUCKS: DYNAMIC TRAILER-MEASUREMENTS CALCULATOR

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KENWORTH

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Introduction

Autonomous tractor-trailers are very likely the future of freight. One of the most important and least researched tasks for and autonomous tractor-trailers is reversing into a loading dock; the variable dynamics of a pivoting trailer makes it difficult to keep track of the trailer's position.

We have designed a system capable of measuring the trailer angle (relative to tractor) as well as calculating the trailer's length and the wheelbase of the entire system.

The system is mountable in its entirety to a Kenworth tractor, which can gather data in near real time.

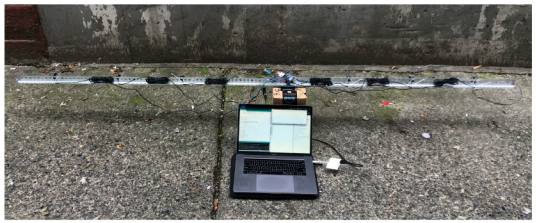
Ultrasonic Trailer Angle Measurement

Designed for a standard truck-width of 94" an array of 6 ultrasonic sensors are evenly distributed on the left and right sections of the array (shown below). No sensors are placed in the center of the array due to the near 0" movements of the trailer relative to the tractor.

The distance measurements are sent to an Arduino Nano which maps the 6 data points to create a linear fit for the data reads, to determine the turn angle of the tractor (θ) relative to a base angle of zero degrees (when the trailer is parallel to the tractor).

A filter is applied to the angle measurement that recalculates the angle if a sensor measures an unrealistically change since the last angle calculation (change of >75")

The trailer angle data is then sent to our system, which communicates it to the truck over the CAN bus protocol.



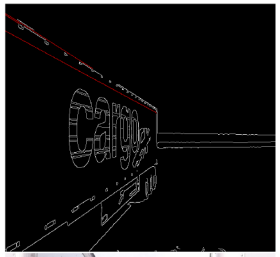
Simulation and Algorithms

As a result of Washington's Stay-at-Home order, we only had access to an actual tractor-trailer for half of our project time. Responding to this, we moved from our original stereo camera setup to a one-camera system that could be simulated in Unity using a tractor-trailer model purchased from the Unity Assets Store.

Trailer Length

In this simulation, we have created a virtual camera mounted on the model's side-view mirror, looking straight back at the trailer. We have to "cheat" a little and take the trailer angle directly from the simulation, as we cannot simulate our ultrasonic array in Unity.

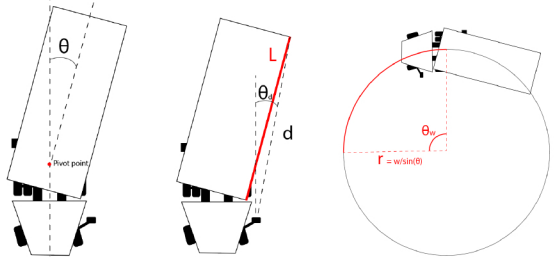
We then put the image from the side-view camera through our image processing algorithm, which applies an edge filter and locates the pixel location of the rear of the trailer. Using known properties of the camera, our "measured" trailer angle (θ), and a fair deal of trigonometry, we can calculate the trailer's length (L). The image above shows our algorithm locating the back of the trailer (red line). The image below is an example of what real cameras would've captured.



Wheelbase

Our method of calculating the wheelbase relies on properties of the vehicle's turning radius, as shown in the top right. For this, we need information about the vehicle's speed. In a real application, we would get this via CAN bus from the truck itself but in our simulation, it is taken directly from the truck model.

Integrating the vehicle's speed as the trailer straightens after a turn, we can calculate the distance the trailer moves sideways as it centers. Using this and our measured trailer angle θ, we can determine the trailer's wheelbase (w).



Experimental Results

Trailer Length

In simulation, our length calculation is fairly accurate. Distances are accurate to +/- 1m, with increasing accuracy as a rolling average is taken. One problematic area is the effect of "busy" backgrounds on the image processing, which cause the rear of the trailer to be located incorrectly. We believe this is due to the polygon-based nature of our simulation, which introduces a lot of noise to the edge-detecting algorithm.

Wheelbase

The wheelbase calculation is more accurate than the length, with accuracy at around +/- 0.5m. Again, as more samples are added the accuracy increases, quickly reaching +/- 0.1m.

Trailer Angle

The angle calculation is quite accurate, being within +/- 1 degrees. While the device is being turned, approximately every 10 data points will read garbage angle measurements. This does not happen while the device isn't being moved.

Future Work

Once the stay-at-home order ends, another group could work on the following additions:

- Alter image processing algorithm to work with different shapes of trailers
- Assemble and mount the system on an actual tractor-trailer to fine tune the error calculation
- Implement the stereo sensor camera set up on both side mirrors of the truck and fine tune the image processing software to clearly detect edges

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