Increasing situation awareness

Finland is currently undertaking a national research program focused on the area of big data. The aim of the Data to Intelligence (D2I) program is to develop intelligent tools and methods for managing, refining and utilizing diverse data across a variety of sectors. Within the overall program, the D2I traffic project (which began a year ago) aims to create situation awareness for traffic circumstances in day-to-day life. The project gathers together measurement device providers collecting and pre-processing measurement data; companies realizing wireless data communication and data storage; as well as companies, institutes and universities developing data pre-processing methods and providing processed data for customer use. The goal is to invent products, solutions and services that use traffic data and related data sources to provide added value to the customers and good business for the providers.

The work is organized into two business cases: traffic-related data from city regions and a data marketplace. The general goal for both cases is to improve the situation awareness of traffic-related players. Situation awareness is enabled by modeling traffic flows, environmental conditions and the behavior of individual drivers based on data collected from a city region. Furthermore, the development of the business ecosystem and technology for the data marketplace is emphasized. The data marketplace is a meeting place for producers and consumers of data. It opens up new possibilities to sell data that has already been collected, to do business by processing data that was not previously accessible, and to buy data that enables novel end-user applications. Due to the aforementioned aspects, the data marketplace would be an excellent test bench for studying situation awareness in other areas of daily life as well.

The vehicle stopping distance application developed by the FMI (Finnish Meteorological Institute) is an example of the novel applications that are created when parties with expertise in processing data get access to new data sources. This particular application exploits Noptel laser radar technology installed above the road. The laser radars detect passing vehicles and measure their velocities. The distances between the vehicles are calculated based on their velocities and accurate timestamps. The gathered data is available for project participants who can then process and refine it.

In addition to knowing distances between vehicles, the stopping distance application requires information about the slipperiness of the road (i.e. friction between a vehicle’s tires and the road surface). Road slipperiness is measured continuously by dedicated instruments at the roadside and it can also be calculated by the FMI’s road weather model. When all required parameters – i.e. the velocities of the vehicles, road slipperiness and the distance between the vehicles are known, the required stopping distance can be calculated.

The calculated stopping distance is presented to drivers via roadside message signs or via an in-vehicle display. Warnings are given to drivers who are traveling too close to other vehicles.

Winter maintenance quality monitoring
Winter maintenance of roads and tracks in snowy conditions typically relies on weather forecasts and weather station data. However, since Noptel laser radars are placed above the road, they can monitor the road surface as well. Therefore Noptel laser radars are applied to winter maintenance quality monitoring by constantly measuring the thickness of the snow on a road or track. By adding this real-time snow quantity information to the road models, users can improve control over winter maintenance. Moreover, when laser radars at multiple locations gather snow quantity information, road users can be advised to select routes with the best conditions.

Need to know?

A key part of a national research program is proving highly valuable to the ITS market

- The traffic project within Finland’s D2I program is deploying innovative traffic data collection and analysis solutions
- Intelligent sensors are being used to gather traffic data to improve situation awareness
- For a country such as Finland, winter road maintenance is an essential part of traffic management and sensors can also assist with this

Laser radars in situ above the road

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The versatility of fast laser measurement technology is not always fully appreciated. Offering an unrivaled flexibility – especially when compared with traditional methods – lasers will play a key role in the future of traffic control.

**LASER GUIDANCE**

**SMART ADVICE ON TRAFFIC MEASUREMENT**

The versatility of fast laser measurement technology is not always fully appreciated. Offering an unrivaled flexibility – especially when compared with traditional methods – lasers will play a key role in the future of traffic control.

One single measurement technology rarely offers perfect solutions for a variety of applications. Each will have its own special requirements and therefore demands optimization to fulfill the needs of the measurement task in question. This is not, however, the case per se: sometimes a single technology is able to offer competitive solutions for several different measurement duties, and one such example is laser technology.

There are a number of different types of measurement in the field of traffic control – and up to 20 different roles should easily spring to mind. But due to its versatility, laser technology offers the capability to measure many variables with a single short laser pulse or a burst of pulses. Among such measurements are accurate triggering of vehicle, speed measurement, profile measurement, over-height measurement, distance between vehicles (for tailgating detection), vehicle counting, and a variety of intersection control measurements.

