Behaviour at Pedestrian Crossings

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Abstract

A contribution on Transport Safety and on Travel Behaviour using a new high-tech method to gather data on the simultaneous movements of pedestrians and cars at road crossings. Presentation of method and first results of a research project funded by the Swiss Fund for Road Safety (Fonds für Verkehrssicherheit).

The Problem

Collisions at pedestrian crossings are a problem which cannot be solved by purely technical measures, because the interaction of the behaviour of the pedestrians and the drivers is not a technical problem. The planning of the campaign "Yellow zebra" (see: www.gelbeszebra.ch / www.zebrejaune.ch / www.zebragialla.ch) of the Touring Club of Switzerland together with Fussverkehr Schweiz (The Swiss Pedestrian Association) has shown, that there are few exact data on the simultaneous motions of the different road users on marked pedestrian crossings. In order to improve the these human related interactions at crossings, and to give the best recommendations for behaviour, a better knowledge of the exact movements at pedestrian crossings under different conditions would be helpful to get the best results.

The Method

Using the recently developed laser sensor „LOTraffic" (Website see Literature), which is able to spot all objects within a range of 20m distance from the sensor, and an angle of 180° at a frequency of 75 times per second, we want to test the different situations and different behaviours of pedestrians, and their effect on the behaviour of car drivers. This way we can find out which measures (such as illumination, central island, visibility) and which behaviours (such as fast motion, bright clothing) influence the drivers positively to yield for crossing pedestrians. We plan 15 weeks of data gathering which will enable us to identify a great variety of interactions of cars with pedestrians. Developing an algorithm that calculates ~~for~~ the correct behaviour of pedestrians and one for car drivers, we can describe with high precision all encounters of cars with pedestrians during the periods the equipment is installed.

We not only want to use different locations to gather data, but we shall introduce in some locations standardised behaviour of test persons (e.g. persons walking with white coat, persons walking with black coat). This way we can see if specific behaviour of the test persons influences the driver's readiness to yield for pedestrians or not.

Results expected

The project started in 2004, using results which the firm LogObject produced in 2004 for the city police of Zurich. In this paper. We explain how the algorithm is constructed, what considerations have been taken into account, and what data are needed to model the different types of dangerous situations as well as correct behaviour at pedestrian crossings. At this juncture we are interested in discussing with other professionals outside of our working group the project at an early stage, because it will still be possible to optimise the set-up of the main series of the data gathering and we look forward to the input of conferees. .

At the end of the project (2006) we should have the information necessary to improve the sites of pedestrian crossings, and be able to give useful and more precise recommendations for behaviour at pedestrian crossings.

Keywords

Pedestrians – Pedestrian crossing – laser-sensor – road safety

1. The Problem

One of the problems which we think is easy to understand, and known to everybody is the crossing of a road on a marked pedestrian crossing or zebra crossing. We have learned as children to: stop, look left, then look right and then look left again, listen, and walk before we proceed. Car-drivers learn that they have to yield at pedestrian crossings for pedestrians who are "about to cross", and they have to get ready to stop, if there are pedestrians in the street. Theoretically, there is no problem, but we all know, that in practice the real behaviour of people is more complicated.

1.1 Current Recommendations

Recommendations which aim at improving road safety cannot follow the line of what is forbidden and what is permitted. Laws and ordinances help to determine who is guilty in case of an accident, but recommendations of behaviour, are something quite different and are aimed primarily at preventing dangerous situations in the first place. We have to recommend to drivers as well as to pedestrians to behave in a way that is not only more cautious than the law would permit, but also more consistent.

To this end, the Touring Club of Switzerland (TCS) and "Fussverkehr Schweiz", the Swiss Pedestrian Association have in 2004, launched the Yellow Zebra campaign which promoted 5 recommendations for pedestrians, and 5 recommendations for car drivers.

