Assessment of visual obstructions at unsignalized intersections

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Abstract—At unsignalized intersections visibility from the minor road to the major road is necessary for safe traffic operations. Required sight distances usually depend on the traffic management, location of intersection, speeds on the major and minor roads and maneuver. Road design guidelines give exact rules, but they are often unachievable. Many of the existing intersections do not have the required size of their sight fields, or there are obstacles placed within the sight field, causing object occlusion The recent survey methods like laser scanning and photogrammetry give effective methods to check the spatial sight distances in detail. However, a detailed but integrated assessment of the sight conditions is missing. Instead of unrealistic requirements like "should be free from any obstacles" a detailed evaluation of the amount, nature, and position of obstacles in the sight field would lead to more realistic requirements which could be really met in practice. This paper intends to outline a detailed and integrated method for the assessment of visual obstructions at unsignalized intersections.

Keywords — road intersection, visibility, evaluation, sight obstructions

I. INTRODUCTION

Intersection visibility is a crucial safety issue. At unsignalized intersections the driver on the minor road has to see the oncoming vehicle on the major road in order to give priority. In addition, he has to see the vehicle entering or crossing from the minor road in order to act in an emergency situation. These sight requirements are defined in various road design guidelines.

Specified areas along intersection approach legs and across their included corners should be clear of obstructions that might block a driver's view of potentially conflicting vehicles. The dimensions of the legs of the sight triangles depend on the design speeds of the intersecting roadways … [1].

II. LITERATURE REVIEW

A. Visibility requirements at unsignalized intersections

Visibility criteria are defined similarly in various international sources. Required sight distances usually depend on the traffic management, location of intersection, speeds on the major and minor roads and maneuver (behavior of drivers).

Although principles are similar, road design guidelines in different countries define different terms and rules for required sight distances and sight fields. The American AASHTO guidelines [1] describe Approach Sight Triangles and Departure Sight Triangles, while the Australian design guide [2] contains Approach Sight Distances, Safe Intersection Sight Distances and Minimum Gap Sight Distances.

These sight distances and sight triangles are defined by

- a viewing point, located at a particular point near the intersection (e.g. 3m from the STOP line) at a particular height (e.g. 1.05 m for cars),
- a target point, located at a particular point near the intersection (e.g. a vehicle on the major road at the minimum gap sight distance) with a particular height (e.g. 2.5 m for heavy vehicles),

The points above define sight triangles or visibility splays. In Figure 1. Sd is the conflicting vehicle distance and de is the decision point distance. These distances vary depending on the type of sight distance in question.

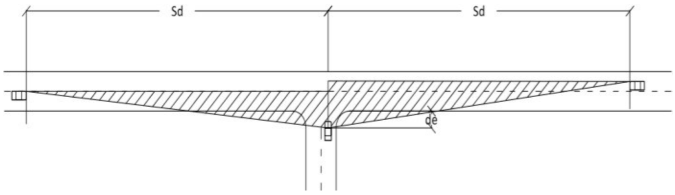

Fig. 1 Intersection Sight Triangles

Design guidelines usually consider visibility as a two-dimensional problem, but it should be three-dimensional.

Regarding these triangles, road design guidelines give instructions like "Each quadrant of an intersection should contain a triangular area free of obstructions" [1] or "… is the minimum level of sight distance which must be available …[2].

Authors of guidelines are aware that sight obstructions are present in many cases. Actions for removing these obstructions are recommended, e.g. "Within a sight triangle, any object at a height above the elevation of the adjacent roadways that would obstruct the driver's view should be removed or lowered, if practical" [1].

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Some guidelines define obstructions according to their size. According to the UK regulations “No substantial fixed obstructions shall be located within the intervisibility zone of new junctions” [3]. Details of what constitutes a substantial fixed obstruction are provided in [4] as follows.