**DISTANCE MEASUREMENT**

Laser technology today has myriad applications and is an ideal technology for developing advanced and small measurement units for calculating geometrical variables such as distances. The technology uses narrow laser pulses sent to an object from a laser source, which is reflected back to the receiver, and more commonly known as pulsed time-of-flight (TOF) measurement. A good way to understand the complexity of the technology is to consider the time that the laser pulse takes to travel to the target and back again. Laser moves at the speed of light at a speed of approximately 300,000km/sec. To reach a single pulse resolution of about 5mm means measurement of pulse flight time with an accuracy of 10 picoseconds (a picosecond is one trillionth of a second).

Although a highly complex technology, it has nevertheless been well mastered by a handful of companies around the world, and is used in many demanding applications that require fast distance measurement to poorly reflecting surfaces. In traffic control, the measurement is used for many applications that require easy installation and non-intrusive measurement of traffic.
One of the world’s leading beacons for the research of this technology is the University of Oulu in Finland, at which the technology has been studied since the 1970s and has been the subject of a number of doctoral theses. Based on these studies and resulting research and development, the technology has been adapted to many products used in industrial and traffic applications. Indeed, the Finnish company Noptel utilizes it in many of its traffic control sensors – products that are in use across all continents in various deployments.

APPLICATIONS
One of the best features of pulsed TOF technology is the ability to accurately detect and measure the distance to practically any object without using a cooperative target, such as a reflector (one form of target can be a vehicle, for example). One basic problem of obtaining a sharp picture from a license plate is to get the timing right. In a poorly lit environment, the distance to the object must be accurate enough, regardless of the speed of the vehicle. Sometimes a distance window of 10-20cm is required, although often 20-30cm is enough. But what is the most reliable way to catch the vehicle in that position? One way is with a pulsed laser. With a pulsing rate of 4kHz, the unit can measure distance to the object driving 200km/h (56m/sec) with an accuracy of less than 1.5cm. Taking into account errors coming from the varying shapes of the vehicle and using multiple pulses for the detection to have better reliability, the triggering accuracy is still around 10cm.

In license plate recognition, there are two basic principles; take the photo from the front of the vehicle or the rear. In both cases, a single laser unit can detect the vehicle with the same level of accuracy. When adding a little more intelligence to the measurement and measuring at the same level as the vehicles, a single unit can measure several lanes by analyzing the triggering distance from the object.

Today, it is quite easy to add further intelligence – even into small sensors – due to increased performance and supply of processor technology. Combining this intelligence with advanced laser technology can make the sensors useful for many difficult measurement tasks and makes the laser technology competitive with loops and other traditional technologies.

Another widely used measurement in traffic control is the speed of vehicles. Main roads, streets, intersections, queues, and multiple lanes can all be controlled by laser. There are four main types of measurement setups and installations: vehicle installation, portable measurement stations from the tripod, fixed measurement systems on the pole or gantry, and light port-type measurements. Laser can be utilized in all of these setups.

There are several measurement principles and technologies within the field of laser technology, one of which is based on fast-pulsed TOF measurement. With this technology, the speed is measured based on a number of successive distance measurements from the object. When the distance measurement is fast, for instance 2-4kHz, the unit takes 200-400 measurements in only 0.1 seconds, which is more than enough to calculate accurate speed value.

The time delay of 0.1 seconds is not fast enough to trigger the camera in an optimal place for taking a sharp picture in the event of speeding. For that purpose, a laser unit can calculate a quick speed value using 20-40 measurements. In such a scenario, the unit can give a triggering pulse to a camera 10ms after having detected the vehicle. If a vehicle is driving at 100km/h, the triggering pulse comes 30cm after the detection point. The same values and detection of vehicle can be conducted for both approaching and departing vehicles.

“Today, it is quite easy to add further intelligence – even into small sensors – due to increased performance and supply of processor technology”
Depending on the installation geometry and measuring setup, accuracy can even be 1-2%, but is typically 2-5% of the speed. As a distance measurement unit will measure distances at high speed, it will also collect distance information from the shape of the vehicle. That information can be used in accordance with the speed information to calculate the height and length of the vehicle and in this way can also be used to measure the distance between the vehicles.

PROFILE MEASUREMENT

Another main application is to measure vehicle profiles, a principle that allows the measurement of vehicle types, shapes and sizes, and allows the use of that information for accurate height and length measurement, as well as vehicle classification. The accuracy is typically less than 1cm, which provides quite an accurate vehicle profile. What users then want to do with that information depends on their needs. Although today the processing capacity of even small embedded controllers is rather high, it is possible, for example, to leave that job to the measurement unit and take out the ready-analyzed classification information.

