DSPE MIKRONIEK

2020 (VOL. 60) ISSUE 5

PROFESSIONAL JOURNAL ON PRECISION ENGINEERING

- THEME: ROBOTICS
- PRECISION FAIR 2020 CANCELLATION
- ULTRASHORT-PULSED LASER MACHINING OF HARD MATERIALS
- MODULAR MICRO-ASSEMBLY PLATFORM FOR INTEGRATED PHOTONICS

MIKRONIEK IS A PUBLICATION OF THE DUTCH SOCIETY FOR PRECISION ENGINEERING – WWW.DSPE.NL

Your one-stop service for Etched and Electroformed metal precision parts

PUBLICATION INFORMATION

Objective
Professional journal on precision engineering and the official organ of DSPE, the Dutch Society for Precision Engineering. Mikroniek provides current information about scientific, technical and business developments in the fields of precision engineering, mechatronics and optics. The journal is read by researchers and professionals in charge of the development and realisation of advanced precision machinery.

DSPE
YOUR PRECISION PORTAL

Publisher
DSPE
Annemarie Schrauwen
High Tech Campus 1, 5656 AE Eindhoven
PO Box 80036, 5600 JW Eindhoven
info@dspe.nl, www.dspe.nl

Editorial board
Prof.dr.ir. Just Herder (chairman, Delft University of Technology),
Servaas Bank (VDL ETG), B.Sc.,
ir.ing. Bert Brals (Sioux Mechatronics),
Maarten Dekker, M.Sc. (Philips),
Otte Haitsma, M.Sc. (Demcon),
dr.ir. Jan de Jong (University of Twente),
ing. Ronald Lamers, M.Sc. (Thermo Fisher Scientific),
Erik Manders, M.Sc. (Philips Innovation Services),
dr.ir. Pieter Nuij (MaDyCon),
dr.ir. Gerrit Oosterhuis (VDL ETG),
Maurice Teuwen, M.Sc. (Janssen Precision Engineering)

Editor
Hans van Eerden, hans.vaneerden@dspe.nl

Advertising canvasser
Gerrit Kulsdom, Sales & Services
+31 (0)229 – 211 211, gerrit@salesandservices.nl

Design and realisation
Drukkerij Snep, Eindhoven
+31 (0)40 – 251 99 29, info@snep.nl

Subscription
Mikroniek is for DSPE members only.
DSPE membership is open to institutes, companies, self-employed professionals and private persons, and starts at € 80.00 (excl. VAT) per year.

Mikroniek appears six times a year.

ISSN 0026-3699

The main cover image by Bart van Overbeeke (three examples of autonomous mobility projects) is courtesy of Nobleo Technology. Read the article on page 10 ff.

IN THIS ISSUE

THEME: ROBOTICS


20


37

FEATURES

THE 5TH INDUSTRIAL REVOLUTION GOES **BEYOND THE MACHINE**

We have 'just' entered the 4th industrial revolution but are already talking about the 5th. In the 4th revolution, the digital and the physical world are engaged in an intricate dance to understand physical environments from within a digital model. We use sensors, data, models and algorithms, i.e. Artificial Intelligence (AI), to interpret the world and make decisions for us. The promise is a more flexible world where (high-tech) systems can make decisions that once had to be made by us, 'mere' humans.

While the world of smart industry is very aware of this process, we sometimes overlook how this technology seeps into our daily lives. I was suddenly reminded of this last week, when I tried to switch lanes while driving my new electric car. The car tried to show its 'intelligence' by deciding for me that there was an obstacle and steering me back into my original lane. This process of systems and devices suddenly taking over our human actions is the essence of robotisation for me.

While we think that robots are rather new and that machines and intelligence are just now coming together, this is far from the truth. The original idea of a robot was already envisioned in 1495 with Leonardo da Vinci's Mechanical Knight. The word robot was first used in Rossum's Universal Robots, a Czech play, in 1920. And while AI is starting to take hold of our daily lives, it's also not a new discipline. AI has its academic origins in the same time as the first digital computers, i.e. formal mechanical reasoning, pioneered by Alan Turing, who also spoke of artificial neurons around that time. Formally, the field of AI research was founded by John McCarthy in 1956, who used the term to distinguish the field from cybernetics, which is concerned with control and communication in the animal and the machine. In that perspective AI, digitalisation and robotics have always been side by side.

In my opinion, the reason the 4th revolution is moving so quickly is not just the availability of data, cheaper computing power and accurate microsystems like sensors and high-precision actuators. It's also due to the increased awareness of systems thinking as a means to improve our capability to handle the complexity of robotics, with its interdisciplinary essence and application. As I usually say, robotics is the summum of technology integration. Tapping into its possibilities requires system engineering, the interdisciplinary approach to realise new possibilities based on the needs of customers and society.

Robotics and system engineering will open the door to new complex systems and applications. If we are able to correctly digitalise our processes and systems, a new age of cyberphysical systems will arrive, woven all around us through devices, infrastructure and society. Intelligent machines already provide us with water, food, mobility, electricity and care. In the dawn of the 5th industrial revolution, cognitive systems learn continuously and adapt, even while operating. The potential of what we have learned during previous revolutions is extremely valuable. My wish is that we would use this knowledge of system engineering, robotics and AI to also create a social revolution amongst all industries.

We are facing a huge challenge and can use this knowledge to accommodate the transitions that are to come, like the energy, material, and protein transitions that we are facing as society. The potential in this field is huge and will have a profound impact on our daily lives. I expect robotised farming, AI-supported healthcare, and many other applications where robotics and AI, backed by system engineering, will support us in our future society.

Daniël Telgen
CEO, Cboost; professor of Robotization & Sensoring, Research Center Technical Innovation, Avans University of Applied Sciences; program manager High Tech Systems Center, Eindhoven AI Systems Institute, TU/e
daniel.telgen@cboost.nl, www.cboost.nl

THE PATH FROM RESEARCH TO INDUSTRY

Robotics research groups around the world are using Robot Operating System (ROS) to develop their prototypes quickly. While the first version of ROS was aimed primarily at the R&D community, its successor, ROS 2, has been redesigned completely to be industrial grade and applicable in research, prototyping, deployment and production. This allows ROS 2 prototypes to evolve into products suitable for real-world applications. To explore the state of the art, Saxion University of Applied Sciences and nine companies are developing an industrial mobile robot. This article describes experiences from the development process and presents an outlook on the potential of ROS 2 for industry.