“The stopping sight visibility envelope shall be free of obstructions by fixed objects with the exception of:

1) a fixed object with a width / length less than or equal to 550 mm;

2) a group of fixed objects with a combined width / length of 550mm or less

NOTE Isolated slim objects less than or equal to 550mm in width / length, such as lighting columns, sign supports, or slim footbridge supports, only result in intermittent obstructions to sight lines.”

Concerning railway-road level crossings, the term “clear zone” is also used to refer to a zone within the railroad corridor along the tracks free of sight distance restrictions. For example, Illinois regulations require a 500-foot clear zone which is to be kept “reasonably clear of … all unnecessary permanent obstructions such as unauthorized signs and billboards” [5].

The recommendations or obligations in the guidelines are difficult to meet. There are surprisingly few statistics about real visibility conditions, but from the ones published it is clear that there are a lot of intersections where visibility criteria are not met.

For example, a study in Japan by Nomura showed that most of the 1629 urban intersections studied have poor visibility. It was found that the accident rate was high when visibility was poor [6].

Another study of 22 intersections in built-up rural area along a provincial road in Poland concluded that the main reason for the insufficient visibility at many intersections is the fact that the geometrical parameters of roads and their surroundings were shaped in the past when the traffic conditions were completely different [7].

In general, we have to be aware that the current guidelines are often unachievable. Many of the existing intersections do not have the required size of their sight fields, or there are obstacles placed within the sight field, causing object occlusion.

B. *Identification and numerical characterization of individual visibility obstacles*

Knowing the layout of the junction and having some visibility obstacles, some indicators can be defined and measured. These are the hidden part of sight distance (Sd), and the hidden area (Sa), which are giving valuable information about safe entry to the junction. Furthermore, two angles can be defined to analyze the visibility obstacles to get more details (Fig. 2).

The angle of the hidden part (α) is a central angle for each object that shows how each obstacle reduces the field of view. From two same sized objects the closer one causes larger obstruction. From two same sized objects at same distance, the one on the edge of the field of view creates larger hidden length. The length hidden by the circle to the right is larger than the hidden length by the first one. For details the directional angle (δ) can be calculated as well

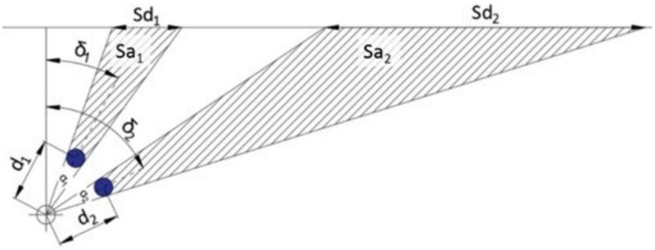

Fig. 2. Indicators to visibility investigation

The recent survey methods like laser scanning and photogrammetry give effective methods to check the spatial sight distances in detail [8], [10]. Results of these are point clouds consisting of a huge number of points measured in 3D coordinates in one space. The evaluation of these point clouds from the aspect of visibility requires lots of calculations, these analyses need less operation in 2D than in a complete 3D point cloud space.

Concluding the above studies, a detailed but integrated assessment of the sight conditions can be mentioned as a further research direction. Instead of unrealistic requirements like “should be free from any obstacles” a detailed evaluation of the amount, nature, and position of obstacles in the sight field would lead to more realistic requirements which could be really met in practice.

A potential approach is shown in [7]. They used a rating scale from ”0” to “5”. The assessment was based on an analysis of the fields of required visibility graphically determined in accordance with the recommendations of the applicable regulations. It was assessed whether the obstacles were found inside the fields of visibility and what kind of obstacles they were. A rating of “5” means there are no obstacles in the required field of visibility and the lines limiting the field of visibility do not intersect. A rating of “0” means that a field of real visibility is negligible.

III. A NEW APPROACH TO AN INTEGRATED CHARACTERIZATION OF VISIBILITY OBSTACLES

The approach to the integrated characterization of visibility obstacles will be presented here on a case study.

