Edition 27 | November 2021

SENSITEC
MAGNETORESISTIVE SENSORS

Sensor.Kosmos.

(Image source: Shutterstock/ ZinetroN)

Everything in View: Creation of LiDAR Point Clouds.

Autonomous driving has brought LiDAR to everyone's attention in the last few years, catapulting the technology into a pioneering role. LiDAR sensors have started to enable future-focused applications far beyond vehicle use, for example in logistics, agriculture, or in the smart city sector.

The LiDAR data may initially appear strange to the human eye, but they can be easily processed by computers in point clouds. We need to take a look at the various LiDAR technologies and how they work before we can understand why the data are presented in this form. The point cloud will look differently depending on technology.

LiDAR sensors are light-based measuring instruments: The distance between the sensor and the object can be determined by emitting light, reflecting it from an object and detecting it again with a sensor. Based on this, several technologies have been developed to record the environment. Flash technology, for example, illuminates the entire scene at once and picks up the reflected signals. This results in a two-dimensional point cloud. Scanning LiDAR sensors are more commonly used, however. When based on the time-of-flight principle, they will emit individual laser pulses that are then deflected across the scene. The scanning sensors are categorised by deflection method. For example, some sensors rotate, deflecting the laser sources onto the surrounding scenery in 360°. Many lasers are arranged stacked one on top of the other so that individual circles can be viewed in the point cloud.

The Blickfeld sensors used to illustrate the creation of point clouds on the other hand are solid-state sensors. This means that they do not have any rotating elements installed and thus are much smaller in size. Only one laser source is installed in the sensor itself to emit the laser pulses. Without the beam deflection unit, the laser would collect information at precisely one point and in one direction. However, the beam deflection unit ensures that the laser pulses are deflected to allow detection of a larger field of view beyond that one point. For this, it deflects the beam line by line to "scan" its environment, which explains the name of this type of LiDAR sensor, the scanning LiDAR.

Two MEMS mirrors produce the scan pattern

Blickfeld has developed dedicated microelectromechanical system (MEMS) mirrors for this. They are arranged in the sensor in such a way that the path of the laser beam passes over both mirrors. When the LiDAR sensor is in operation, the two MEMS mirrors oscillate, deflecting the laser beam and creating the field of view through their movement. One of the mirrors oscillates in a continuous and approximately harmonic curve that determines the horizontal field of view. The other one, in contrast, is variable in amplitude. The position of the mirrors in each axis is measured with free pitch sensors based on the anisotropic magnetoresistive effect in order to ensure beam deflection in the desired direction with high accuracy, thereby enabling precise scanning of the environment. The continuous change of the oscillation amplitude of the second mirror creates the scan pattern.

This is how it works:

When the sensor is put into operation, the first mirror starts its continuous horizontal movement from left to right. The aperture angle of the first mirror determines the horizontal field of view. Half the oscillating movement of the mirror, i.e. the movement once from right to left, or from left to right, describes a scan line. Since the mirror starts out straight, the first movement describes half a scan line. The second mirror starts to oscillate out of phase at a small amplitude. This

Short profile Blickfeld

Founded in 2017 and based in Munich, Germany, Blickfeld is a provider of cutting-edge LiDAR technology for autonomous mobility and IoT applications.

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initially deflects the laser beam in a virtually straight, horizontal line. For the second scan line, the horizontal mirror now swings from right to left, while the vertical mirror moves from top to bottom. The second scan line is located above the first one as a result. The third line runs below the first line from left to right and continues on like this until it reaches the maximum vertical field-of-view, i.e. the maximum opening angle of the second mirror. The scene is then recorded completely once. One frame is completed.

Configuration options for resolution and scan rate

Throughout the process, the mirror properties significantly determine the design of the scan pattern and the sensor field of view. The size of the mirrors is particularly crucial. Of course, this affects their weight. That in turn lowers the natural frequency at which the mirrors oscillate once they have been set in motion. The natural frequency determines the time required to scan a scan line.