Another interesting measurement task is the control of overheight vehicles entering a tunnel or other area with limited access. There are two basic solutions and also two basic problems involved. First, the detection device must detect even small parts of the overheight vehicle. Second, those parts must be detected at all speeds. The two solutions are to measure vertically from the top of the lane, or horizontally from the side of the lane. When measuring from the side, on occasions when it is possible to install the cooperative part on the opposite side of the road, a light port can be used. If a more advanced solution is required, a high-speed laser distance measurement unit can measure without the cooperative part, and can even automatically select the vehicles on separate lanes. If a measurement speed of 6kHz is used, the smallest part to detect at 100km/h speed is 0.3cm. This gives a practical minimum size for the detected pole or part of about 2cm. When measuring from the side of the road, the installation must be made to the selected maximum height. In this case, the profile of the vehicle cannot be measured, but the measurement unit will detect all overheight parts.

If the profile of the vehicle is vital, it should be measured from the top. In this case, a potential issue is that the laser beam is pointing to a small area in the lane and not detecting all the highest parts of the vehicle. Of course, these two setups can be combined to measure both the type of the vehicle and the exceeding of the height limit.

INTERSECTION CONTROL

In the intersection control field, several tasks can be performed: control of lights, vehicle presence detection, red light violation control, and also speed measurement. One widely identified problem with using inductive loops for control of lights – especially in large cities – is that vehicles do not get any turning light in crowded traffic. This is due to the fact that the loops detect the vehicle when they arrive but can easily forget them. Laser distance measurement works differently: as the measurement is continuous, it detects the vehicle continuously when it is waiting for the lights to change. At problematic intersections, this principle makes the traffic flow smoother by always giving the green light for vehicles that are waiting.

TRAFFIC INFORMATION SYSTEMS

A final example of what laser technology can offer the traffic market relates to real-time information, which can help make traffic flow smoother. The requirement for such information is constantly increasing and even if it is not used to directly control the traffic, it can be disseminated to drivers to help them make educated choices when selecting an optimal route.

ITS is a catchphrase that forms the subject of many projects targeted to making driving a pleasant experience. To achieve that goal, not only are advanced systems needed to bring information to drivers, but a comprehensive gathering of information from different sectors of traffic is also required. For that task, laser technology can play a big role, by supplying information such as vehicle speed, type, size, length, height, count, flow rate, gap between vehicles, occupancy, and classification.

Laser cannot perform everything, but it is a great source of information for many traffic control and information systems. In a proper and innovative design, the same basic measurement and technology can serve in many different measurement tasks, meaning the same unit can be produced in large quantities and tested in different environments to make both the measurement and the device reliable.

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LASER QUEST
THE TRUE VALUE OF TEST PROGRAMS

Thorough testing of lasers for use in traffic management applications is essential. Comparing lasers with alternative technologies also provides some interesting results that can help investors make the right choices.

Lasers are playing a major part in shaping the future of automated traffic control. The development of different types of laser sensors and units has brought a notable new alternative to traffic measurement. Although this new technology has remarkable benefits, it also has limitations. Similar to many other technologies, it requires a lot of innovation, research, development, testing and analysis to come up with reliable and useful information for the control systems.

The latest technology allows the manufacture of small units, capable of many different applications, from accurate and fast triggering of vehicles to speed measurement and other control tasks. To make the units suitable for the most demanding tasks, they must go through a thorough testing and optimization process. This process takes a long time, in different traffic and environmental conditions, but gains excellent results, both in performance of the units and in the reliability of the results.

One of the best features of a laser sensor for traffic control is its ability to measure the specific target it is pointed at. With a microwave radar, the user often cannot be sure which vehicle is being measured if more than one vehicle is in the field of view. A laser sensor is able to trigger a camera at the moment of speed measurement, providing the speed and image that are definitely from the same vehicle. A laser range finder can be used to replace inductive loops and operate as a presence-detecting instrument, and compared with loop installations the lane is closed for a very short amount of time – if at all. The laser sensor can also detect standing vehicles, even motorcycles, which is helpful in presence detection – for example when controlling traffic lights.

GOALS OF THE TESTING PROJECT
The aim of Nopel’s project was to improve the performance of its laser range finder outdoors, and to investigate its accuracy with different measurement geometries, as well as considering the developmental potential of the speed calculations. The effects of the measurement geometry, the benefits of noise reduction in the distance results and the accuracy of different speed calculation methods were also studied.