- An intersection is surveyed and modelled in 3D. In Fig. 3 a T-intersection on the university campus is shown with various isolated and continuous obstacles (trees, buildings).
- A viewpoint is defined as the eye position of the driver on the minor road.
- A target plane is defined. This is a vertical plane (surface) following the path of the vehicle on the major road (Fig. 4). The height of this plane may differ, depending on the height of the object to be recognized (car, bus, pedestrian, child, etc.).

- Definition of visible and non-visible points of the target plane. Projection of obstacles from the viewpoint (Fig. 5). The density (resolution) of the points may vary. In Figure 5 green points of the target plane are visible, red dots are not visible. The goal is here to find indicators describing the shares and distributions of visible and hidden areas. As a start, we have two point-clouds. One is on the reference plane, created with a given point density. This is indicated with red points in Figure 5. The other one is the point-cloud after the removal of hidden points, the remaining points indicated with green. These two point-clouds are located in a vertical plane, with minimal deviations in the Y direction. After merging these two point-clouds, a new set of points was created with about 16k elements.
- In the next phase, these points were merged with a rasterization procedure. This procedure means to create a structured mesh from randomly distributed points. The mesh should continuously fill in the space, either by a triangular or by a grid structure.
- Evaluation of the visibility of the target plane at different resolution levels.

The last phase may contain calculation of percentages, i.e. how much from the total target plane is visible. This can be calculated from the surface area of the target plane. The share of visible and hidden areas can be different, as the resolution changes. Besides the percentage, the distribution of visible and hidden areas is important to assess the quality of the “picture”. If your window has a mosquito screen, it may cover e.g. 20% of the window, but you still perfectly see, as a person or a car is passing by. On the other hand, if the same 20% occlusion is concentrated on a crucial part, you have no information about what is happening in the area-

Going from high resolution to lower, larger sections receive the attribute of the majority of smaller sections. Fig. 6 shows an example of a 71 m long target plane in the case study.