Recommendations for Pedestrians:

Do not step on the carriageway suddenly, make safety a priority and stop in your path if necessary.	Take into consideration that your right of way is never absolute: Any vehicle in motion needs a certain distance to be stopped. Do not expect abrupt breaking manoeuvres successfully stop the oncoming vehicle.
Show your intention to cross the street with a clear posture.	Show your intention clearly, by standing upright at the edge of the carriageway. Signs with the hand are not compulsory, but permitted Children are advised not to give handsigns because they falsely might assume that that they can stop cars with a sign in all cases.
Step on the stripes only if you see that there is no danger .	Before stepping on the carriageway watch out for cars from the left and from the right side as well as from the ones turning from ahead and from behind. Make sure that drivers

	have seen you. Watch out: The tram has the right of way even at marked pedestrian crossings.
Pay attention to vehicles on all lanes, to the ones approaching on the far side of the street, as well.	When a driver has given you the right of way, you still have to make sure that no other driver is about to overtake that vehicle from behind. This is particularly important if there is more than one lane in that direction. Other cars or cyclists may be unseen by you because of bigger vehicles, in turn, you are hidden from them.
Be aware of all possible mistakes made by drivers. All humans have strong and weak points.	Diversion, stress, emotions, and many other reasons may lead to unexpected reactions by drivers. Don't take any risks, and calculate enough space for possible misbehaviour. Bright coloured clothes or reflecting patches are good for your safety at night.

Recommendations for Drivers

Watch out for pedestrians – and be ready to put on the breaks.	Make it a habit to observe pedestrians, especially close to zebra crossings. In the dark and in poor weather you have to expect "invisible" pedestrians, in particular those with dark clothes.
Give priority to pedestrians coming from the right hand side as well as from the left hand side.	Stop when you see that a person has the intention to cross, and not only when the person is stepping on the carriageway. Be aware of pedestrians in particular while making a left or a right turn.
Stop completely and wait for children, handicapped and old persons.	Pre-school children are not able to estimate speeds. Police instructors teach them to step on the road only if no car is visible, or if an approaching car has stopped. Only when the wheels have stopped children are allowed to step forward. This is the case, even if they are accompanied by adults. Children, handicapped persons, and old persons may unexpectedly move ahead, stop, or turn back. – Stop completely, and wait until pedestrians have left the pedestrian crossing.
Never overtake slow, breaking, or stopping vehicles, and certainly DO NOT attempt to pass on the right-side of a	Pedestrians may be covered by vehicles. Therefore, you must not overtake slow, breaking, or stopping vehicles while approaching a pedestrian crossing. Be particularly prudent on roads with more than one lane.

slowing or stopped car.	In front of pedestrian crossings you are allowed to stop only to give way to pedestrians. Otherwise stopping or parking in front of or on pedestrian crossings is always prohibited. Not even in a congestion you are allowed to stop on a pedestrian crossing.
Be aware of possible mistakes by pedestrians. All humans have strong and weak points.	Don't take the correct behaviour of pedestrians for granted. They may not have been instructed, they may be restricted in their perception, or they may be somewhere else in their thoughts. If a pedestrian does not observe your vehicle, this is a sign of alarm to you.

The texts in German, French and Italian you find under: *www.gelbeszebra.ch*, *www.zebrejaune.ch* and *www.zebragialla.ch*

1.2 The need to improve the recommendations

The work on these recommendations has shown, that it is not certain which recommendations would have what effect, and, in particular, it was not sure which ones were the most necessary to improve the situation. They were grouped together as "best practices". The meetings between pedestrians an drivers at pedestrian crossings are subject to a great variety of perceptions and emotions. Throughout the campaign, in the media it has been noted with sympathy that recommendations were made at the same time to pedestrians and to drivers. The analysis of accident data shows that children, and even more so elderly people, are in great danger while crossing a road on a zebra crossing. To improve this situation we need to improve these recommendations, fine tuning them with greater specificity and for different target groups.

2. The Method of the research project

We had to find a method with which two movements, the one of the pedestrian, and the one of the approaching car can be analysed simultaneously. There have been projects, where students have been employed as observers (Ewert, 1997). However, observers will have difficulty to observe the two simultaneous movements correctly, because in practice it is difficult to look at an approaching car at a distance of 30 meters, and look at the pedestrian waiting at the crossing at the same time. The use of a video camera does not help a great deal, if you want to make a statistical analysis, because each hour of film needs hour to look at it, an even more time to extract data if something interesting happens on the video. It is interesting to have a tool, such as the laser sensor combined with a computer that extracts data from a longer period of time, and condenses the observation process into useful data that can then be quickly downloaded and used in a statistical analysis.