The goals set for the performance of the range finders were fulfilled in indoor measurements. However, when outdoors, the background-induced noise was initially problematic, so increasing the transmitter power was found to be the best method to enrich the SNR in this environment. The mean error in the speed calculations is less than 2% in traffic monitoring. This requires a measuring distance where the device works in dynamic range and the mounting height of the device versus the measuring distance is smaller than 1.5. With the range finder, the measurement geometry and the calculation methods described, the mean error is less than 2%, but may be more in other setups.

PROBLEMS WITH THE LASER MEASUREMENT
When a speed sensor is used as a fixed unit, typically 5-7m above the road, it creates a demanding geometry for measurement. In such installations it is critical to ensure that
the shape of the vehicles does not affect the speed measurement. This effect may be minimized by using a measuring geometry where the angle to a vehicle is as small as possible, so having as long a measuring distance as possible. The tests showed that advanced sensors can reach very good accuracy, with 1:5 geometry (sensor installed at a height of 5m, aimed to the distance of 25m). In many applications, the geometry is limited to distance, where the camera still has good enough resolution for license plate recognition. That makes the geometry very demanding for the measurement.

The shape does not affect the measurement if the vehicle is followed during measurement, or the sensor is located at the vehicle level, which is usually the case with handheld or portable units. The shape of the vehicle mainly causes problems when license plates are not reflective.

One question that is often asked is if there are problems associated with the weather conditions, which is certainly a valid question. In optical measurement, the system works like a human eye, in that it has to "see" the targets/object. This visibility can be limited in two ways: if the window lenses are dirty, or if there is an obstacle between the measurement unit and object. Such obstacles can be rain, fog or snow, for example. Moderate rain and fog are not typically problematic, but heavy snow could be. In practice, the unit needs to be cleaned occasionally, particularly if it is in a location where the window can become dirty, and this is part of normal maintenance. Such extreme conditions that prevent the correct measurement occur quite rarely.

Another question is the MTBF of the unit, which is determined mainly from the lifetime of the laser. The lifetime is typically about 15 years and depends on several things, such as the pulsing frequency. That leads to a long service time, if the normal maintenance tasks, such as cleaning the lenses, are not considered.

TEST SITE AND SETUP
To adjust and finalize the reliable operation of the laser sensor in a speed measurement application with LPR, Nopel installed a multisystem test station on a main road, where daily vehicle count was 11,000 vehicles, with a speed limit of 80km/h.

The test system arrangement was made to be flexible and versatile, to allow comparison of data measured from all possible geometry: top-down, tilted, street level, approaching and departing. The system, set up by supported automated data collection to a single computer from all units: laser sensors, radar, camera and trigger units. With a single computer system, it was possible to combine data during testing and also keep an exact time base for the results. This made the variation of measurement set up and data collection easy.

The leading principle was to study the speed measurement with a single laser unit in different installations, with various algorithms and with a variety of vehicles to be able to optimize the operation of the laser unit in a range of measurement situations. Several alternative methods were used as a reference: another laser sensor, radar, laser triggers, as well as moving the speed measurement unit.

COMPARING RADAR AND LASER
The reference radar had approximately a 12° measurement beam, which was specially designed to measure difficult angles where a vehicle can be detected for only a short period of time. Nevertheless, Nopel has continuously encountered problems with the radar detecting vehicles other than the one that the laser sensor was supposed to be measuring.

It seems that in some cases a large vehicle driving behind a smaller car is detected, leading to a false speed reading. Indeed, sometimes the radar also measured a vehicle that is not even near to the measuring point.

"With a microwave radar, the user often cannot be sure which vehicle is being measured if more than one vehicle is in the field of view"
The measuring system tests were carried out with a variety of vehicle shapes and sizes, from normal passenger vehicles to large trucks. Additionally, the tests were carried out over a period of one year, which meant that the data could be collected in all weather conditions. The measuring system is at vehicle level.

Accuracy of the CMP sensor compared with the microwave (offset caused by measurement geometry)

Some customers ask for a detection percentage of 100%, which those involved in measurement technology will know is simply not achievable.

CONCLUSION
Noptel's measurement project lasted for approximately one year and encompassed all four seasons, featuring weather conditions such as sunshine, snow and fog, and measured tens of thousands of vehicles. The improvement in the final results was tremendous, providing some hope that this complex technology is more than capable of producing excellent results for the traffic management field. As a result of such results, Noptel believes that the benefits of the laser principle make it one of the most reliable measurements in this field.