With the size of the MEMS mirrors of Blickfeld's industrial LiDAR "Cube 1" and their corresponding natural frequency, a maximum of approx. 500 scan lines per second can be generated. They can be configured flexibly and adapted to the needs at hand. For example, a high number of vertical scan lines per frame can be set for a particularly high resolution of the point cloud. The more scan lines generated per frame, the longer it takes to scan the entire field of view. The scene would thus be captured once per second, each pixel thus measured once per second at the maximum possible approx. 500 scan lines. This may be too low a scan rate for some applications, e.g. in security. After all, a lot can happen in a second. The required resolution has to be determined and the scan rate adjusted to it.

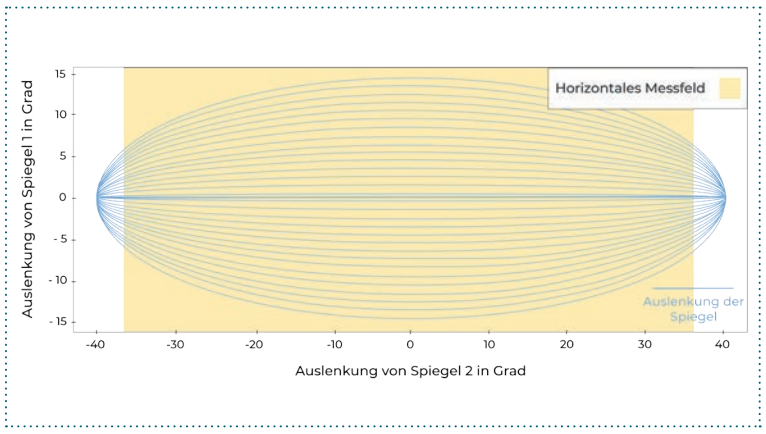


Fig. 1: Measurement field depending on the mirror movement. (Image source: Blickfeld)

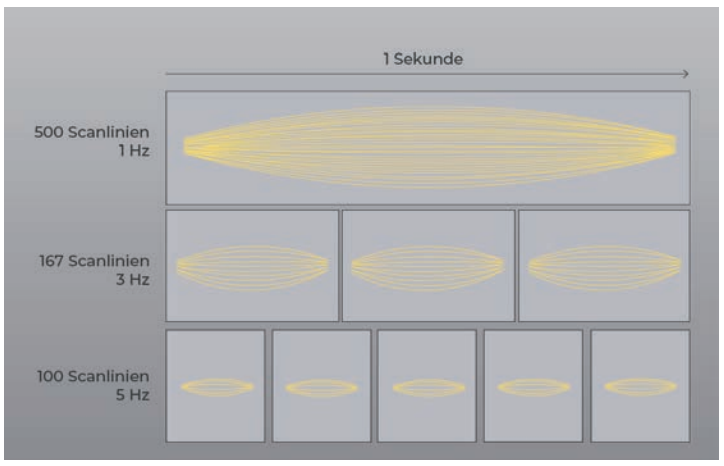


Fig. 2: Flexibly configurable scan lines. (Image source: Blickfeld)

Now, the scan lines are no longer continuous lines because the laser beam is pulsed rather than emitted continuously. This means that the scan lines comprise of many individual points, which can also be used to configure the resolution of the point cloud. For a higher horizontal resolution, the distance between the emission of the laser pulses must be reduced and the pulse frequency increased accordingly. The pulse frequency is determined by the waste heat of the laser diode and the necessary compliance with eye safety. The horizontal resolution can also be adjusted by either transmitting the dots in parallel vertical lines or by pulsing them in an offset manner so that each dot in a row is placed between two dots in the row above it.

Flexible configuration for many application options

All of these settings – the flexible number of scan lines, the adjustable horizontal resolution – can be made live in the user interface and of course via the API. This allows adaptation to the current application and the corresponding requirements and can also be changed in operation.
This allows the LiDAR sensors to be configured individually for each application. If, for example, vehicles are to be detected in front of a toll station in order to automate the payment process, the scan rate does not need to be particularly high since cars drive slowly within the toll station. The scan rate can be reduced to increase resolution in this case. High resolution will be required to distinguish between the different vehicles in this example. In smart city applications, on the other hand, a sensor may detect fast-moving cars or determine the precise number of people in a crowd. This flexibility is a major advantage of the configurable scan pattern.

By: Blickfeld

Sensitec goes Global.

Sensor manufacturer Sinomags Electronic Technology Co. Ltd, China, is the new owner of Sensitec GmbH.

Wetzlar / China,
September, 28th 2021.