Fig. 3 Terrestrial laser scanner modelled intersection

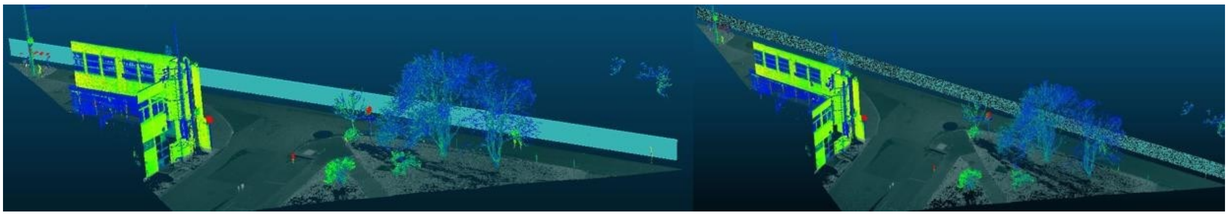

Fig. 4 Target plane

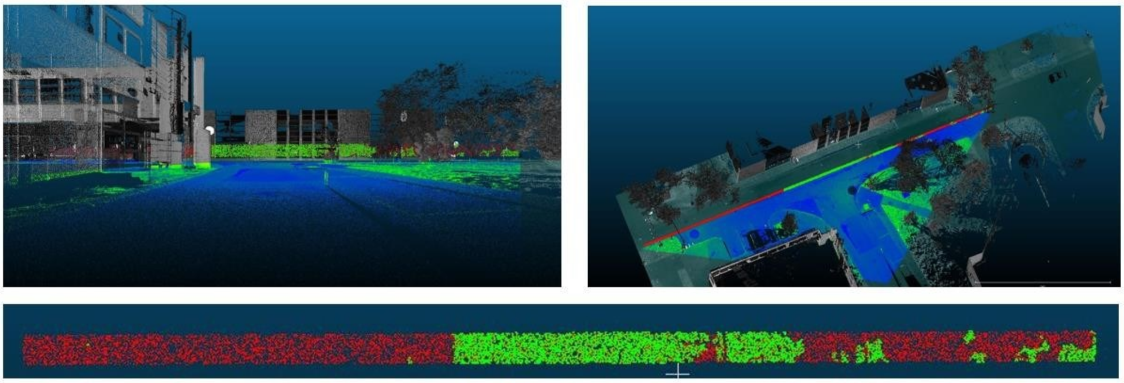

Fig. 5 Visibility of the target plane

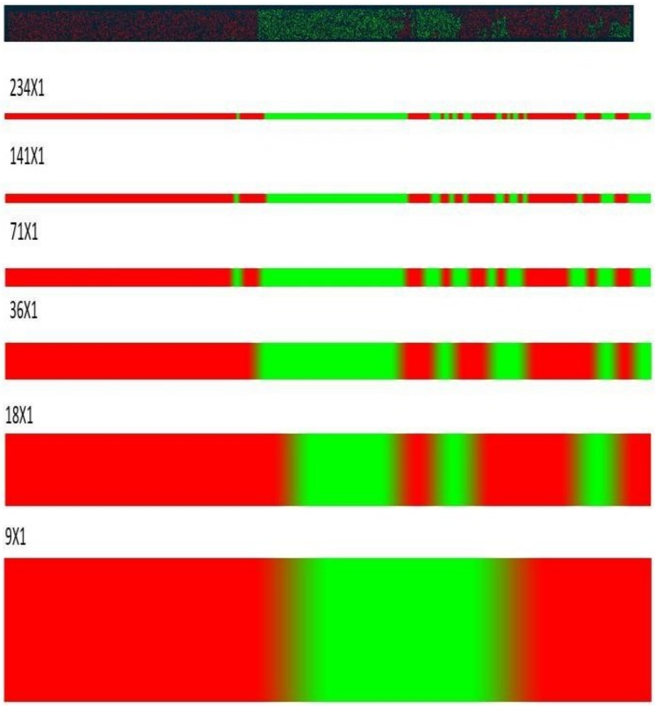

Fig. 6 Visibility of the target plane at different resolution levels

Table 1 is another interpretation of the case, showing that the share of visible points/sections is relatively stable, irrespective of the resolution level.

TABLE 1 VISIBLE AND NON-VISIBLE SECTIONS

Resolution [m]	Number of units	Number and share of visible points		Number of continuous units	
0.1	701	253	36.1%	31	4.4%
0.125	561	206	36.7%	29	5.2%
0.25	281	104	37.0%	19	6.8%
0.5	141	52	36.9%	9	6.4%
1	71	27	38.0%	7	9.9%
2	36	13	36.1%	3	8.3%
4	18	6	33.3%	2	11.1%
8	10	4	40.0%	3	30.0%
16	5	2	40.0%	2	40.0%
36	3	1	33.3%	3	100.0%
71	2	1	50.0%	1	50.0%

IV. DISCUSSION, CONCLUSIONS

Evaluation of intersection visibility is a complex task. This research shows that visibility criteria of road design guidelines are rarely met, therefore simple yes/no answers are not adequate for a whole intersection.

Simple percentages will not describe visibility, as e.g. a building blocking the view in 50% has a different impact than a fence with 50% transparency/occlusion. Therefore, visibility has to be evaluated at different resolution levels.

Furthermore, state-of-the-art laser scanner or LIDAR equipment is an appropriate tool for detailed evaluation of intersections. However, besides details of intersections and identifications of individual obstructions, an integrated evaluation is also needed. This paper tried to outline such an assessment method for conventional T and X intersection. For roundabouts, more complicated approaches are needed [12].

The issue is relevant also for autonomous vehicles, how to navigate in difficult situations like occluded intersections. Research is this direction has started already (e.g. [11], [13]).

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