Automated Traffic Monitoring

by helicopter video imagery with optical flow method

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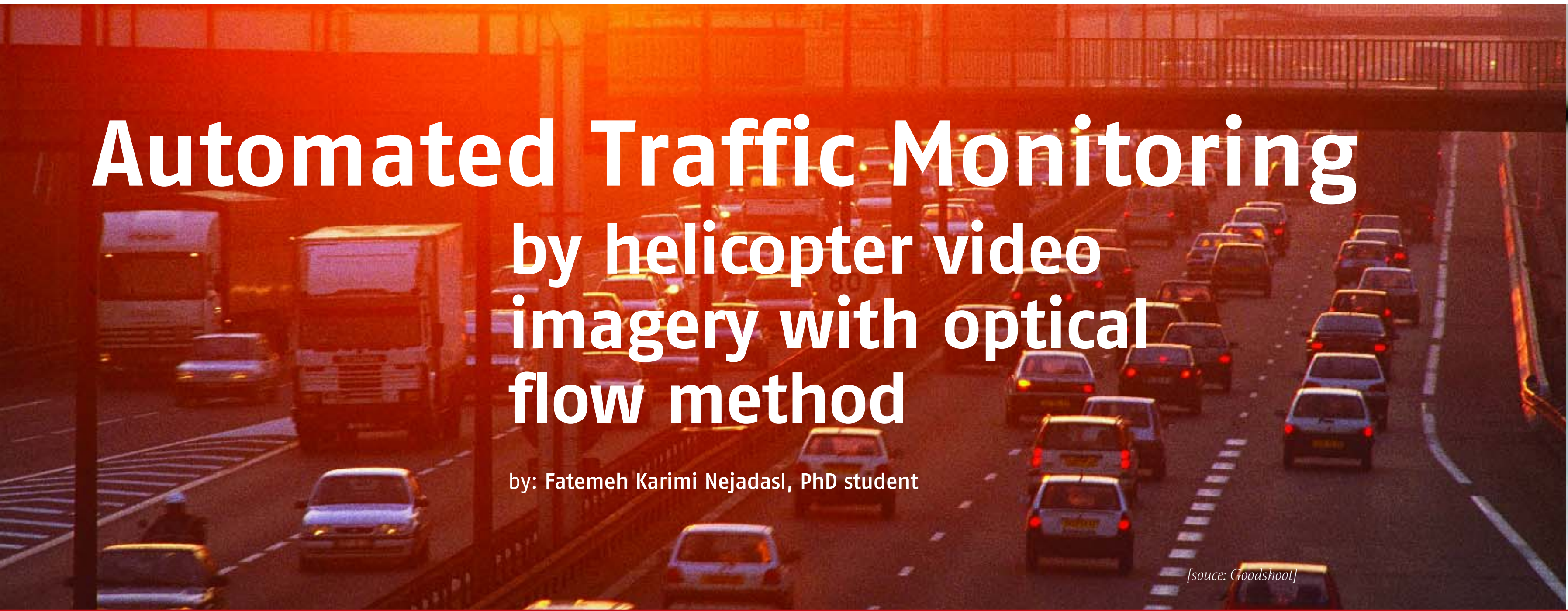

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Traffic congestion

Traffic congestion is an important problem in modern society. Lots of money and time are wasted in traffic jams. Moreover, car crashes and accidents are more frequent during busy traffic conditions. Several efforts are made to tackle this problem: better facilities and regulations should improve the situation on existing roads while the number of roads is expanded as well. It turns out, however, that traffic congestion is highly dependent on the behavior of individual drivers. Reaction times in braking or techniques for changing lanes vary from driver to driver. The effect of braking or changing lanes on drivers affected directly or indirectly by these issues is dependent on the behavior of the individual drivers. Therefore it is useful to model the behavior of individual drivers before new decisions and regulations for traffic jam controlling are initiated. Current traffic theories are not yet able to correctly model the behavior of drivers during congestion or nearly congested traffic flow.

Improving these models requires data of the behavior of each individual driver during traffic jams. Recent technologies such as magnetic loops, which are widely used in the Dutch highways for data collection, only provide point measurements of traffic flow and average speed. Thus, the time-dependent traffic parameters such as position, velocity, acceleration, and deceleration of individual cars at specific moments in time are still unknown.

The goal of this project is to find a data collection method for determining these parameters. The project is a cooperation of the DEOS department in our faculty with the Traffic Management group in the faculty of Civil Engineering.

Data collection

A video camera can continuously record events and seems to be the right tool for traffic data collection.

Video cameras are already used for traffic monitoring, but only in case of direct human interpretation of the video data. The kind of information obtained in this way is used for obtaining a general view of the traffic process. For obtaining traffic parameters as described above, automatic processing of the video data is necessary. Therefore, traffic parameter extraction becomes a computer vision problem.

The location of the camera is an important issue. By increasing the height of the camera above the road surface, the viewing area is increased and therefore more vehicles will be observed in a single image frame.

