Increasing Functionality in Agricultural and Construction Machinery

AUTHORS

Christian Astor
is Business Developer in the Off-highway unit at ITK Engineering GmbH in Rülzheim (Germany).

Kevin Hirsch
is Expert Engineer at ITK Engineering GmbH in Lollar (Germany).

Dr. rer. nat. Lienhard Pfeifer
is Expert Engineer and Project Manager at ITK Engineering GmbH in Lollar (Germany).

In order to enable agricultural and construction machinery to work ever more independently, reliable recognition of the surroundings on uneven and unstructured terrain must be ensured. ITK Engineering has developed 3-D terrain mapping for this purpose, which not only enables the reliable detection and analysis of objects, but also their classification and an automated response to obstacles or ground conditions.

Automated mobile machines are being used more and more frequently in the agricultural and construction industries to increase productivity. Modern communication and information technologies are used to ensure safety. ITK Engineering's 3-D Terrain Mapping (3DTM) ensures that the machine environment is reliable mapped, also on uneven terrain. With the help of different sensors such as stereo camera, radar or lidar, for example, passability or ground conditions analyses can be carried out. The focus here is on obstacle detection, surface scanning for automated functions, and automated machine control based on terrain properties.

OBSTACLE DETECTION

Human error is to blame for the majority of road accidents. The same holds true for mobile machines. Impaired visibility is one of the most frequent – and sometimes fatal – causes. Visibility is indeed crucial. The machine operator has to be able to survey the entire hazard zone around the machine to spot conspicuous objects such as other vehicles or barriers as well as less conspicuous personnel – for example, a kneeling worker – in the machine's immediate environment. Additional challenges arise from environmental disturbances such as dust, dirt or fumes.

Conventional solutions rely on cameras and displays to monitor all hazard zones. These systems afford a view of machines' immediate vicinity, but operators have to devote their full attention to the screen while driving and making adjustments to equipment. This can result in excessive demands on the machine operator and thus to reduced performance. Drivers would benefit from a sensor-based system to alert them to persons and objects detected in hard-to-see areas.

Sensor and camera technologies are advanced for such assistance systems. With the right image processing algorithms, they can be tailored to suit the customer's needs and type of mobile machine. While automotive applications frequently operate under the assumption that obstacles or objects are located on a planar surface, mobile machines have to cope with the difficulties of uneven terrain. Different conditions demand different tools to reliably detect obstacles. 3DTM represents such a method, which was explicitly developed for use in uneven terrain, **FIGURE 1**. It deduces the position of obstacles with great accuracy from a precise approximation of uneven terrain. To do this, it requires input from a 3-D sensor system that suits the use case, for example stereo cameras. Data is sourced from sensors to generate a grid-based survey map in which each 3-D point is plotted to a cell according to its coordinates, **FIGURE 2**. Mathematical approximations flesh out terrain details such as slopes, inclinations, and elevations. The approximated image of the surrounding terrain and the height of plotted 3-D points provide references for identifying obstacles. The system combines individual points that have been identified as obstacles into larger objects and then calculates their minimum distance from the vehicle.

A data set comprised of identified objects and their immediate surroundings feeds into an object identification procedure that determines their number and type, for example, people, vehicles, animals, or signs. This capability comes courtesy of machine learning or deep learning algorithms that are trained to recognize these types of objects. This means the system can independently determine if an object in the machine's surroundings is for example a person, an animal, or a sign. It draws on the associated image data and clusters of 3-D points to help identify objects. 3DTM supports the machine operator by reliably detecting and analyzing obstacles in the hazard zone, particularly on uneven terrain. That enables safer operation and smoother workflows.

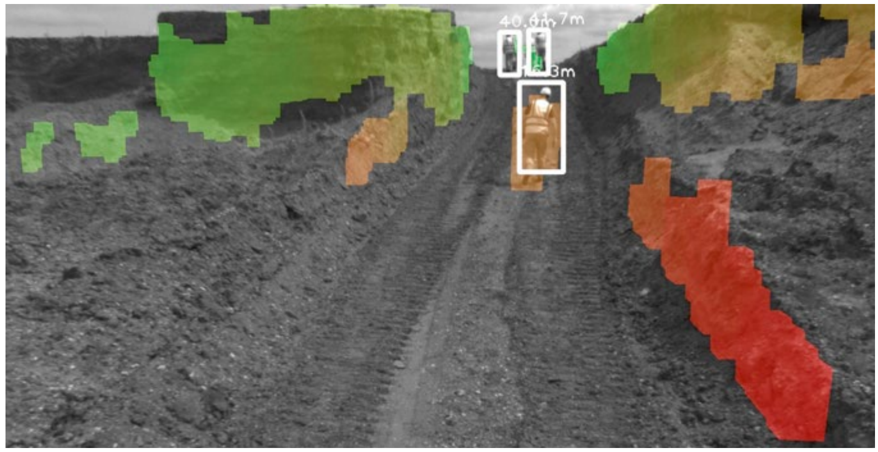

FIGURE 1 Detection and color-coding of obstacles according to their distances from the camera (green: distant objects; red: objects in close range; pedestrians are additionally marked by a white frame) (© ITK Engineering)

SURFACE SCAN FOR AUTOMATED FUNCTIONS

In addition to environment and ground detection and analysis, 3DTM can also be used to implement automated functions for mobile machines. Not every vehicle is suitable for every terrain. Some topographies are passable, others are not, depending on the type of machine, attachments, and payload. The vehicle may require adjustments to navigate the terrain, which places an additional burden on the operator who is already occupied with the task of driving.