WILCO BONESTROO

The plan to explore ROS 2 for industrial mobile robots was born during a meeting on open issues in robotics. This discussion resulted in the Next Generation Navigation, or NeNa, research project, a collaboration by Saxion with the companies Demcon, Hencon, Hollander Techniek, Indes, Opteq Mechatronics, Riwo, Romias, Singa and Wewo. The project is funded partly by SIA, the Dutch Taskforce for Applied Research (*Nationaal Regieorgaan Praktijkgericht Onderzoek*).

During that first meeting, several companies explained how they developed their navigation functionality for their robots or AGVs (automatic guided vehicles) such as those shown in Figure 1. Most of the attending companies used commercial, closed-source solutions for navigation and fleet management, such as Navitec Systems and BlueBotics. Other companies had built their software from scratch. Both approaches have their drawbacks: the first creates a dependency on an external party, while the second requires considerable software development effort for maintenance and further development.

The Mechatronics research group at Saxion had been working with smaller robots for both research and education, such as those shown in Figure 2. Those robots use the open-source navigation solution provided by ROS. We wanted to explore whether that solution was also applicable to the larger industrial robots developed by the industrial partners, so we started the NeNa research project in 2019. Our main question was whether we could build a robust and accurate navigation solution based on ROS that would provide a similar functionality and quality as the current approaches.

Requirements

The companies in the project apply their robots in different fields, ranging from mining and heavy industries to logistics and farming. As it was impossible to select one use case that could address all the application fields, we decided to develop a new use case that could demonstrate the feasibility of our requirements. We needed a prototype that could demonstrate:

AUTHOR'S NOTE

Wilco Bonestroo is a researcher in the Mechatronics research group of Saxion University of Applied Sciences, located in Enschede (NL). He focuses on autonomous systems and AI with a special interest in navigation and localisation.

w.j.bonestroo@saxion.nl
www.saxion.nl/onderzoek/smart-industry/mechatronica


1a

1b

Examples of mobile robots from project partners.
(a) Hencon.
(b) Wewo.

2

Lightweight research and education robots.

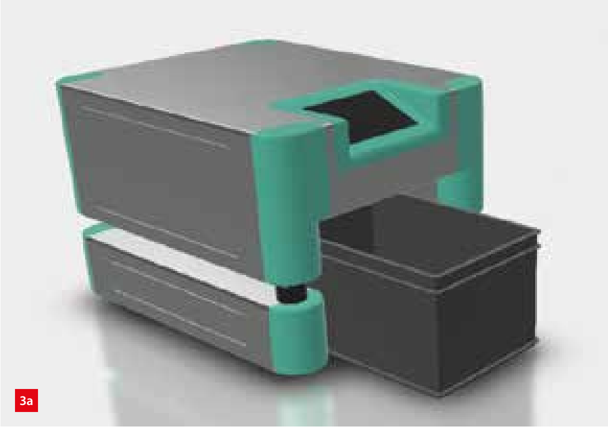
- autonomous navigation, including dynamic obstacle avoidance, no-go areas, speed zones and virtual line following;
- localisation without installed external infrastructure, such as reflectors or induction wires;
- integration with existing fleet manager software;
- precision docking for specific tasks.

Our use case was inspired by straddle carriers, which carry their load underneath instead of putting it on top. We wanted to demonstrate solutions on industrial equipment, but we also wanted to use the prototype in our research labs and offices. Therefore, a small industrial robot was designed and developed. The robot is a tunnel vehicle that can drive over euro crates, pick them up and move them around. Figure 3 shows impressions of the concept and design.
To make our findings relevant for the bigger robots, we provided our NeNa robot with the components that are also used in the larger machines developed by the companies. It has two 2D Sick lidar sensors to provide a 360° view of the environment. The lidars are used for safety, but also for localisation and obstacle avoidance. The robot is also equipped with a 3D Intel® RealSense™ camera to detect the crates.
The partners in the project were not only interested in navigation functionality, but also in the ability of a robot (or fleet of robots) running ROS to be integrated into their automation ecosystem, as the robots had to be controlled from a fleet manager. The navigation behaviour also had to be adjustable by the end user. For example, in some areas such as hallways, the robot should follow a virtual line, while in other areas, such as large rooms or production halls, the robot should navigate freely. In addition, some areas have speed limits, or the speed of the robot should be adjusted based on whether there are people around it.

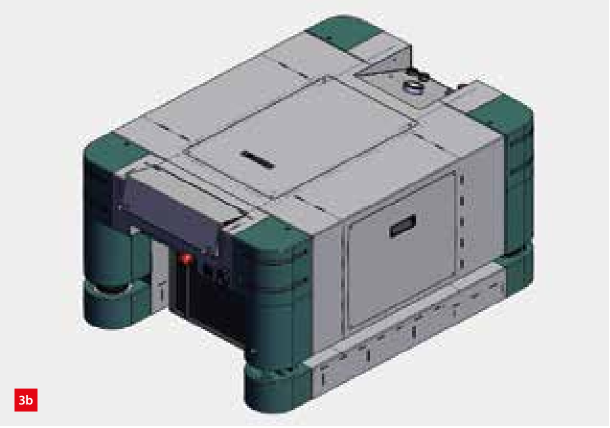
Parallel development

To manage the lead time of our project, we designed and implemented our hardware and software in parallel. So, while the first CAD drawings were being created, the simulation model of the robot was developed in ROS. This model had all the sensors that we planned to use in our robot. In Gazebo, the default simulator in ROS, the virtual robot could be tested in different environments. For example, we could work on a precision docking manoeuvre based on simulated sensor data while the actual robot was still under development. Figure 4 shows the robot in a simulated office environment as well as a simulation of robot-crate interaction.

