Computational Desire Line Analysis of Cyclists on the Dybbølsbro Intersection in Copenhagen

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Extended Abstract

Safe and functional cycling infrastructure is necessary to support the uptake of cycling in cities [1]. Especially street intersections are important conflict points where cars and bicycles meet, causing a large fraction of road deaths and injuries [2], and must therefore be planned with human behavior in mind. The intersection at Dybbølsbro, Copenhagen, is a notorious example which has been criticized for confusing cyclists due to its difficulty to navigate, and is currently scheduled for a second major redesign [3]. To understand to which extent intersection designs are adequate for cyclists, some studies have begun tracing and recording cyclist trajectories and behavior [4,5]. However, these methods are manual, therefore costly and not scalable.

Here we first ask: How can we use computational methods to automatize the analysis of cyclist trajectories? Focusing on Dybbølsbro, we then ask: How much do cyclist trajectories deviate from the design's intended paths and why? Finally: What are the implications for the design of intersections?

Our starting point is a set of 11,553 cyclist trajectories, which had been extracted via custom-trained YOLOv5 model from a high-resolution 1h video from 2021-06-09 07:00-08:00 of the Dybbølsbro intersection. This intersection has been redesigned in 2019 with a bidirectional bicycle track on the south side (S), which has made it difficult for cyclists to navigate due to the need to switch sides when coming from north (N) [3].

Applying DBSCAN to origin-destination pairs and filtering of broken trajectories, yielded 4432 trajectories over 9 origin-destination (OD) clusters. To each of the OD-clusters we applied dynamic time warping, generating 20 additional path-clusters respectively, denoted by different trajectory colors in Fig.1. Finally, we contrasted these path-clusters with the designed paths to study how cyclists are actually moving from each origin to each destination versus how it was intended by the planners.

We found that at least 11% (495 out of 4432) trajectories are not following the designed paths. The mismatch is especially strong in particular OD-clusters. For example, only 466 out of 733 cyclists follow mostly intended behavior in OD-cluster N→S (Fig.1), implying a mismatch between design and reality of at least 36%. Analysis of trajectory durations reveals the likely cause: On average, diagonally crossing cyclists spend only 13s, and cyclists crossing via the NE corner spend 32s. Contrast these values to 43s, which is the time spent by cyclists who follow the designed path with the additional stop.

Our mostly automated method can well support the behavioral analysis of a large number of cyclists, and it has quantified a non-negligible number of at least 495 not intended, potentially life-threatening trajectories - all happening in just one hour. It is an open question whether our method can be generalized and fully automatized, and how the quality of analysis compares to manual methods. In the future, every step of our computational pipeline should be scrutinized to ensure high trajectory quality. In particular, bias could have been introduced by lost trajectories from occlusion or tracking errors in specific parts of the study area. In any case, we expect our method to scale better and to be less costly.

For the upcoming re-design of the Dybbølsbro intersection, consultants have considered traffic counts from video analysis and qualitative assessment of behavior, but without quantifying desire lines [3]. A repeated evaluation with our method after implementation could provide an assessment of the re-design's success rate, and whether a more profound analysis or re-design is called for. Our results confirm the intentions of the re-design [3] that intersection complexity should be lowered and the momentum and smooth wayfinding for cyclists should be respected, as also found in previous research [4,5].

References

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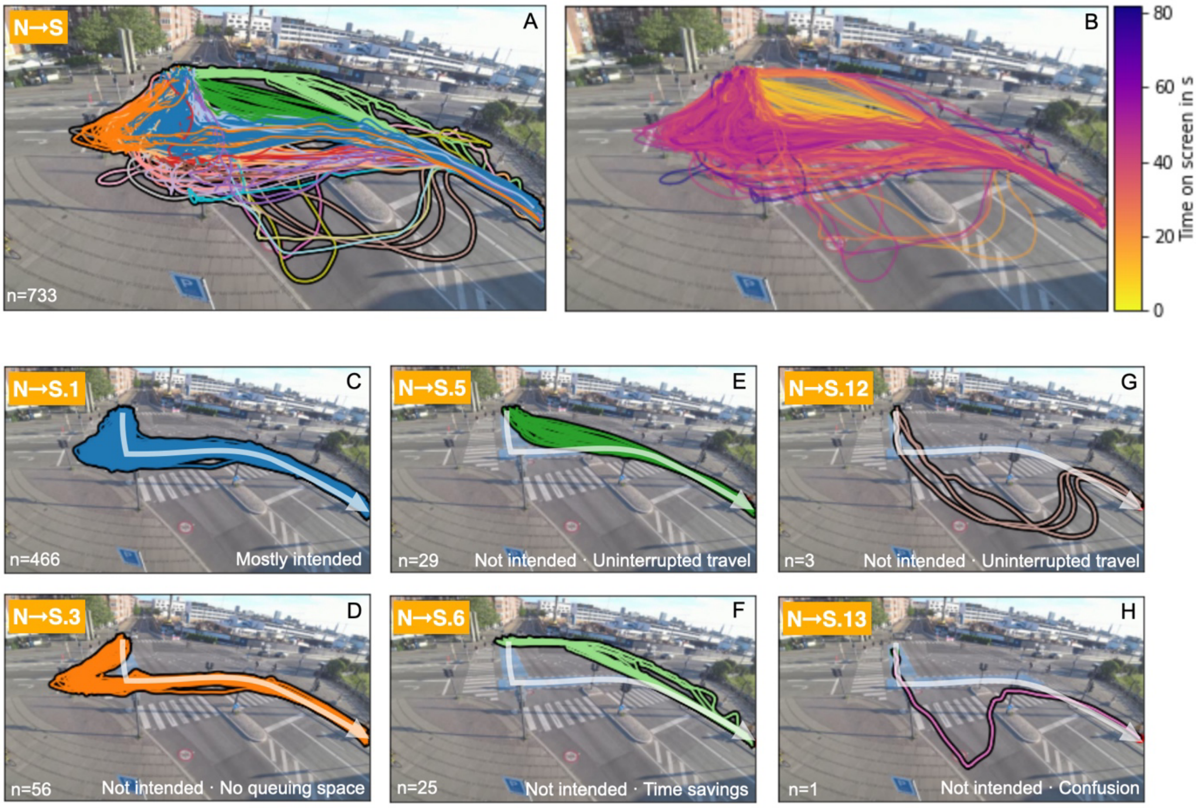

Figure 1. Investigation of OD-cluster N→S and some of its path-clusters. White arrows show the intended, legal path. A) OD-cluster N→S and its 733 trajectories. B) Time on screen demonstrates that crossing the intersection diagonally, while illegal and not intended by the planners, provides substantially shorter crossing time (13s on average) than following the intended path (43s on average). Crossing via the NE corner is also faster (32s on average) than the intended path. C) Path-cluster N→S.1 shows mostly intended behavior (466 trajectories). D) Path-cluster N→S.3 shows not intended behavior because cyclists move onto the crosswalk, presumably due to lack of queuing space (56 trajectories). E) Path-cluster N→S.5 shows not intended behavior, crossing diagonally (29 trajectories). F) Path-cluster N→S.6 shows not intended behavior, crossing via the NE corner instead of the SW corner (25 trajectories). G-H) Path-clusters N→S.13 and N→S.12 show not intended behavior, entering street space that is intended for cars only, possibly due to uninterrupted travel or confusion (3 and 1 trajectories, respectively).