International Co-operation on Theories and
Concepts in Traffic Safety

Spatial and temporal errors when measuring SMoS

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Introduction

Critical situations in road traffic have been identified and evaluated semi-automatically by the use of modern surveillance technologies (e.g., video cameras, lidars) and efficient methods for content extraction for approximately two decades. For instance, metrics such as time-to-collision (TTC) quantify the closeness of car-following interactions, which have to exceed some threshold to be considered a conflict. Rarely, the question is asked about the error introduced in measures such as the TTC by such an approach. So, the question arises whether a TTC = 0.5s is a real conflict, or is it the result of measurement uncertainties. Here, we fill this gap by simplifying what has been presented in Leich et al. (2016).

Research methodology

A simplified error model based on a camera is obtained that considers the following parameters: camera aperture angle (β), distance of the camera to the traffic scene (d) and error (Δd), object size angle (α) and error (Δα) to derive the real-world object size (p) (see Figure 1). Note that possible correlated errors (e.g., speed) are not considered here, which might lead to an overestimation of actual errors. Consequently, the results shown here may be an upper limit.

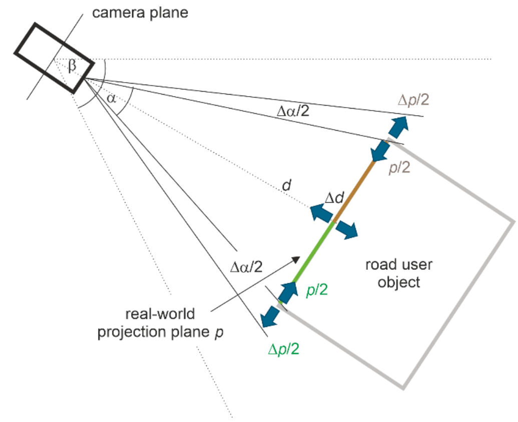

Figure 1. Simplified error model

Clearly, the spatial error of the projection in the real world leads to:

$$\tan\left(\frac{\alpha \pm \Delta\alpha}{2}\right) = \frac{p}{2(d \pm \Delta d)}$$

Rearranging this equation leads to the projection in the real world:

$$p = 2(d \pm \Delta d)\tan\left(\frac{\alpha \pm \Delta\alpha}{2}\right)$$

We can now apply this model to obtain temporal errors in determining conflicts calculating TTC in car-following. TTC is calculated with the spatial net-gap ($g = p$) and the speeds of the leading and following road users (i.e., v_l and v_f respectively) provided by a model-based approach such as Kalman Filter (note that the same approach as for quantifying the distance and object size errors can be applied to determine the speed errors in each of the data frames, but it is not considered here):

$$ttc = \frac{g}{\delta v} = \frac{g}{v_f - v_l}$$

Obviously, the camera can measure the distances of the interacting road users either as too short or too large. Consequently, if both extremes hold (i.e., the gap-distance errors are within $2\Delta g$), the TTC can be computed as:

$$ttc = \frac{1}{v_f - v_l}(g \pm 2\Delta g)$$

Results

In Figure 2 (left), the spatial real-world projection errors (Δp) are shown for different distance and object size errors in case of a camera-based traffic surveillance system with an aperture angle $\beta = 50°$, camera distance to the real-world object of $d = 60$m, horizontal object size $\alpha = 60$px and horizontal camera resolution of 1556px. In Figure 2 (right), TTC-errors (Δttc) are shown for different spatial real-world projection errors ($\Delta p = \Delta g$) over speed differences (δv).

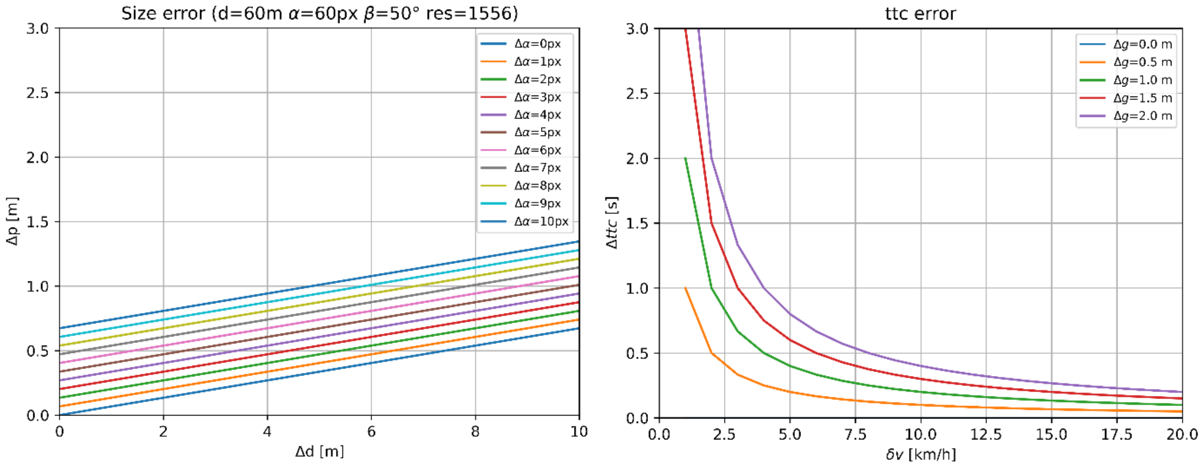

Figure 2. Spatial object size errors for a real camera-based surveillance system (left) and derived TTC-errors (right).

Discussion and conclusions

Distance error (Δd) and object size error ($\Delta\alpha$) do linearly affect the real-world projection errors (Δp) with an increase of approximately 10%. For instance, in case of $\Delta d = 8$m and $\Delta\alpha = 7$px, projection error becomes $\Delta p \approx 1$m. The TTC-error is independent of the actual distance of the road users to the camera, but it is dependent on the gap-distance error (Δg) and grows linearly. In case of low speed differences, TTC-error is expectedly large (but has hardly an effect on traffic safety due to less kinetic energies in a crash). For instance, if $\delta v = 10$km/h and $\Delta g = 1$m, $\Delta TTC = 0.36$s. What such a ΔTTC-value means by interpreting the results of conducting traffic safety studies with SMoS is the question. This error model is extended to crossing conflicts and finally, minimum requirements to road traffic surveillance systems are met.

Literature

Leich, A., Kendziorra, A., Saul, H., Hoffmann, R. (2016) Calculation of Error Rates for Detection of Critical Situations in Road Traffic. 95th TRB Annual Meeting 2016, 10-15 Jan. 2016, Washington, USA.