To use both the industrial hardware and the advanced navigation algorithms from Navigation 2, we orchestrated computation over two different computers: an industrial PLC and a general-purpose PC. The PC runs Linux with ROS and executes the navigation algorithms that perform complex tasks like localisation and path planning. The PLC provides strict timing and handles the safety functionality of the robot. It takes care of low-level communication with the sensors and motors. Moreover, it checks whether the PC is operating as expected. For the communication between the PLC and the PC we have experimented with OPC UA (Open Platform Communications – Unified Architecture). We did some initial tests and concluded that this provides



3a



3b

The NeNa robot prototype (with crate).
(a) Artist impression.
(b) CAD design.

ROS, ROS 2 and ROS Industrial

ROS development started around 2007, at Stanford University and in the company Willow Garage [1]. The first official ROS release was in 2010. One of the main ROS goals was to stimulate collaboration between developers by providing standard communication interfaces. Although developed originally for one specific humanoid robot, more and more people started contributing to the project and ROS was applied to many different robots. Using ROS allowed research groups to focus on their own specific research topics and simply use the functionality provided by others.

Up to now, the ROS community has released 13 distributions. The first letter of the distribution name indicates their order. The most recent ones are Kinetic, Lunar, Melodic and Noetic. The distributions alternate between five-year support (long-term support or LTS) and two-year support. Support means that they are actively maintained and updated by the community. Each distribution is supported on exactly one Ubuntu Linux distribution. Canonical, the company behind Ubuntu, is one of the 17 companies in the ROS technical steering committee. Their main focus is on the security of robotic systems running Ubuntu and ROS.

Within a distribution, software is organised and delivered in ROS packages. Today, there are hundreds of them. Some packages provide drivers for common robotics hardware, such as lidars, inertial sensors and cameras. In addition, there are advanced packages for navigation, localisation, path planning and robot manipulation, as well as ROS packages that provide wrappers for common libraries, such as OpenCV for image manipulation, the Point Cloud Library (PCL) for handling 3D point cloud data from cameras and lidars, and YOLO or TensorFlow for object detection and localisation. They are installed easily with the Ubuntu package manager.

Over the past decade, ROS has become the standard framework in the academic world and in research environments. However, because ROS was not designed for production environments, it was quite a challenge to go from prototype to software that could be deployed industrially. Companies would have to review all the software used in their product. Based on requirements from industry combined with insights gained from working with ROS, there was a discussion on whether those requirements could be integrated into the existing framework, or a redesign was needed. Around 2015 it was decided that it would be better to design a new ROS version from the ground up to provide security, reliability and real-time capabilities. It should also run on many platforms, not only on (Ubuntu) Linux, Mac and Windows, but also on embedded and real-time systems. This was to become ROS 2.

A remarkable difference between ROS and ROS 2 is the middleware that is used to communicate between components, or – in ROS terms – between 'nodes'. The middleware in ROS was developed from scratch. In parallel, however, in the past decade a number of middleware solutions have matured, such as ZeroMQ, Protocol Buffers and Data Distribution Service for real-time systems (DDS). After analysing these existing solutions, DDS was selected as the middleware for ROS 2. DDS is a proven standard used typically in mission-critical systems, such as in military, aerospace and industrial automation. In ROS 2 there is no longer a single master node that controls the whole system. Nodes discover each other automatically using DDS and the system is truly distributed.

ROS 2 is also released in distributions. Again, the first letter indicates the order: Dashing, Eloquent, Foxy. As ROS 2 is still under heavy development, the support is shorter than for ROS. Foxy is considered an LTS version and has come with three-year support. ROS 2 is expected to be as stable as ROS within a year.

To complicate things a little more, there is also an initiative called ROS Industrial. Its goal is to bring the advantages of ROS, such as reuse of existing software, to industrial robots. However, ROS Industrial is not another version of ROS. It builds on the existing ROS core and provides packages that are aimed specifically at industry, such as deterministic path planners for manipulators and drivers for robot arms. Manufacturers of robot arms are actively encouraged to develop and support their own drivers in the ROS Industrial initiative. As code quality and reliability are essential for industrial applications, each ROS Industrial package has a status description that indicates whether the package is experimental, developmental or production ready. Although ROS Industrial is open source, it also provides commercial services, such as training, development and support. As ROS 2 targets industry, ROS Industrial is pushing its community towards ROS 2.

Navigation has always been a major part of ROS and is used on many existing service robots. The navigation functionality of ROS was also redesigned for ROS 2, resulting in the Navigation 2 package [2]. Navigation 2 is aimed at dynamic environments and supports a wider range of sensor to be used in mapping, localisation and navigation. It also supports contextual navigation behaviour. This means that the navigation can be adapted based on the area where the robot is driving or what the sensors are seeing.