2.1 The definition of a meeting between pedestrian and car

The first question to be solved is the definition of a “meeting” between a pedestrian and a car: If a pedestrian sees a car from afar and crosses, this is not yet a meeting; if a pedestrian comes to the crossing at the moment a car is passing, this is no longer defined as a “meeting”, because pedestrian and driver don’t interact. Somewhere in between the real meeting with some sort of interaction takes place. In order to reduce the number of all the movements of cars and pedestrians to the ones that fit our criteria of “interaction”, we have to make a mathematically precise definition of what a meeting is (so that this study could be duplicated and tested by other traffic researchers).

In the tests that have been made so far for the city of Zurich, the meeting was defined as follows: An arrival-space for pedestrians on the sidewalk (brit: pavement) was defined along the curb (German: Randstein), and a minimum time of stay in that zone ranging form 1 sec. for persons approaching from the side to 3 sec. for persons approaching along the road was defined to trigger the right of way to the pedestrian, i.e. the surface of the crossing was virtually “closed” after these seconds, and any car passing through this surface was registered as violating the right of way of the pedestrian. - This definition may be good enough for a rough analysis of a site, but it is not good enough to analyse the highly dynamic interactions between pedestrians and drivers. With respect to that study, it did not say enough about the simultaneous movements of all the actors.

Basically, we have to distinguish three different sorts of “meetings”:

- Normal meetings are meetings, where drivers and pedestrians interact and react on their respective behaviour in a correct way, i.e. the pedestrian waits at the curb, possibly putting one foot on the carriageway to demonstrate the intention to cross, and the car driver slows down and/or stops to let the pedestrian pass.

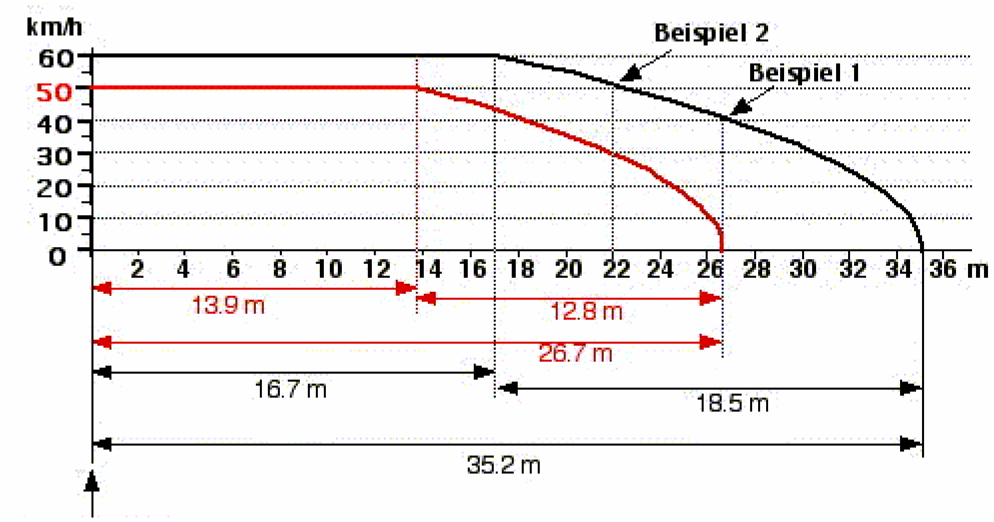
- The forced stop when the pedestrian forces the driver to jerk to a sudden stop and as a consequence endangers himself /herself.

- The driver does not yield the right of way to the pedestrian and forces his/her car along the road (a clear violation of the pedestrian priority).

In these descriptions we have several terms which need further interpretation in order to become useful for mathematical and statistical analysis. Here, we need to simplify a very complex set of possibilities of behaviour.