Therefore, other platforms or methods are suggested for increasing the viewing area. A highway could be covered by video cameras at different locations. This is an expensive option however. Another solution is using a camera with a large viewing angle. Such cameras are less accurate and still don't cover the complete area in one frame. Yet another option for increasing the working area is to use higher monitoring platforms like buildings, helicopters, zeppelins (airships), motor gliders, airplanes or satellites. The use of tall buildings would limit data collection to very few locations. From the remaining possibilities we chose a helicopter, because it can record a movie above a fixed point for a long time (see: figure 1).

Video camera

For efficient traffic data collection, capturing many vehicles at the same time, it is necessary to look at a fairly large highway section. This is governed by the opening angle of the camera and the flight altitude of the helicopter. A limitation is imposed by the required spatial resolution. To be sure that every vehicle is detected, and to be able to measure vehicle positions accurately, the image has to show sufficient detail. Combining these two conflicting requirements leads to choosing a camera with the highest possible resolution.

Moreover, we do not only want to record each vehicle's position, but also the derivatives: speed, acceleration (positive and negative) and even changes in acceleration. How much time does it take before a driver starts to brake, after the vehicle in front of him started to brake? For this we need a good temporal resolution (or frame rate), in addition to a good spatial resolution. These are conflicting requirements as well, because satisfying both of them leads to excessive data rates. We found a compromise using a digital camera with a much higher spatial resolution than usual video cameras, but with a slightly lower frame rate. Because of the data rates and data volumes, the camera is connected to a computer that stores the recorded data on a hard disk in real time.

Another choice to be made was between a black-and-white or a color camera. As we realized that the most difficult cars for automatic detection would be the grey ones (against the grey road surface), we decided that color information would not add a lot of value, but only increase data volume. Therefore we are using black-and-white imagery.

After the selection of the camera, the extraction of information such as position, speed, velocity, acceleration, deceleration and size of each car during the sequence is the main purpose of the project. Indeed, facing the large number of images, tracking lots of cars means a tremendous amount of work. Therefore automation is very important.

Automatic vehicle recognition and tracking in the image frames belongs to the task of image and video processing also called computer vision. The goal is to learn the computer to recognize the vehicles in the image and then follow them in all of the frames in which they appear. Therefore, a digital video camera is used in this project.

Motion

The position of the object in the successive image frames shows the movement of the object as a time-dependent parameter. The object movement can be defined as the displacement of the object in two consecutive frames expressed by the difference in image coordinate.

If the camera is not stable, the displacement of an object will be affected by motion in the object and in the camera. For extraction of the object motion from the displacement result, knowledge about the motion of the camera is needed. The human understanding of motion works in the same way. The difference is that humans use their knowledge about the object's environment for finding some fixed reference object useable as a reference frame.

In our project, the camera motion is in fact a platform motion: the hovering of the helicopter around its fixed observation point causes a motion of the camera due to turbulence. In fact, by small motions of the air, turbulence increases. As a consequence, every object in the movie seems to move. Therefore, the problem boils down to distinguishing pixels that move because they belong to moving cars from pixels that move because of platform instability.

After the motion of the camera has been calculated, the relation between any two frames of the movie is known. By removing the motion of the camera, new corrected image frames can be made. This process is called camera registration. In the specific situation of removing helicopter movement, this process is also called stabilization. The stabilized sequence contains no camera movement but only object movement.

In the case of a moving helicopter, movement and shaking of the helicopter come together. Therefore, the movement of each object is quite large. The motion of the camera is determined from two consecutive frames, so stabilization is not useful here. Two frames are just registered together.

In the case of registration of two consecutive images, only a limited number of common points, 4 or 5, is needed in both images. The selected points should be selected from all over the image area and should only contain camera motion. Detection of fixed points - points that are influenced only by the motion of the camera- should be done automatic. Therefore, automatic stabilization is one of the goals of this project.

Vehicle Detection and Tracking

Humans have knowledge about cars, so for them detection is easy. For a computer, object recognition is a very difficult task.

Even for a human, vehicle tracking is quite complex. He combines knowledge about the shape, the speed and the color of the car in the 3D domain and then tracks it by mak- »

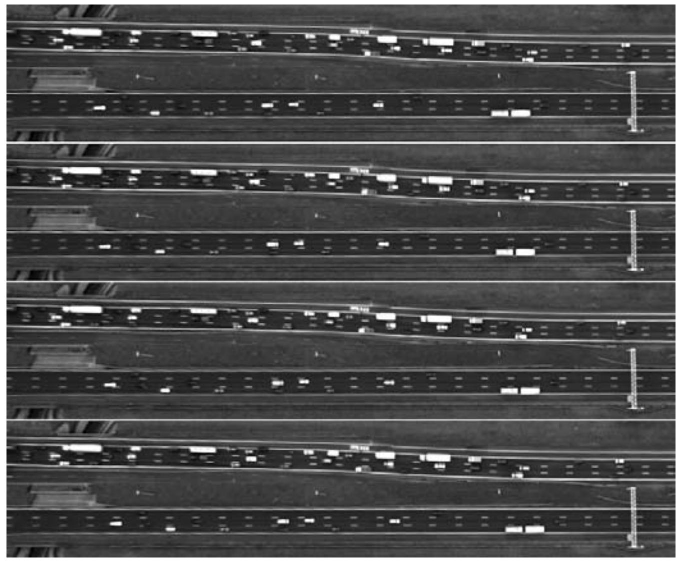

figure 1: Image frames. [source: F. K. Nejadasl]