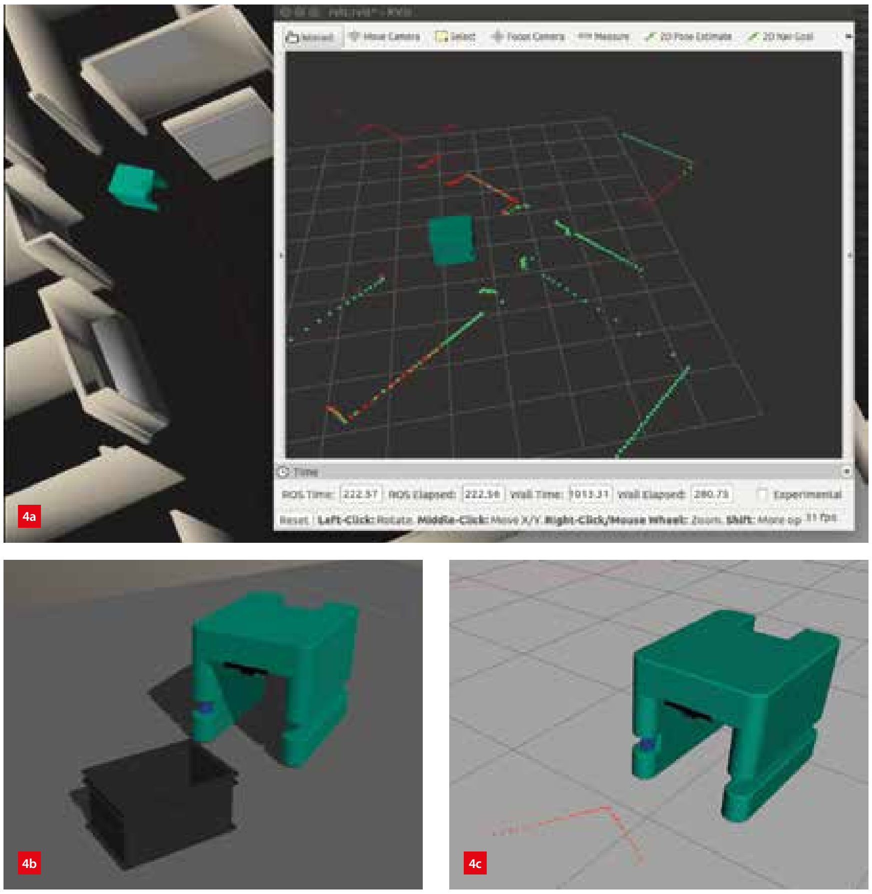


Figure 4. Simulation of the NeNa robot and a crate in an office environment.
(a) Robot model in the office, with visualisation of sensor data in the right screen.
(b) Robot-crate interaction.
(c) Visualisation of sensor data: how the robot sensors actually 'see' the crate.

a modular approach, because OPC UA is available on both the PC and PLC. The goal is to be able to replace the PLC or the PC with any other system that also supports OPC UA. We are now in the final phase of the project. The hardware has been delivered, the drivers for the hardware are currently being developed and tested, and the high-level software has been partly demonstrated in separate simulations while new features are still under development. When all the hardware has been completed (Figure 5), we will start integration and system tests to determine whether we can meet all the requirements. In the final phase of the project, everything has to be integrated into two robots performing their tasks based on a fleet manager. We aim to complete the project in April 2021.

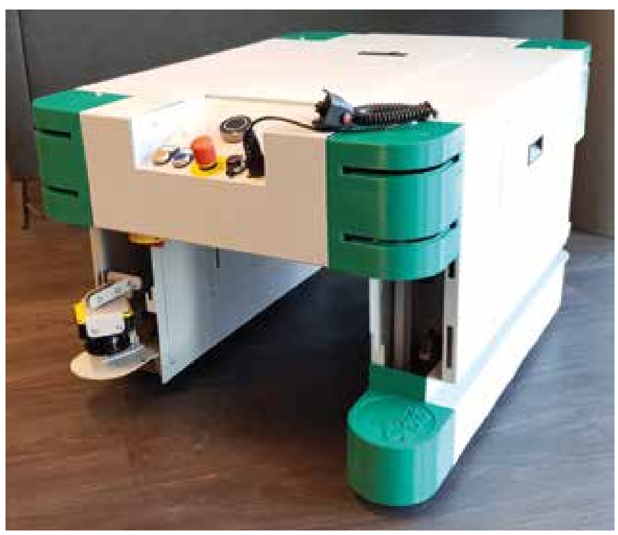
Which ROS distribution to choose?

We have spent quite some time developing our software for different ROS distributions. When we started in 2019, navigation in ROS 2 was unstable. As the involved companies were still mainly interested in ROS 2 and because ROS and ROS 2 can be combined in one system, we decided to develop our first robot model and simulation of the robot both in ROS and ROS 2. During the project, the recommended distributions in ROS progressed. Moreover, newer distributions of ROS 2 became more stable and provided functionality we needed in the project. Eventually, we have developed our robot models and software in five distributions, and this required a lot of effort.

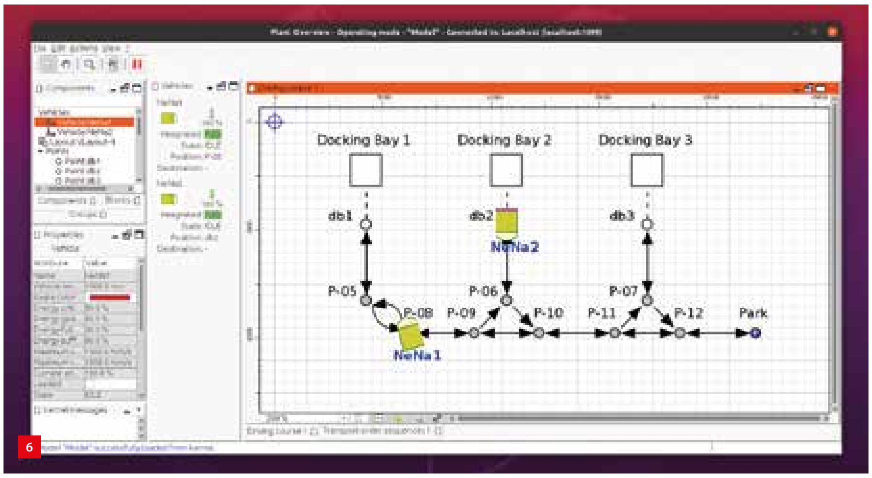
In hindsight, we should have been more careful in selecting the distribution(s). For companies, such choices are even more important. Currently, ROS is more stable than ROS 2 and features more packages; support for ROS, however, will end in 2025. Meanwhile, robot and application developers are already moving their focus towards ROS 2 and the ecosystem is growing. We also experienced that navigation in ROS 2 is quite advanced compared to other parts. For developing a functional prototype quickly, ROS is still the logical choice, because it is stable and there are many packages to build on. When aiming to actually use the software in a product, ROS 2 would be the logical choice. To summarise: "If you want to go fast, go ROS. If you want to go far, go ROS 2."

Integration in the industrial ecosystem

In a research setting it is acceptable to control a robot manually or even by typing commands from a terminal. However, mobile robots or AGVs in production environments have their own place in the automation ecosystem. One of the specific requirements in our project



Realisation of the NeNa robot, in two views.



Screenshot of a factory model in OpenTCS.

was that the robots should be controlled from a fleet manager. The fleet manager translates tasks from ERP or MES systems into navigation tasks, then dispatches those tasks to the appropriate robots and keeps track of the whole fleet. To demonstrate interoperability between ROS and fleet managers, we have integrated our robot with OpenTCS, an open-source fleet manager developed by Fraunhofer IML. One of the project partners was already using OpenTCS in their systems. Figure 6 shows a screenshot of a factory model with several docking bays and two NeNa robots.