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Lasers are rapidly becoming the tool of choice for a variety of tasks in the traffic world. The second of our focuses on Finland explains why...

Inductive loops have been widely used for years in a variety of traffic control applications. However, since laser technology has reared its head, loops have been forced out of many enforcement jobs. Modern laser technology offers a very worthwhile alternative, not only technically but also with a competitive price.

There are clear benefits for using lasers too. Not only are they simple to install and maintain, but also new possibilities open up.

The earliest well known application for lasers in the traffic industry was long distance speed radar. The technology has developed dramatically since those first units were used and today lasers are probably the leading speed checking technology.

The integration of electronics and optics has given a
Often, measurements are taken thousands of times a second, putting a lot of pressure on the controller to handle the data quickly.

Modern laser sensors use effective controllers for measurement data processing. The basic distance information can be directly used in some cases for an upper level system, but usually the controller processes the necessary information. Often, measurements are taken thousands of times a second, putting a lot of pressure on the controller to handle the data quickly. Thanks to modern processor technology, this can be done in an economical and effective way.

One application for a laser sensor is vehicle detection, when the vehicle is coming toward the LPR camera. (This can in fact be done either for approaching or departing vehicles.) The operation principle is to quickly measure the distance to the object and use that to define the exact triggering moment. Typical sensor installation is five to seven meters above ground looking forward, down at the road. When the vehicle enters the trigger area, defined by the parameters, the sensor sends a pulse to the camera. In such cases the triggering accuracy can be as high as 5-10cm (or one millisecond), depending on the installation.

Similar installations can be used for measuring the speed of approaching or departing vehicles. The speed measurement is very fast; the information is available 20-30 milliseconds after the vehicle has passed the measurement point. The speed can be measured in the range of 10 to 250km/h. To give the overspeed trigger information for the camera, the measurement can be arranged in two phases.

First, the unit calculates a rough speed value, which it uses for the trigger. This can be done in a few milliseconds. Then the unit uses its processing power to study the data and give the final speed value to the camera system. This allows reliable measurement, even if vehicles are driving near each other.

A fast distance measurement with scanning mechanics is used in industrial
Figure 4: Traffic light control system with laser detection

applications for profile measurement or area protection. In traffic control, fast distance measurement without scanning mechanics can be used for vehicle profiling, because the vehicle itself is moving. A simple fast range finder can easily generate a profile that can then be used for classification purposes. Combined with speed measurement, the unit produces the height and length of the vehicle and the profile data can then be used for further analysis of the vehicle type.

A typical laser sensor is shown in Figure 1. The water tight, nitrogen filled device uses pulsed time-of-flight technology, which allows distance measurement to poorly reflecting surfaces at high speed with a very good resolution. The low power consumption device can be used in both fixed installation and portable systems in varying temperatures and environments. The high level of integration makes the sensor small and reliable. As it is just 35 x 70 x 75mm, it is suitable to be mounted into any system, fixed or portable.

In any measurement where people are involved, it is essential that the laser device fulfils the appropriate safety standards. The international standard for laser safety is called EN 60825-1:1994 and EN 60825-1/A11:1996: Safety of laser products. This defines the level of laser power used as well as some other technical limits. The standard splits the products into several classes, starting with class 1. The required level of safety in traffic control is class 1, where the measurement is 'eye safe'. Classes 3 and 4 are widely in use in industrial measurement applications, and further classes include more powerful lasers. Because the limitations of class 1 are high, the technology must be optimised to allow effective measurement.

A laser device is also a good option for intersection control. The devices controlling several lanes can be installed in one place to make installation and handling easier. Each sensor may be directed to measure its own lane. The sensor can also be used as a vehicle detector for changing lights or it can check for red light violation. It can easily pick up vehicles in separate lanes.

Green light?
The feedback from the use of lasers around the world has been good. Projects and installations with laser sensors are multiplying. Many control system manufacturers and system integrators have seen the benefits of lasers and have adopted the technology to be the main sensor in their systems. The easy installation, multifunctionality, adaptivity and maintainability make lasers very interesting for both system suppliers and end users.

Figure 5: LPR-system picture at night, speed enforcement

Figure 6: Profile measurement with laser sensor, used for vehicle classification