The internationally active sensor manufacturer Sinomags Electronic Technology Co., Ltd. based in Ningbo/China takes over Sensitec GmbH, the technologically leading supplier of magnetic sensors based in Wetzlar. A corresponding contract between Sinomags and the previous shareholders, Körber AG, based in Hamburg, and Dr. Rolf Slatter, was negotiated in advance and the purchase process formally concluded between the contracting parties on September, 28th 2021.

„The portfolios of Sinomags and Sensitec complement each other perfectly," explains Dr. Jianguo Wang, founder and CEO of Sinomags Technology Co. Ltd. „Sinomags is a specialist in TMR-based current sensors and sensors for magnetic code and image recognition. Sensitec has its strengths in magnetic measurement of displacement, angle and length. For our existing and future customers, the great advantage is that these competencies are now bundled", Wang continues.

Sensitec has stood for high-precision sensor technology for more than 20 years. Originally founded as a research institute, the company has now established itself worldwide as a supplier of MR sensors for demanding measurement tasks.

Founded in 1999 in Lahnau, Sensitec has been part of the international technology group Körber since 2013. With its wafer factory located in Mainz, Sensitec is one of the specialised suppliers of magnetoresistive sensors and solutions for customers with demanding measurement tasks, including in automation, the automotive sector and drive technology.

The bundling of the know-how as well as the decades of experience and the innovative strength of Sinomags and Sensitec offers a unique market opportunity for both companies. There will be synergies not only in technology and product portfolio, but also in sales. For the business partners, nothing will change in the operational cooperation. Previous contact persons and contact details will remain unchanged. The quality of the products and services as well as the close cooperation with business partners will remain the most important claim.

„We are very pleased to have a new strategic owner in Sinomags, who, like us, is committed to innovation and customer proximity," emphasises René Buß, CTO at Sensitec. „The merger is a great opportunity for both companies. The product ranges of Sinomags and Sensitec complement each other ideally. We are convinced that we can offer our customers a portfolio of solutions that will give them clear competitive advantages in their industries."

„Sensitec is a successful company with many years of expertise. It is ideally positioned and has an experienced and highly competent workforce. We will of course use the synergies and the joint strength. It is important to us that Sensitec's customers continue to receive optimal technologically and personally support, and ultimately benefit from the merger and the overall solution portfolio it generates", says Wang.

With the closing, the previous CEO Dr. Rolf Slatter left the company.

Short profile Sinomags

Ningbo Sinomags Technology Co., Ltd. was founded in 2013 in Ningbo / China by Dr. Jianguo Wang.
The studied physicist received his doctorate in 2002 at the University of Lisbon in the field of TMR technology and then worked in the USA at Seagate and TDK in the field of computer hard drives. With 20 scientific papers and 70 patents in the field of magnetoresistive sensors, he is an outspoken expert. Sinomags Technology Co. Ltd. employs 600 people who develop, manufacture and supply GMR / TMR wafers and magnetic sensors. They offers its solutions in the field of renewable energies, electromobility and for applications in the field of the Internet of Things (IoT). The products include a wide range of current sensors as well as switching sensors and sensor arrays for banknote authentication. The company also offers solutions for measuring electrical parameters and various other applications.

MR Sensors Offer Advantages for Automated Condition Monitoring.

Informative yet efficient condition monitoring is indispensable for detecting damage and estimating the remaining service life of machine elements for lifecycle-oriented services in industry 4.0 and automated maintenance. Automated machine learning reduces the required prior knowledge and time, lowering the entry barriers in particular for SMEs. MR sensors differ from conventional accelerometers by offering automatic recording of physically motivated features.

In the last issue from May 2021, we published an article on condition monitoring of machine elements, among other things covering initial results on a gearbox vibration test rig at the Darmstadt Technical University. MR sensors of different technologies as well as classic acceleration sensors were examined for their suitability for condition monitoring of a gearbox in a cooperative project between Sensitec and the local Institute for Product Development and Machine Elements (pmd) there. A pinion within the gearbox was progressively damaged and the effects of the damage were examined at several measuring points within the gearbox for this purpose.