To provide an interface between the fleet manager and the robot, OpenTCS uses 'vehicle drivers' to send commands to specific robots. We have developed a ROS 2-OpenTCS vehicle driver, which makes all functionality from the fleet manager available in ROS 2. Developing a driver is conceptually straightforward, but in Java this turned out to be a challenge. ROS 2 can be used with any programming language, with support for different languages being provided by client libraries that translate between the specific language and the generic ROS functionality. The ROS client libraries for C++ (rclcpp) and Python (rclpy) are well developed and thoroughly tested. However, OpenTCS is written in Java and the client library for Java was under development at the start of the project. Eventually, developing the driver and integrating it with a client library 'under construction' took more effort than expected.

An interesting aspect of ROS 2 is that it can be deployed in different ways. By default, it uses the standard open-source core, but there are also companies providing commercial and certified versions. For example, Apex.AI has developed a version of ROS 2 for safety-critical applications in the automotive industry. Their software is real-time, reliable and deterministic. Moreover, it is certified according to the automotive functional safety standard ISO 26262. The communication middleware in ROS 2 can also be exchanged easily. The default implementation Fast RTPS is suitable to be used within ROS, but it does not implement the full DDS standard. However, it can be replaced with Eclipse's Cyclone DDS, which is open source and does implement the full standard. Moreover, when support is required, there are also commercial versions such as Adlink's Vortex OpenSplice providing DDS.

Conclusions

We jumped on the ROS 2 train rather early. In only a year and a half, navigation in ROS 2 has developed from highly unstable to a complete functional navigation system. On the Navigation 2 website [3], the 'Getting Started' steps can now be followed to have the navigation in a simulation up and running within an hour. However, specific features, such as virtual line following, require additional development. ROS 2 and Navigation 2 are still under development and getting the most out of them requires a serious software development team to work on them.

For companies involved in robotics, developments in ROS are interesting to follow. Developers of sensors or other components can reach a large worldwide group of potential customers by providing a well-maintained package with ROS drivers. Companies such as Intel, Xsens, Sick, Universal Robots and ABB robots provide drivers for their products. For system integrators, ROS 2 is interesting because it allows prototypes combining existing components to be built quickly, while also developing these prototypes into production-ready code. In our opinion, ROS 2 is currently not yet stable enough to ship in products, but based on discussions within the community, we expect that this will be realised within a year. ROS 2 is already used by the robotics teams in companies such as Amazon, Bosch and Rover Robotics.

As robotics students around the world are using ROS in their projects, it is interesting for companies to tap into this knowledge. To keep up to date with the general developments, it is advised to follow the discussions and announcements on the ROS forum [4]. There are many ways to learn ROS, with online tutorials, books and videos available. However, we have experienced that learning ROS is challenging, because there are so many different topics (Linux, ROS concepts, packages, tools, tool chains, algorithms, etc.) that one would have to grasp at once to get started. To get up to speed, ROS Industrial training courses can be followed all over Europe. In the Netherlands, these training courses are organised by Fontys University of Applied Sciences, Delft University of Technology and Saxion University of Applied Sciences.

REFERENCES

[1] Quigley, M., et al. , "ROS: an open-source Robot Operating System", *ICRA Workshop on Open Source Software*, Vol. 3 (2), p. 5, 2009.
[2] Macenski, S., et al., "The Marathon 2: A Navigation System", *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, 2020.
[3] *navigation.ros.org*
[4] *discourse.ros.org*

TOWARDS THE NEW NORMAL

We are living in a fast-changing world where automating human work has been everyday business for a long time. If social distancing becomes the new standard, it might further accelerate change – towards even more automation. Companies will then have to employ more machines that work together with (fewer) human operators for them to stay safe and healthy, and also stay in business. Nobleo Technology uses autonomous technology developed in house to support, and sometimes even take over, the dirty, dull and dangerous work of humans, a task which requires robust systems ready for reliable operation in industrial applications. This article elaborates on the possibilities and technical challenges.

CÉSAR LÓPEZ, TIM CLEPHAS AND RIK KRUIDHOF

Introduction

Starting with the development of automated guided vehicles (AGVs) in the 1970s, autonomous mobile robots have now been around for quite some time. Due to their high costs, their usage has long been limited to special applications. With the advent of the open-source Robot Operating System (ROS) [1] and the ongoing cost-down of electronics, the total cost of ownership for an autonomous mobile platform has decreased dramatically. As with all disruptive innovations, however, there are still some challenges (that the open-source ROS stack does not tackle).

Nobleo Technology provides autonomous solutions that can be retro-fit to a mobile robot or indeed any existing drive-by-wire motion platform. Robustness both in concept and implementation is essential for successful, sustainable, reliable operation. In this article, we will elaborate on a few highlights and building blocks of the Nobleo ‘plug & play’ autonomy solutions.
Nobleo has been active since 2016 in developing mobile robots. By investing in a model architecture for all robots, we are able to gain traction in new projects quickly. While the actual set of executables and libraries may vary, all robots have the same building blocks and interfaces.
This leads to stable and robust software components, even when work is being done on multiple robots simultaneously.
Nobleo has delivered a dozen autonomous robot designs to date. During the development of these robots, we have identified where the open-source ROS software is valuable, but also where it is lacking real-world applicability.

AUTHORS’ NOTE

César López (senior robotics designer) and Tim Clephas (senior software architect) are associated with Nobleo Technology, located in Eindhoven (NL). César López is also an assistant professor at Eindhoven University of Technology. Rik Kruidhof is business manager a.i. at Nobleo Autonomous Systems, part of Nobleo Technology.

cesar.lopez@nobleo.nl
www.nobleo.nl

Building on ROS

ROS in its core is a middleware framework (see the text box), which allows different software components to communicate not only within a single robot, but also across multiple machines. On top of that, the open-source community has developed a stack of software modules offering a wide range of functionalities for robot localisation, navigation and data visualisation, among others. Despite this, developing robust robotic applications that comply with industry expectations remains a challenge. Most ROS modules have been tested mainly in lab prototypes, without focusing on robustness and other type of requirements that are specific to industrial applications. Therefore, Nobleo has focused on building ROS-based robotic solutions with high standards for industry.