The original set-up for the city of Zürich takes into consideration the appearance of the pedestrian to the car-driver. Yet, we have to take into consideration the speed and the respective breaking distance of the car. At a speed level of 50 km/h (normal speed limit on main roads in built-up areas), breaking at $7.5 m/s^2$, we can calculate with a stopping distance of 26.7 meters composed of 13.9 m reaction distance and 12.8 m breaking distance:

Stopping distances, breaking distances, and remaining collision speed
at 50 and 60 km/h, $a=7.5 m/s^{2:}$ Rection-point at 0 m



Example 1 (Beispiel1): At the point, where the vehicle with the speed of 50 km/h at the beginning of the breaking manoeuvre is brought to a stop (26.7 m) the collision speed of an other vehicle with a beginning speed of 60 km/h is still 40 km/h.

Source: Arbeitsgruppe für Unfallmechanik, Zürich

The same result we find through an internet-calculator:
http://www.autokiste.de/start.htm?site=/service/anhalteweg/

However, a normal and safer manoeuvre would be smoother, one that would not pull the driver's seatbelt. If we take the coefficient for motorcycles of 4 m/s2 (back wheel only) we are probably close enough to a smooth manoeuvre for a car (to be verified). This would make a stopping distance of 35.4m according to the calculation made by the following table: http://www.auto-und-verkehr.de/bremsweg.php, or 38m according to the Excel-File "Anhaltestrecken.xls" *(difference to be discussed).*

A difficult question is the way we distinguish the forced braking movement (jerking to a stop) from a smooth breaking movement (slowly coming to a stop). The ordinance requires that pedestrians let a car pass, "if the vehicle is already so close that it could not stop any more in time." (Art. 47.2) This text does not define clearly how fast a driver is obliged to stop, but to be on the safe side, we cannot assume a stop as fast as described above for the purpose of making recommendations.

2.2 How to calculate the different situations

Accordingly, we could use the following algorithms for defining and calculating the three possible groups of behaviour:

- A car-driver is making a mistake if he arrives at the entrance to the measuring area (30 meters from the crossing) at more than 50km/h (speeding), or if he does not let a pedestrian pass (refusal of pedestrian priority) if this pedestrian has at that time been in the arrival-zone of the pedestrian crossing for one second and more (3 sec, if we extend the space along the road. This interval is long enough to give the driver the information that he is about to use the crossing.)
  Consequently, the following data should be registered:
  - Speed and deceleration of all cars at the distance of 30m from the crossing. (This would permit us to find out, whether or not cars pass generally at a higher speed when no pedestrians are in sight .)
  and after the entrance of a pedestrian in the arrival-zone the following data should be registered:
  - Passing of the cars entering the 30m-zone after a pedestrian has arrived in the arrival-zone, and their speed an their deceleration at that point, and at the distances of 20m and 10m as well (in order to analyse the movement of the cars);
  - deceleration or stop of any pedestrian on the crossing up to ¾ of the distance to the other side of the road or to the central island, if a car passes in front of him. (A pedestrian should always be able to cross at his/her normal speed while crossing.

If a pedestrian slows down or stops after having left the pavement, some car coming from his right side is not giving the right of way, because normally no pedestrian would want to slow down or stop on the carriageway). This way we are be able to observe both directions of the traffic even though the laser sensor does not reach to sense the approaching cars on the other side. *(to be discussed)*

- A pedestrian makes a mistake (urging a car to stop, even though the car has the right to pass), if he or she steps more than 30cm (one step) on the carriageway while a car approaches, which has been in the measuring area (up to 30m) before the pedestrian leaves the arrival zone, and which has a deceleration at 20 or 10 m distance, which has to be fixed somewhere between 4 and 7m/s2. *(to be discussed)*
  Second half of the crossing: We can assume that it hardly ever happens that a pedestrian urges a car-driver to jerk coming from the right side of the pedestrian, except if there is a central island which interrupts his/her right of way. This case we won't analyse, because the range of the laser sensor is not wide enough to include the movement of the approaching car.

- Normal (correct) meetings occur, when a pedestrian is in the arrival space at the time a car is entering the measuring zone (30m from the pedestrian crossing) , and if this pedestrian crosses the carriageway before the car passes.

(Note: The 30 meters chosen as the beginning of the measurement is due to the range of a reliable measurement of the sensor in use. The normal smooth stopping distance for a car at 50 km/h could be a little longer (35m), but since we include 1 to 3 sec. time for the pedestrian to be in the arrival area, we compensate more than 5 meters difference.)