The research group of Prof. Schütze from the Saarland University (UdS) was involved in the project in a second phase. The UdS uses methods based on artificial intelligence (AI) to extract information on damage, wear, or fault conditions from sensor signals. The challenge is in identifying the important patterns from the plethora of data. For this purpose, the UdS developed a machine learning toolbox that permits partly automated processing of training data for people from other subject areas and beginners as well, cf. Figure 1.

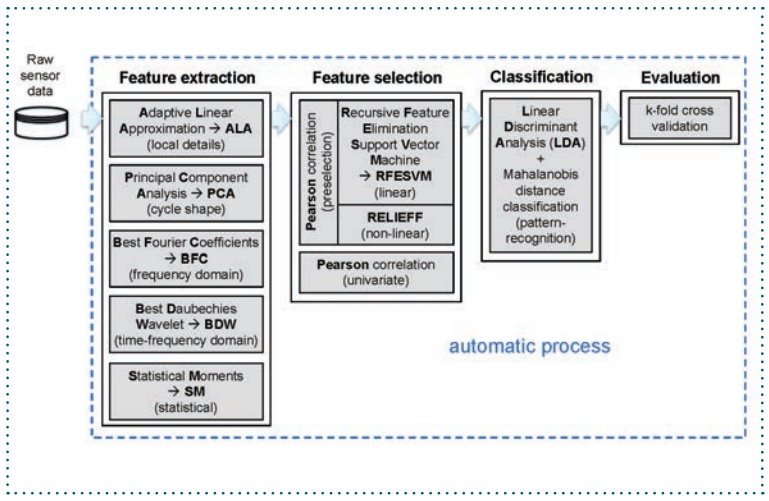


Figure 1: Toolbox schematic, adjusted by Dorst et al., "Metrology for the factory of the future: towards a case study in condition monitoring" in 2019 IEEE I²MTC.

The training data system is important for successful teaching of the model. This is ensured by a design of experiment that has all combinations of all variations of the specified varied test parameters (speed, load, damage state, ...) appear in the training data. The number of required measurements is growing exponentially with the number of test parameters. Therefore, a compromise between good coverage of the parameter space and feasibility of the measurements in terms of time has to be found here.

A systematic design of experiment was defined for a new series of measurements in order to meet these requirements and obtain the most reliable results possible. The following test parameters were defined:

- 7 states of the pinion under consideration:
  1. undamaged [= damage class 0]
  2. undamaged following removal and installation (to estimate mechanical effects not caused by the damage) [= damage class 1]
  3. progressive damage stages 2 to 6 (more finely graduated than in the 1st measuring series)
- 5 drive motor speeds: [300, 700, 1300, 1600, 2000 rpm]
- 6 load torques of the output motor: [20, 35, 55, 70, 85, 96 Nm]
- 4 quadrants for rotational and load torque directions

Measurements were performed in a total of $7 \cdot 5 \cdot 6 \cdot 4 = 840$ settings since every possible combination of the four features must appear in the training data. This considerable number highlights in particular that the main effort is often in planning and acquiring the necessary training data before a model can even be trained in AI-based condition monitoring.

In addition to these quasi-static (i.e. constant speed and load) measurements, dynamic measurements where either the speed or torque changed after half of each measurement period were also performed. However, these measurements have not yet been used to develop a machine learning model.

The dataset will be published soon to allow potential users to test their own analytical methods.

Results

Several models were trained and validated from the data of a single sensor at a time for comparisons between the sensors. The best predictions by far were provided by two MR sensor arrangements. They were significantly outperforming the acceleration sensor used.

For example, Figure 2 shows a visualisation in the form of a 2-dimensional linear discriminant analysis (LDA). Several damage conditions were combined in each case, forming a total of three groups:

1. undamaged (damage levels 0 and 1, dark blue)
2. slightly damaged (damage levels 2, 3, and 4, cyan)
3. heavily damaged (damage levels 5 and 6, yellow)

Only data from damage conditions 1, 3, 4, and 6 were used for training. The remaining data were assigned to the three groups by the model. The accuracy was 78% here.

The physically sensible progression of damage from "undamaged" to "heavily damaged" is clearly made visible, even though the model data were only available in discrete classes without any ordinal correlation, and in particular conditions "unknown" for the model are classified in the correct target groups.