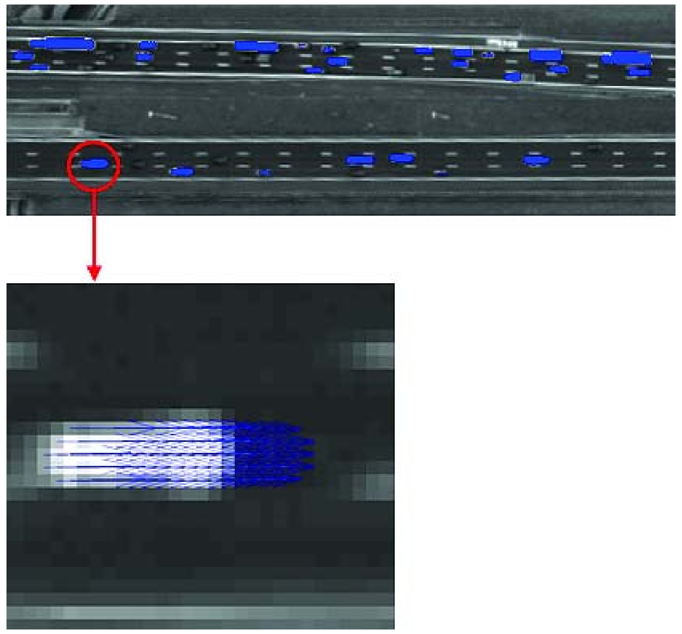

figure 2: Optical flow result in trajectory problem. [source: F. K. Nejadasl]

ing a prediction for himself of the expected position with respect to other cars and the surroundings, like the road boundary.

But the tracking capability of humans is limited to only a small number of objects. In our project we have to track a large number of cars however in many frames. We first try to simulate the human ability for car tracking and next strengthen the human approach to encounter a larger number of objects at the same time.

The accurate calculation of the motion of the camera and the motion of objects, and the detection and tracking of entire vehicles in the appearing video images are main goals of this project. On the other hand, the result is called the monitoring or trajectory of traffic.

Optical flow

Optical flow is a measurement of the object movement in a video sequence; it is defined as the projection of world motion vectors onto the image plane.

The object motion and motion of the camera are projected from the real world into video. Each frame contains the intensity and position of the projected object.

When a human follows an object such as a car, he looks at the same object but in a new view, which means that the object appeared at a new position at a different moment. Therefore, the appearance specifications of the object such as shape and intensity remain constant. Although these parameters always change because of different viewing angles or other problems, even after short time intervals of 0.1 seconds, these parameters are will not change too much.

The same principle holds for video: each pixel in each frame reappears in the next frame. This is the constraint that is used in optical flow. Different techniques try to find the displacement vectors. Depending on the type of the movie, different constraints are used to find the displacement vector for each pixel.

Optical flow in trajectory problem

The optical flow method uses both information in space and time together to determine the displacement vector. This makes it a useful tool for solving the trajectory problem. In the following parts, the importance of optical flow for solving the trajectory problem will be described.

The vehicles in the helicopter movie appear in small size in comparison to the whole image. Therefore, by zooming out the image-frame, the cars are removed. The remaining objects are only influenced by motion of the camera that we need for the stabilization process. Then, by automatic point detection and finding the displacement vectors of these points, corresponding points for each consecutive frame are determined. These points are enough to find the transformation between two frames. By implementation of the transformation parameter to the entire image, a new image is obtained without camera motion.

After stabilization, displacement vectors for each pixel of the image can be found by the optical flow method. All displacement vectors having the same direction and values are put in the same group. A car is a rigid object, therefore all pixels in a car move the same way As a result, each group shows one moving object. By considering objects within the highway boundary, vehicles are detected.

After vehicle detection, following of the cars is only done in the vehicle regions by optical flow. The new displacement vector will point to the new position of the vehicle in the following image. After calculation of the displacement vector for each car and in each frame, the tracking process is finished (see: figure 2).

Result and Discussion

Optical flow is sensitive to brightness changes. As a result, it may happen that fixed regions are detected as moving objects. Shaking of the helicopter causes differences in reflectance of especially road lines and road surfaces, therefore they are easily detected as moving objects.

As mentioned above, errors in the vehicle detection will give incorrect results; therefore an error analysis is an important part of this project.

Conclusion

Optical flow appears to be a promising approach for automatic car detection and following cars from video data. The results of this project may serve as a new contribution in analyzing traffic behavior of individual drivers. Hopefully this will give new insights leading to new solutions for solving the traffic congestion problem.