The arrival space has to be defined according to the visibility in the location chosen: It has to be narrow in case of poor visibility (parked cars), and it may be larger in cases where there is no obstacle. The driver is obliged to observe the movements in his field of visibility, and react accordingly.

With this research project we can hardly analyse the behaviour of car-drivers approaching from the right side (as seen from the pedestrian), because the reliable range of the laser sensor is only 20 meters, however, we can make clues from the behaviour of a pedestrian in the middle of the road on the correctness of a driver coming from the right side.

Our research project is focussed on road safety. Therefore we would like to introduce the notion of endangerment of pedestrians. We could compare this with a near-miss in air traffic, and in a working group we defined this phenomenon as a distance of less than 3 meters between a pedestrian and a car at a speed of a car of 20 km/h and more. If possible this sort of manoeuvre should be registered.

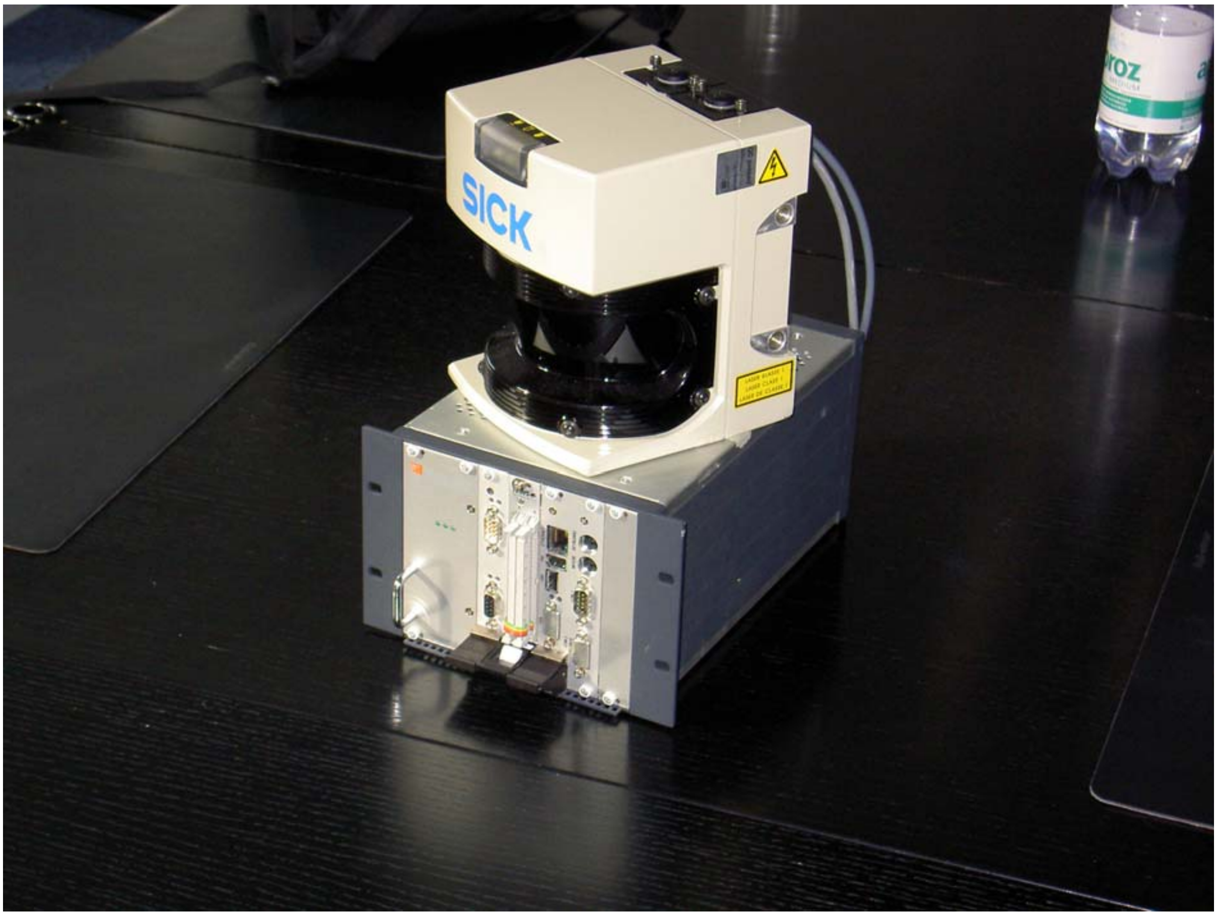
The distinction between legally correct and safe behaviour is again a very tricky problem, because it is not necessarily illegal to drive at 50km/h until 12 m before the crossing, and stopping just in front of the pedestrian (deceleration = 7.5m/sec2), but this is certainly not a safe behaviour. Therefore from the point of view of road safety, this behaviour is a mistake.