An important advantage of the use of position or velocity sensors as compared to state-of-the-art acceleration sensors was identified here as well in the fact that the measured frequency spectra can be relatively easily standardised using the measured current (rotational) velocity. This can be decisive in particular in later operation, where the rotational speeds or velocities are not known in advance. Standardisation is of advantage since all mechanical frequencies that can be used for condition monitoring scale proportionally with the speed or velocity. This automates the well-established order analysis technique in operation. By extracting speed-independent and, in particular, physically motivated features, we were able to train machine state models that were more accurate and at the same time easier to explain.

Further results are currently being published by the pmd Institute of the Technical University of Darmstadt and the Centre for Mechatronics and Automation Technology (department for measuring technology at the UdS) of the Saarland University. Statements on transferability of the results to any other specimens cannot be made yet. More work remains to be done here.

[1] Tanja Dorst et al., Automated ML Toolbox for Cyclic Sensor Data

By:
Sebastian Pültz (UdS), Lukas Rauber (Sensitec), Yannick Robin (UdS), Yanik Koch (pmd), Jörg Traute (Sensitec)

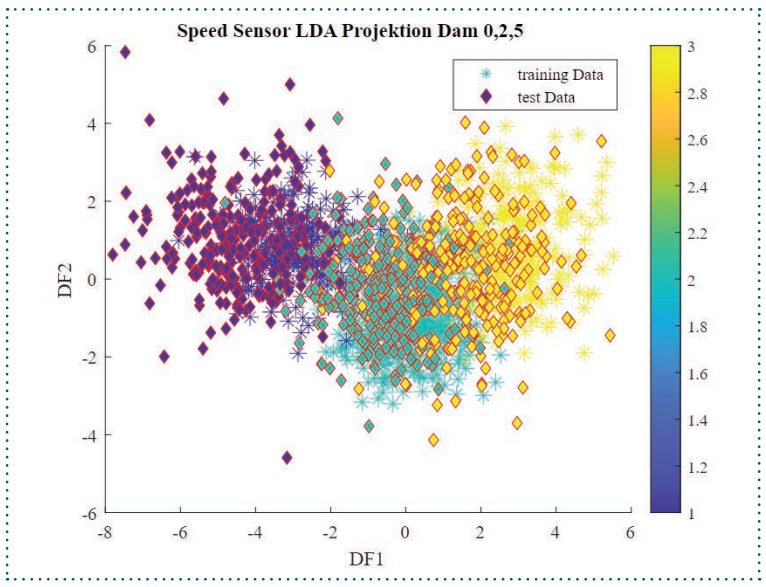


Figure 2: 2D LDA plot speed sensor. The training data are displayed as stars: Damage class 1 (dark blue), damage classes 3 and 4 (cyan), damage class 6 (yellow). The test data (classes 0, 2, and 5) are shown as rhombuses filled in the corresponding colour.

Company-News | Employee-Interview

Work at Sensitec.

We have invited Manuel and Jonas, who recently joined Sensitec, for a short interview to give you an insight into the working world at Sensitec.

How long have you been with Sensitec now? When did you join the company?

Manuel: I have been with Sensitec for about a year now. I joined on 01/07/2020.

Jonas: I started just before Manuel on 01/06/2020.

Manuel: Luckily, this was during the "Coronavirus summer break". That allowed us to meet most of our colleagues in person.

Manuel Palzer, Productmanagement

How did you hear about Sensitec and what made you decide to apply?

Manuel: I am closely connected to the region. I already knew Sensitec by name. Looking for a new professional challenge, I saw the job advertisement on the website and applied. I was quickly invited to a job interview, and this is how we joined forces.

Jonas: I saw the project engineer's position advertised on an online job portal. Since I had only dealt with optical measurement technology at that time and found magnetics exciting during my studies, I really wanted to get to know more about MR technology. I also found the tasks of a project engineer very appealing and therefore applied.

What is your position at Sensitec and what are your tasks?

Jonas: I work as a project engineer in development. At the moment, I am supervising two projects. This includes organisational project management. For example, we create project plans or define and coordinate tasks. I am also involved in technical development, e.g. creating test setups and performing measurements.

»Work and family can be combined wonderfully. This is not the only reason why working for Sensitec is so much fun.«

Manuel Palzer, Product Manager

Manuel: I take care of the position sensor segment in product management. My tasks are very diverse and span all steps of product development, i.e. from the customer inquiry over the development up to the series maturity of a product and at some point also its discontinuation. Customer support is among my tasks as well, and so is participation in trade fairs and marketing support.