To enable high-quality robotic solutions, our development process includes the definition of a generic software architecture, implementation of best software practices, extensive software/hardware testing, and the use of state-of-the-art and enhanced robot skills.

Architecture

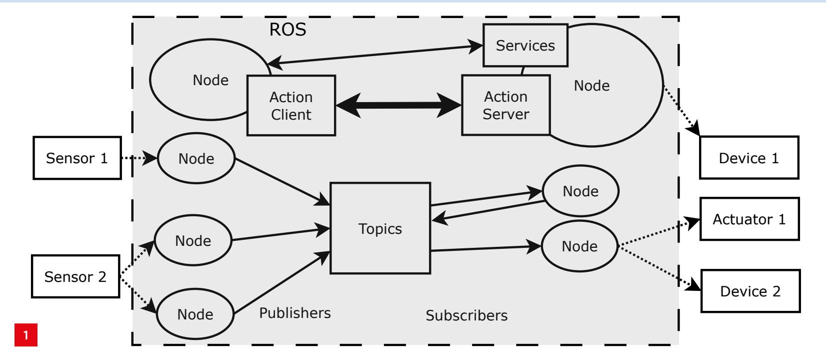
Firstly, a well-defined generic software architecture, as presented in Figure 2, is key to robustness. It allows not only a common ground for different robot platforms and applications, but also the use of automated software testing tools. As a result, various software components are reusable, and their level of maturity can be steadily increased. Therefore, when starting a new robotic application, we can benefit from past projects and focus on the specific innovations of the new challenge upfront.

Best practices

An architecture concept is only the initial step towards high-quality software. To enhance its implementation

ROS middleware

ROS (Robot Operating System) is in essence a 'software glue' between different components. In robotics specifically, such components might contain hardware drivers, motion controllers or high-level coordination algorithms, for instance. The main middleware components of ROS are illustrated in Figure 1.



1

ROS basic units are nodes. As middleware, ROS offers different ways of communication between nodes, via topics, services or actions.

Core functionality in ROS is contained in nodes. Nodes can access low-level hardware interfaces to collect sensor data and to send commands to actuators and devices. Nodes can also communicate with other nodes, via topics, services or actions, depending on the level of interaction required. For instance, topics offer a one-way communication channel such as sending sensor data from one node to another using a publish/subscribe model. Services offer an interface for single request-response operations like turning a light on/off. Actions offer an interface for sustained request-feedback-response operations such as navigation from point A to point B.

process, we make use of software development best practices. It starts by having a Continuous Integration (CI) process in place. CI aims to create an environment in which software is continuously tested against its requirements and the integration with other parts of the software. This promotes confidence and awareness about the 'health' of the software. CI can be applied to different levels of the software, not only to specific modules, but also on a system level.

In addition, we use robot simulators like Gazebo [2] and Webots [3], creating digital twins of every robot application being developed. This includes not only very detailed models of the robot dynamics, but also specifics of the environment in which the robot needs to operate. Therefore, we can frequently run full application simulation tests to discover software bugs, which are then identified and solved. Taking it one step further, we also do extensive real-life testing. Depending on the robot and its operational environment, these tests can be run 24/7, thanks to the use of several safety layers in hardware and software.

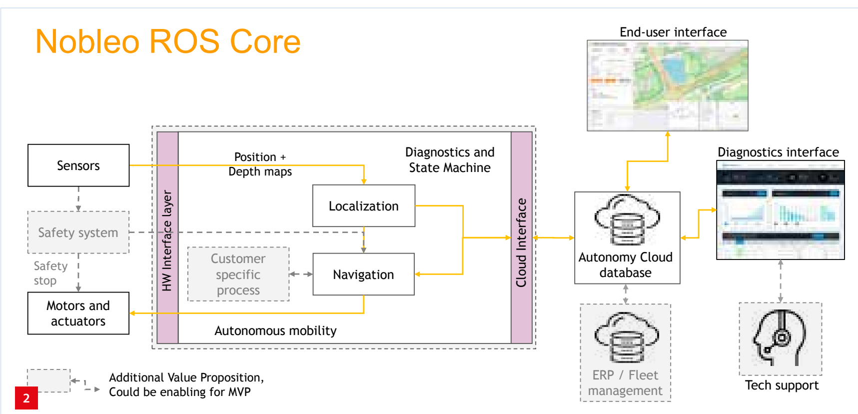
To close the development cycle towards the client, we also offer 'over-the-air' software updates via BalenaOS [4]. Among other key features, Balena enables updates to a fleet of robots at a single 'push of a button'. The updates are conducted in a safe way by resorting to back-ups in case of failure. This guarantees that the robot functions in a robust and reliable way.

Localisation and navigation

As an example, we will elaborate further on our localisation and navigation modules. One of the most challenging tasks of a robot is to localise itself in its environment. A common method used by the open-source community is the so-called Advance Monte Carlo Localization (AMCL). For most industrial robotic applications, AMCL does not offer a suitable solution due to poor accuracy and drift. To tackle these issues, Nobleo uses a sensor-fusion module that processes data from different sensors such as lidars, inertial measurement units (IMUs), RTK-GPS (Real Time Kinematic - Global Positioning System), and dedicated optical sensors like the optical odometer that Nobleo has helped develop for Accerion.

We make use of open-source software components, but experience has shown that in many applications they are not sufficient. This is especially the case with robot navigation. The few available mature motion navigation algorithms in the ROS community were developed for a wide range of applications. As such, they offer a lot of flexibility, however they have proven inadequate in meeting application-specific needs as well as predictability and reliability requirements.

Therefore, we have developed and verified our own robot navigation plug-ins. For instance, we have partnered with the ROS Industrial [5] initiative to develop a full-coverage path planner (FCPP) and a highly customisable path-tracking PID control algorithm, both of which are already available in open source [6].