2.3 The use of a laser sensor

As far as we can see, no laser sensor has yet been used to observe the simultaneous movements at pedestrian crossings except by the above mentioned firm LogObject in Zurich. In a German project, the entire speed-profile of approaching cars has been registered by a laser-sensor, but the related movements of pedestrians have not been registered (Füsser et al. 1993).

The young ETH start-up enterprise LogObject has developed in the last few years a software to combine a laser sensor with a computer which enables the system to define movements. This system is called LOTraffic. It is aimed at pervasive traffic monitoring and scans a planar region of up to 40m, 180 degrees, 75 times per second detecting and tracking arbitrary objects, such as pedestrians, bikes, cars and trucks.

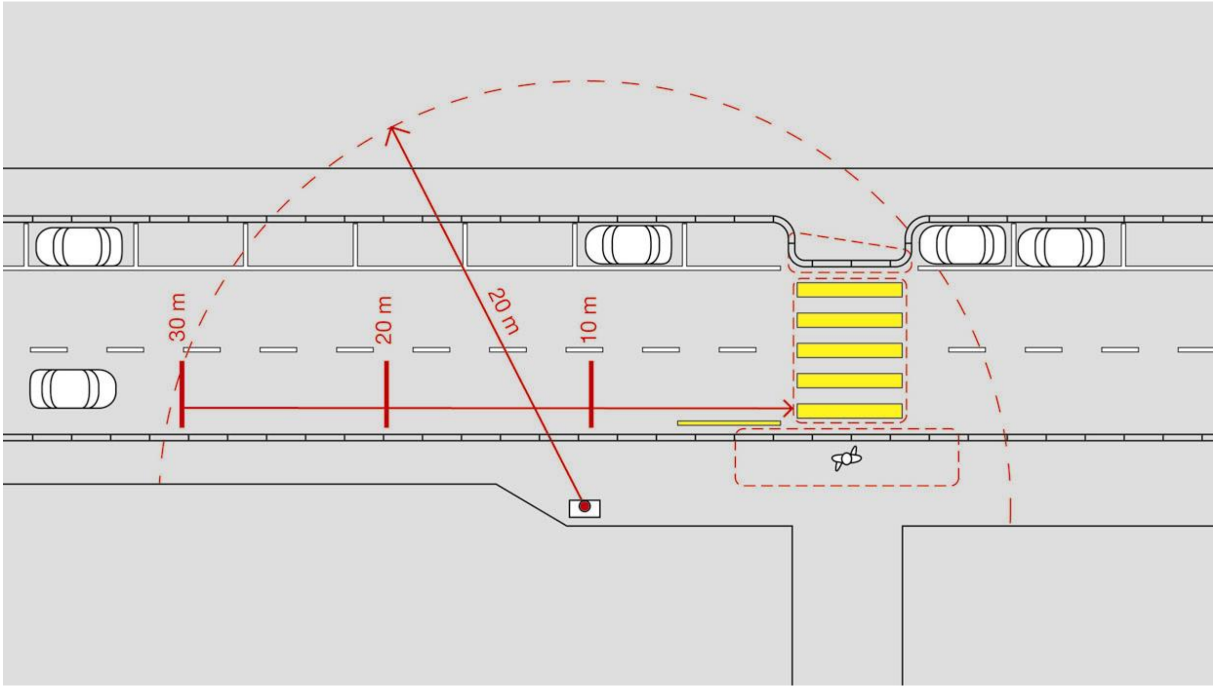
The laser sensors used for these purposes are the SICK LMS 221/291 laser range finders which provide radial, metric, sensory information. The laser senses a semi-circular environment 75 times per seconds and sends the resulting data stream to the processing unit (180°, 0.5° resolution). The industry standard processing-rack packs a twin processor pair: The first one processes the sensory information, a second one could document violations with the help of a high resolution digital camera.