What do you like about your work and working environment?

Manuel: As mentioned, I love that it is a very diverse and varied job. We work a lot with other departments and are in contact with customers, which ensures exciting and varied work and tasks. However, it is just as important that my colleagues made my start easy. I was integrated into the team right away, and there has been good interaction and cohesion among the group. It's a fun way to work. With the option to work from home now and then (not only in Coronavirus times), it's also easy to reconcile work and family.

Jonas: What I like about my job is that I can manage projects very extensively. I get to look at all aspects of the development process and can contribute and work in a targeted manner. Sensitec also offers a very pleasant and family-like working atmosphere. This permits open communication, which made it easier for me to learn the ropes.

What project and content do you find particularly exciting at the moment?

Jonas: I am in charge of projects for the development of platform products. Designing them as flexibly as possible for different applications is a demanding task that is also an interesting challenge across all development steps. We are currently working on transferring the products to series production. After working in basic development in my previous jobs, I find this to be an exciting new role.

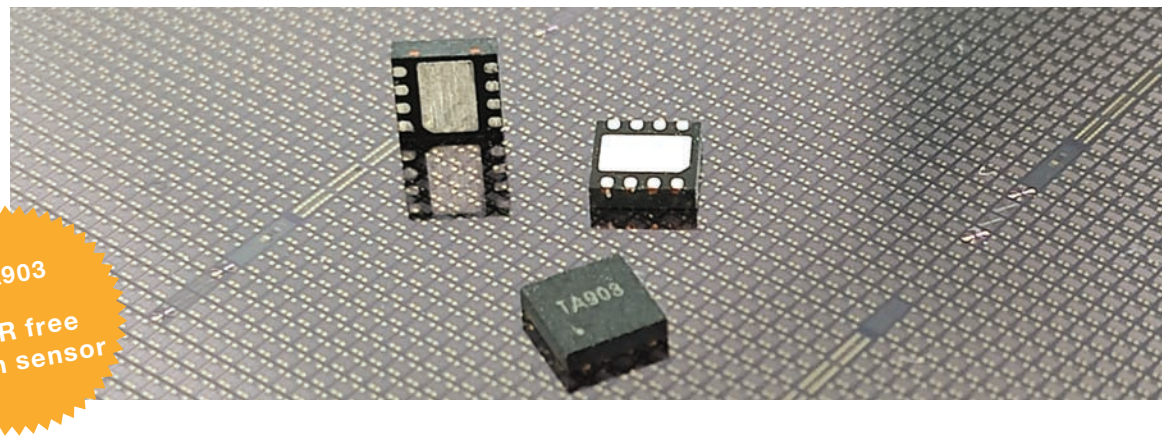
Manuel: There are several. It is exciting to see that our sensors are used in a great many application areas. That also makes for a very diverse task. Since I joined Sensitec, I have been in charge of our new platform products in the scope of product management,

Jonas Rottmann, Development Department

just like Jonas. They are scheduled to enter serial production soon. This has been and will continue to be an exciting first phase in my new job.

Many thanks to both of you and we wish you a successful and interesting time at Sensitec.

Product-News | TA903



The TMR based free pitch sensor TA903 has been available for some time. It is now also offered in a very compact SMD solderable DFN package. The 8-pin sensor package, only 0.75 mm thick, is extremely compact with 3 mm edge lengths and, with the sensor chip placed centred in the housing, ideally suited for "on-axis" or "end-of-shaft" applications. The integrated TMR sensor provides differential sine and cosine signals with an amplitude of approx. 100 mV/V at a dipole magnet. The sensor also has integrated ESD protection with 2 kV (HBM) and can be operated with typical supply voltages of 5 V, 3.3 V, or even 1.8 V.

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Nürnberg, 23. – 25.11.2021

We look forward to welcoming you again in person at SPS – Smart Production Solutions in Nuremberg from 23. to 25. November 2021. More than 1,600 national and international exhibitors will be waiting for you at one of the largest international industrial automation trade fairs for electrical automation, systems & components. Visit us at our stand in

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and check out our products and solutions.

Published by:

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