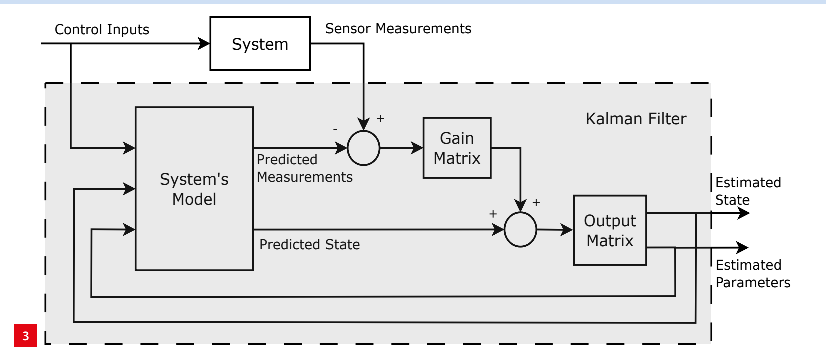


2

For software that functions robustly over several robot platforms, a well-defined architecture is very important. The interfaces between the modules need to be the same for all different robot configurations. This ensures reliable automated software testing and makes it possible to keep all the software releases stable and mature.

Sensor fusion

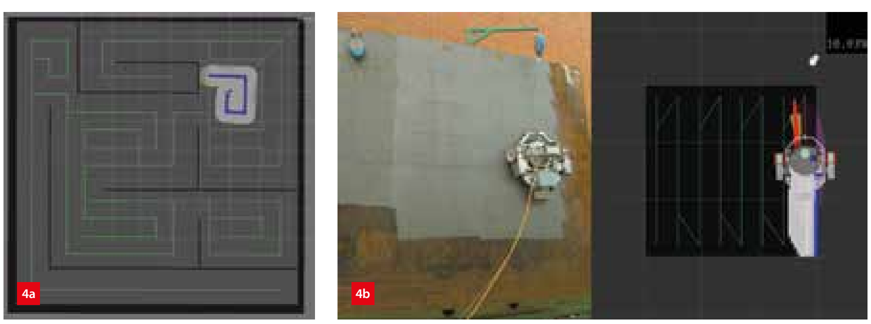
Sensor fusion is a technique that allows several measurements of certain processes to be combined. In robotics, sensor fusion is used typically to obtain an estimate of the robot's motion. Think for instance of a robot whose motion is measured using different sensors, such as IMUs, encoders and GPS. These sensors measure the system, i.e. the robot's motion, by looking at different variables of the dynamics: acceleration, velocity and absolute position, respectively. One of the most widely used concepts for sensor fusion is the Kalman filter method, which is illustrated in Figure 3.



Kalman filter sensor-fusion concept. The goal is to obtain an optimal estimate of the system's state. A model of the system is used to predict measurements and the system's state. These predictions are combined with actual measurements to arrive at the estimated state. Signals are multi-dimensional, allowing several signals to be fused.

One of the key features of the Kalman Filter is that the whole state of the robot's motion can be estimated based on an arbitrary number of measurements. It is also possible to combine measurements at different time instances. For instance, a GPS gives an update every 100 ms, while a velocity encoder every 1 ms. The Kalman filter then allows an estimate of the absolute position to be obtained at a rate of 1 ms as well.

The proposed FCPP is based on the Backtracking Spiral Algorithm [7]. An example of a path generated with the FCPP is shown in Figure 4. As the name suggests, it uses a spatial search in a spiral form to cover the entire available space. The FCPP can be used in applications such as cleaning and surveillance robots.



Examples of paths generated by Nobleo's full-coverage path planner (FCPP). Black pixels represent obstacles.
(a) The algorithm divides the space into cells and explores them in a spiral way. The process is repeated until all obstacle-free cells have been covered.
(b) A dedicated coverage planning for tank cleaning.

To be able to track the generated path, two steps are taken. Firstly, a path interpolator generates a global point (GP) in space that is moving across the path with a prescribed acceleration and maximum velocity. In this way, a high degree of repeatability during different executions is guaranteed. Secondly, our custom tracking PID algorithm controls the robot to accurately follow the moving point in space. We have developed two methods of tracking the path, as illustrated in Figure 5. In the first one, called the 'carrot' method, the robot follows the moving GP at a fixed distance 'l'. This method is suitable for non-smooth paths that do not have orientation information. If higher tracking performance is required, and a smooth path with orientation data is provided, the second method can be used. By computing and tracking a projected global point (PGP), tracking the path with the robot's base link (BL) is indirectly achieved.

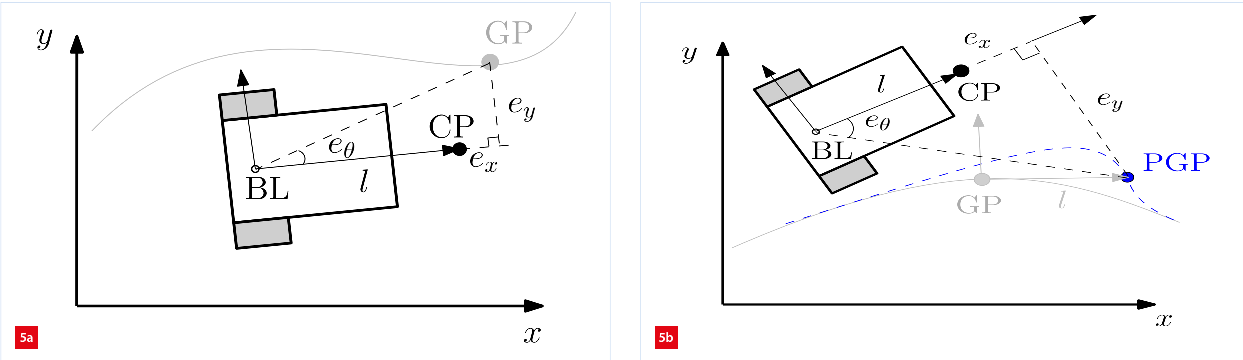
Additionally, we have developed another path tracker that is especially suitable for big and heavy mobile robots like automated tractors and forklift trucks. The main difference with the tracker in Figure 4 is that no interpolator is used. Instead, the forward velocity is generated in an open-loop fashion. As an advantage, this offers full control over the generated forward velocity profiles, for which also arbitrary acceleration limits can be guaranteed without stability issues. In addition, smooth velocity profiles help to keep the amount of power the vehicle's electronics have to handle limited. We also offer a custom model predictive control (MPC) algorithm, which dynamically adjusts the vehicle velocity to guarantee a maximum tracking error, as illustrated in Figure 6.