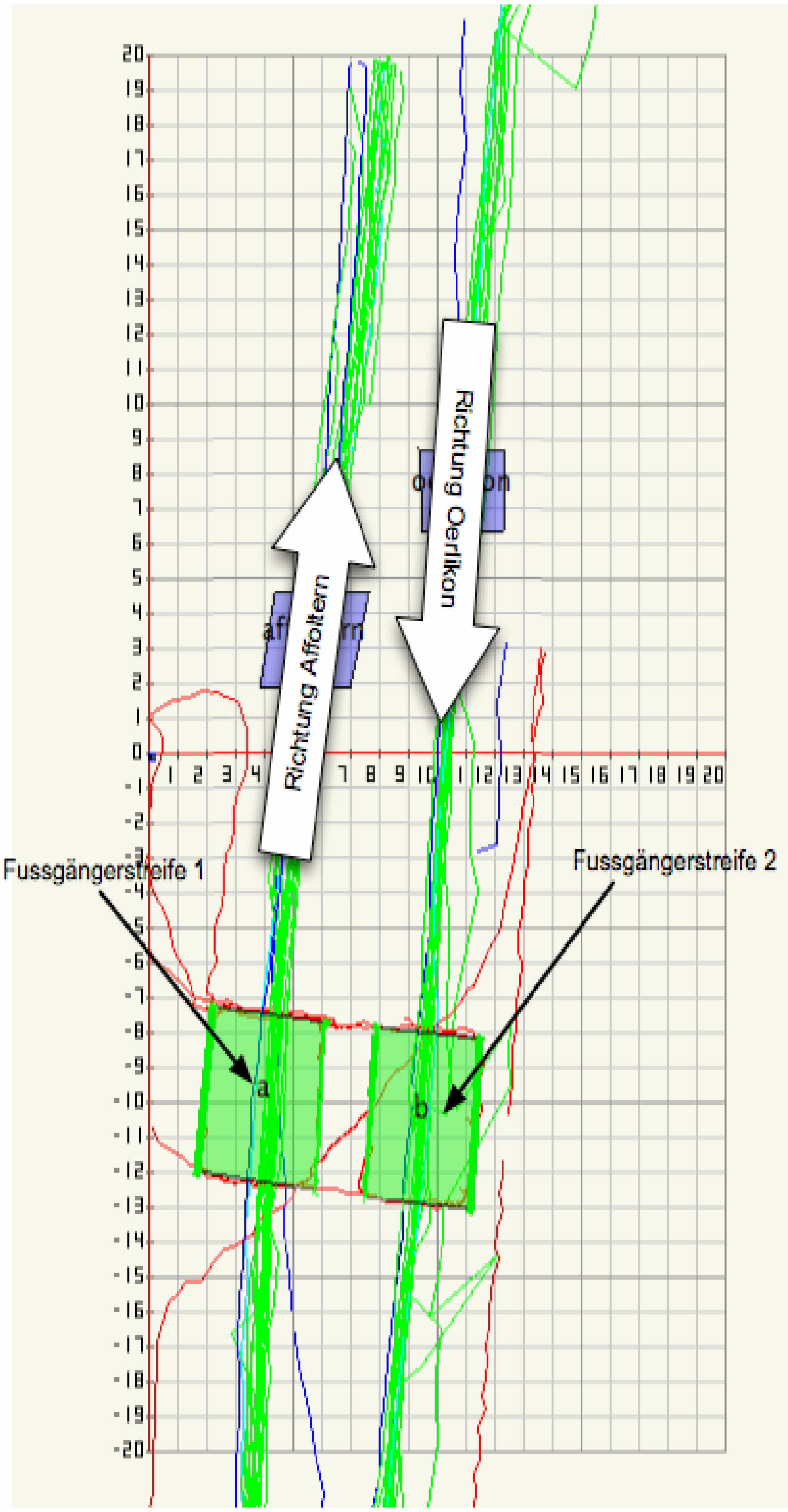
The components of LOTraffic: Laser sensor and industrial computer

LOTraffic can (1) detect arbitrary objects, (2) track moving objects, (3) infer geometry information, (4) compute speed, acceleration, (5) classify object, (6) deploy custom applications.

LOTraffic Speed Measurement is certified by METAS (Metrologie Amt der Schweiz). With its mean error (-0,1%), variance (0.51%) and high recognition rate (>90%). This is the most precise and versatile traffic sensor on the market. The sensor is easy to install and maintain. Its planar, radial scanning is able to cope with imperfect positioning and allows for error correction trough redundant sensing. The system tolerates variable weather conditions: Snow, fog and heavy rain to a certain degree. Its performance degrades linearly by heavy snow and thick fog. Its high precision, high recognition rate, ease of installation and fault tolerance make LOTraffic suited for speeding measurements — as a fixed or mobile installation.



Typical situation for the use of the laser sensor at a pedestrian crossing: In front of the sensor no cars may be parked. The sensor can reach a radius of 20 meters. Thus a normal stopping distance of 30m to the pedestrian crossing and the movements on the zebra crossing may be analysed. The breaking manoeuvre on the opposite side cannot be analysed, but the number of pedestrians who's priority is not respected can be counted. The dotted lines show the surfaces of the arrival spaces on the sidewalks in which the pedestrians about to cross are registered, and the surface of the pedestrian crossing. These surfaces are registered by waking the dotted lines on site as soon as the sensor placed.



The illustration shows the installation of the laser-sensor at a pedestrian-crossing (green rectangles) The cars are green lines, the bicycles are blue lines, and the trucks (or buses) are light blue. The red line shows the pedestrian who was marking the site of the pedestrian crossing with central island.

3. The Results expected

The research project wants to produce results on the efficiency of measures such as building a central island, better lighting, enlarged sidewalks (i.e. curb aligned with parking cars) and warning signs. The laser sensor will be placed in locations before and after such measures have been taken.

The laser-sensor can only give information on location, motion and size of objects within the distance of 20meters. It cannot detect all the behaviour relevant at a car-pedestrian meeting, because hand-signs, eye-contact, special characteristics of the pedestrian such as good or poor visibility, age, and other cannot be recognised. We plan to include such properties in the series of test by introducing model persons during specified hours of observation. We could for instance have a test-person in bright clothing pass at night during a certain hour, and a test-person with dark clothing during a different hour. The behaviour of the drivers in these time-slots can be analysed. Or we could have a group of children try to cross during one hour, and another group with the same instructions accompanied ay a policeman in uniform during another hour. (The police-force of the city of Zurich takes part in the research group with a police-officer doing children education.) This way we could find out to what extent drivers are conscious that they do something unlawful while they pass a group of children waiting to proceed on a pedestrian crossing.

According to the need to have a better understanding of the specific behaviour of children and elderly people, and of car drivers seeing them at the crossing, we want to design specific situations involving these age groups.

The method using a laser sensor which will be installed for a week in each place, will give us the opportunity to collect data on a much larger number of meetings between pedestrians and cars at all times of a day, and on all week-days. This way we can measure the influence of the presence of pedestrians on the behaviour of car-drivers. In a German study on pedestian crossings without zebra stripes, i.e. without pedestrian priority (Füsser et al. 1997, p. 23) we read: “The speeds driven show no changes as a mere result of the presence of pedestrians … (except if pedestrians force the priority form the cars).” We want to find out to what extent the right of way on marked zebra stripes makes a difference in this behaviour.

The possibility to measure for many weeks, will give us enough “meetings” between cars and pedestrians to make a statistical analysis of the data.

4. Points of Discussion

The research project has just started, and we are interested in getting feedbacks from the STRC-participants on how to align the algorithm for the three categories of behaviour mentioned. The discussion of the following questions would be interesting for us:

- What situations and elements of behaviour create frequently dangerous situations at pedestrian crossings? How can we set the parameters measured to find out.

- To what extent do car-drivers and pedestrians not judge the situation right, and to what extent do they make mistakes deliberately?

- What experiments with test-persons should be made during the observation periods?

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