The possibilities that 3-D terrain mapping provides here are illustrated by the example of a wheel loader with a loaded skip bucket, **FIGURE 3**: With good knowledge of the elevation profile, the bucket can follow the terrain automatically. This ensures that the material to be transported remains in the bucket even when traveling uphill and downhill. Simple solutions only have one point of reference – the vehicle's current inclination. The approximated terrain data furnished by the basic 3DTM function is a value-adding asset – it provides far more accurate means of positioning of the skip bucket. The computed surface properties and vehicle speed serve as references to determine when and where to move the bucket. This minimizes latency. It also prevents overshooting when the vehicle travels over a crest because the system factors the upcoming descent into the equation. This adjustment to the bucket's position is more than just a response to the situation at hand. The system automatically anticipates the terrain ahead for the adjustment to be made on the fly, in real time.

Adjusting the bucket's tilt angle is not the only thing 3DTM can do to help the operator. It can also vary the bucket's height to provide the best view in the given situation. Usually, the bucket rides low to afford the operator a good view. Depending on the bucket's size and shape, it may have to be elevated to avoid ground contact when traveling uphill or stopping at the bottom of a hill. The system lifts the bucket only as high as the environment requires. The system can manipulate a machine part position to suit the terrain in many other applications. Thus, adjusting the height and angle of a tractor-mounted field sprayer can also offer added value. Because on uneven terrain, the sprayer can be steadily adjusted with the correct distance to the ground – and this is independent of the position of the tractor

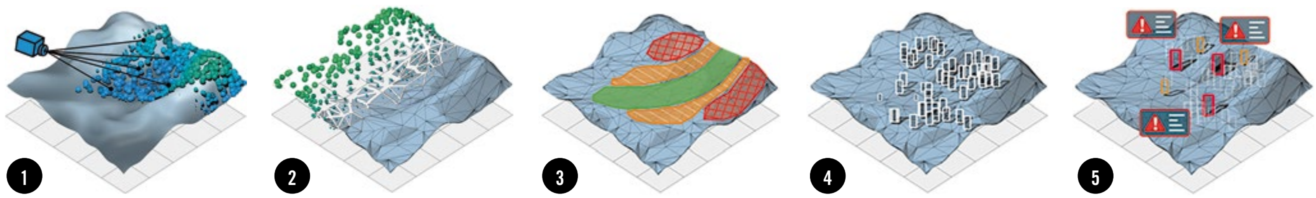

FIGURE 2 Different steps for 3DTM (© Florian Müller | Bosch)

itself. Assistance features like these not only add value by bringing the benefits of convenience to drivers of mobile machines. They also help conserve energy. This technology provides the means to predict the hydraulic power requirements in the scenarios described above. When energy demand is a known quantity – that is, when, where, and how much power will be needed – a smart energy management can conserve hydraulic power by drawing on it only when required.

AUTOMATED MACHINE CONTROL

For agricultural machinery, the goal of development for uneven terrain is to realize reliable, automated machine control based on 3-D terrain details. In a typical scenario, a baler or forage harvester picks up hay a mower has arrayed in rows called swaths. The machine travels a defined path. Keeping the vehicle in line and on track is also a consistent, protracted task that requires only little concentration on the part of the operator. This can often lead to fatigue and inattention. The driver also has to monitor other workflows at the same time, which can be distracting and the root cause of handling errors. In this application example, the terrain information can reliably detect the hay swath even in uneven terrain and side slopes and guide the machine or the attachment along the swath.

Farmers already use GPS guidance systems that reference that tractor's position to keep vehicles on track. However, the swath may be off the course, for example

FIGURE 3 The computed surface properties and vehicle speed serve as references to determine when and where to move the bucket (© Salienko Evgenii | shutterstock.com)

FIGURE 4 Detection of hay lying in a row (© Denisfilm | depositphotos.com)

if crosswinds have blown it away. Purely location-based guidance systems are not up to those challenges, but detection-based guidance can keep the vehicle following the swath in an accurate and reliable way. To optimize the workflow, the machine also has to be aligned according to a swath's properties such as its center of mass. Purely location-based tracking cannot help with that, even if the swath's exact position is known.

Simpler systems rely on a fixed height variance threshold to detect and track the ground's topography. They also make assumptions about the terrain ahead, for example that the ground is even. Neglecting the terrain conditions or not taking them sufficiently into account in the track detection leads to deviations in the track guidance of the working machine, especially in the area of depressions, elevations or on slopes. The 3DTM can apply 3-D information to approximate the terrain surrounding the pathway. This approximation may then be used locally as a base value for a threshold-based assessment of the terrain's height variance to detect and track the path. Information about the terrain not only helps to reliably detect a swath, it can also serve to predict the vehicle's position. This precludes potentially unstable driving conditions and allows the attachment's parameters to be adapted to the given conditions. With this terrain information, a swath's height above ground level is a known quantity that can serve to predict the volumetric flow rate. Parameters such as the speed of the vehicle can be adjusted to this for an optimal workflow. This reduces fatigue, extends working hours, saves on operating costs, and boosts productivity.

SUMMARY

The 3DTM developed by ITK Engineering not only enables the reliable detection and analysis of objects, but also their classification and an automated reaction to obstacles or ground conditions. This boosts workflow efficiency and safety, and allows additional machine functions to be executed.