Proofpoints

The need for navigation and localisation solutions has been proven in several projects. To illustrate where autonomous mobility can help in commercial processes, presented below are examples of the automation of dirty, dangerous and dull work.

Dirty

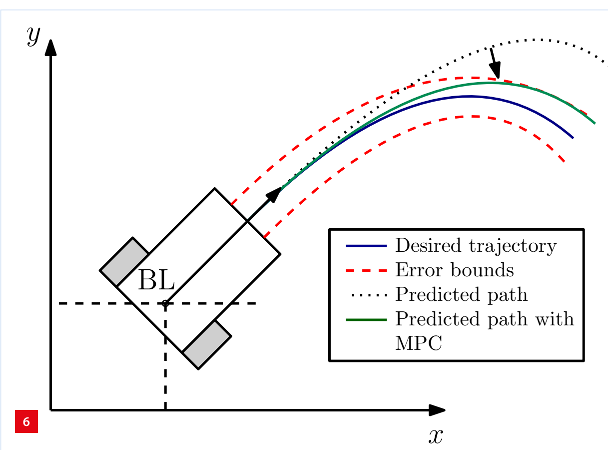
A good example is the WasteShark autonomous waste-collecting boat developed for start-up RanMarine (Figure 7a). As the vessel is underactuated (no sideways thrusters), strong currents or wind can affect it in following straight lines. This robot uses RTK-GPS, lidar and accelerometers to determine its position, direction and speed. The localisation solution is plotted on the known map, then compared to the wind direction and given planning. This ensures that all the rubbish is collected. The lidar is also used to detect unexpected obstacles in the water, which will cause the plan to be paused until the way is clear. As a PID controller is used, standstill at this point is possible; the WasteShark will act as if it were on a virtual anchor, keeping its front at a single point and compensating for winds and currents.



To track a trajectory, first a moving global point (GP) is generated from an interpolator. Then a control point (CP) is projected at a distance 'l' in front of the robot.
(a) When the path does not contain orientation, the carrot mode is used, where the control objective is then to minimise the error between the CP and the GP.
(b) If the path contains orientation data, there is the option to compute a projected global point (PGP). The control objective is then to minimise the error between the CP and the PGP, which results in tracking the path with the base link (BL) of the robot.

Dull
The localisation solution is flexible enough that it can also accommodate sensor solutions for indoor localisation, as is required for warehousing solutions. The warehouse AGV demonstrator can bin-pick items and deliver them to the packing belt (Figure 7b). In contrast to other fields of navigation, flexibility is not the dominant feature in industrial applications – robustness and predictability are. Sticking to a generated path is therefore part of the AGV navigation solution.

Dangerous
The tank-cleaning robot developed for the oil & gas and chemical industry cleans industrial tanks with 3,000 bar water pressure by driving in horizontal lanes over a vertical wall, using magnets in between the wheels (Figure 7c). The soiled wall and the gravity pull can result in a significant lateral slip, so here also the PID controller used in the navigation solution can take these disturbances into account and follow the line prescribed by the full-coverage planner.



Path follower using model predictive control (MPC). Predicted paths are continuously estimated to check whether a maximum allowable error is violated. In such a case, the robot's velocity is adjusted to guarantee the specified maximum error requirement is respected.

Technology and humans working together

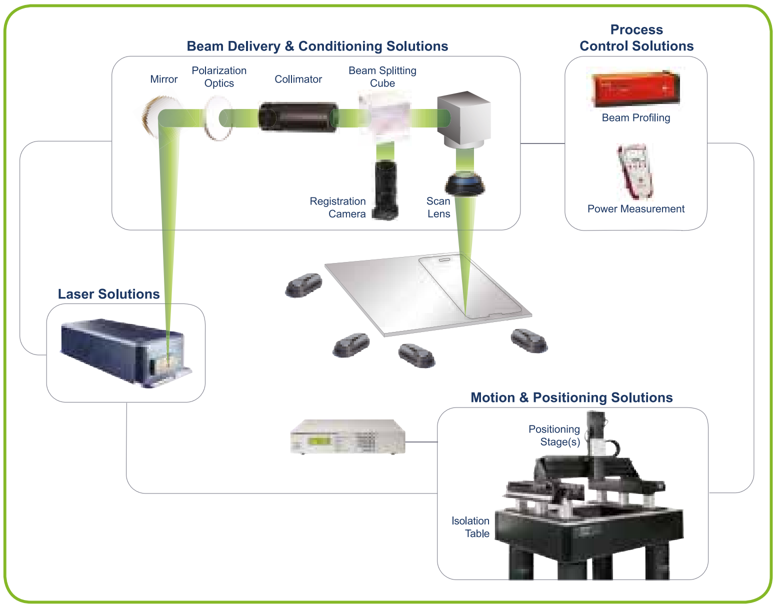
Nobleo believes that combining the creativity of an open-source community (ROS) with rigorous industrial qualification has helped pave the way to an autonomous future where humans are relieved from dirty, dull and dangerous activities. This is not a threat to jobs, but an opportunity for technology and humans to work together, to be more efficient and, most importantly, to stay safe.

REFERENCES
[1] *www.ros.org*
[2] *www.gazebosim.org*
[3] *www.cyberbotics.com*
[4] *www.balena.io/os*
[5] *www.rosindustrial.org*
[6] *www.github.com/nobleo*
[7] Gonzalez, E., et al., "BSA: A complete coverage algorithm", *Proc. 2005 IEEE Int'l Conf. Robotics and Automation*, pp. 2040-2044, 2005.

Examples of Nobleo's autonomous mobility projects.
(a) WasteShark autonomous waste collection boat: using wind-direction information and GPS for collecting floating rubbish from waterways.
(b) Warehouse item-picking robot: autonomously driving to the correct location and picking the required product from the shelf.
(c) Tank-cleaning robot: using 3,000 bar water pressure to clean the inside of oil tanks or strip the paint from the outside of the tank.

We Have You Covered

Surround the Workpiece[SM] with Our Full Portfolio of Solutions



Surround the Workpiece[SM] is an MKS offering that serves the needs of Advanced Markets that require laser-based solutions. We provide customers with the key components, systems, and services to enable the successful implementation of these solutions, including:

- Full Portfolio of Laser, Photonics, and Optics Solutions
- Application Labs and Support
- