

# Good Milk from Happy Cows

## Time of Flight Imaging Enables Automated Milking

The output of worldwide agricultural milk production in 2007 has been 560.5 million tons with an 83.5% share of cow's milk. The biggest milk producers have been USA, India and China. In the European Community 150 million tons are produced annually, the E-15 is the biggest market for milk-based products. The production of milk is an industry, so it comes as no surprise that here as well automation technologies, especially in the area of automated milking, are in high demand.



Automated milking in dairy farms is rapidly expanding. The automated process not only frees up valuable time for the farmer, but also makes happier cows that produce higher yields of better quality milk. There are only a select few companies in the world who specialize in these technologies as this is a very difficult and demanding application of machine vision and robots.

A key enabling component in automated milking systems is the 3D sensor



that identifies and locates the teat positions on the cow's udder as it steps into the milking box. The information derived from the sensor is used to guide a robot arm to attach the milking cups to the teats. The entire process of locating teats and attaching cups must be robust, fast, accurate and safe, without disturbing or stressing the cow.

### Sensor Challenge in the Barn

GEA Farm Technologies, formerly GEA Westfalia-Surge, offers worldwide leading innovations and whole product solutions for dairy farming. When GEA decided to develop a new generation of automated milking systems, they

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approached LMI Technologies to create the vision guidance sensor. GEA recognized LMI as a leading edge 3D sensing technology solutions provider, with particular expertise in implementing sensors in challenging applications in extremely harsh environments.

One of the challenges in automating the milking process is reliably guiding the milking robot to attach the milking cups to the cow's teats. Cows are highly individual animals in both behavior and appearance. The sensor must cope with significant variations in target shape and colour, moving animals, in a naturally dirty environment cluttered with mud, straw, water and other uncontrolled objects that interfere with reliable operation of vision sensors. The sensor must also ignore sections of the 3D images caused by other components within the field of view, such as the cow's legs or swinging tails.

Ultrasonic ranging and laser triangulation techniques had previously been applied to provide robot guidance for automated milking applications, but had drawbacks, including the need for moving parts and/or laser safety concerns.

### Unique Time of Flight Imaging Solution

LMI is one of only a few companies in the world that have expertise in successfully implementing machine vision technology.

### About LMI

LMI Technologies specializes in application specific 3D sensors for a wide variety of measurement, control and guidance applications. LMI sensor solutions are used in lumber processing, pavement inspection, molten metal pouring level control, automotive assembly, rubber and tire manufacturing, and many others. LMI's application specific sensing solutions are based on 2D or 3D sensing technologies, and in many cases effectively combine 2D and 3D sensing in a single sensor package. Founded in 1976, LMI developed much of the 3D sensing market, and holds over 100 patents related to 3D sensing technology.

gies for applications such as robot guidance in extremely difficult environments. Tasked with finding a better solution for guiding milking robots, LMI determined that implementing innovative time of flight 3D imaging would provide a unique and dramatically improved solution to this guidance application. The sensor based on this technology and developed by LMI in conjunction with GEA, is named the Tracker 4000.

TOF imaging cameras have a 2D array of pixels, with each pixel capable of returning time of flight information as well as intensity. The TOF information produces 3D images of a scene where the brightness of each pixel is proportional to the distance from the sensor to the object, creating an image similar to a topographical map.

TOF imaging provides many unique advantages when applied to guiding milking machine robots. The 3D image field of view includes the entire udder as well as the milking cups. The 3D image information from the sensor is analyzed to determine the position and angular orientation of each individual teat, as well as the milking cups. The location information is transmitted to the robot controller through Modbus over Ethernet. Use of industry standard protocols simplifies the integration effort for the machine builder.

The sensor currently operates at a frame rate of 8.3 Hz, with faster operation in development. Multiple images are taken as the cups are guided to the teats, which track movement of the cow during the attachment process.

Determining the locations of both individual teats and milking cups enable differential guidance, where the offsets to guide the robot to the teat locations are determined as the differences in location of the teats relative to the location of the milking cups on the robot. The result is improved reliability in guidance, as well as simplification of absolute calibration requirements for both the sensor and the robot over the full field of view.

### 3D Images with no Moving Parts

The TOF sensor is small in size and low in weight, allowing it to be easily mounted on the robot arm, so its position can be

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changed by the robot. This allows the viewing angle to be changed, very useful to obtain an unobstructed view of all teats, particularly if two teats are seen to overlap from one viewing angle. Obtaining 3D data from a single TOF camera provides a much smaller sensor package than would be required for two camera stereo imaging, which also requires extensive image analysis software to create a 3D image.

The TOF principle provides complete 3D images with no moving parts and no laser lines or spots. Traditional laser scanners require use of a mechanical scanning device to capture a full 3D image, which increases time required to capture an image, and adds complexity while reducing reliability.

The Tracker 4000 sensor is implemented with infrared LED illumination integrated into the sensor housing, which does not distract the cows in the milking station. Also, LED illumination eliminates laser safety concerns and related regulatory documentation, an issue with laser triangulation based sensing.

To survive in the harsh uncontrolled milking machine environment, the Tracker 4000 is housed in a sealed package, with a sealed watertight cable connector. The mounting bracket covers the top and sides of the sensor to protect from cow kicks and dirt.



### Award-winning Teat Location

The Tracker 4000 is implemented with the field proven FireSync platform, developed by LMI to simplify the often complex task of integrating and synchronizing the many components of a 3D sensor system. FireSync is a synchronized, scalable distributed vision processing architecture for building reliable high performance systems. Real-time image processing algorithms running in the FireSync processor located inside the sensor use proprietary software to extract teat and milking cup locations in the images, ignoring other objects in the field of view, like a cow's leg or a swinging tail. The final result, coordinate positions for teats and milking cup locations in a predefined coordinate system, is delivered to the robot controller via an Ethernet connection. The FireSync platform is used in all of LMI's new products.

LMI's Tracker 4000 sensor is a technologically advanced device that will create significant improvements to yield performance and farm productivity, livestock well-being, enhance reliability, increased speed of farm operations and profitability, and improve product quality in the milking process. A short video demonstrating the Tracker 4000 sensor guiding a robotic milking machine to attach suction cups onto a cow's teats can be viewed at: <http://www.inspect-online.com/en/webcasts/time-flight-imaging-enables-automated-milking>.

In 2008, GEA Farm Technologies (GEA) was awarded the prestigious silver medal for "New Innovations" presented at the EuroTier 2008 tradeshow in Hanover, Germany for developing the innovative milking robot system with the LMI Tracker 4000 sensor.

This implementation of TOF technology is so unique that in February 2009, LMI Technologies was awarded US Patent 7,490,576 B2 from the United States Patent and Trademark Office for the use of Time of Flight sensors in livestock management.

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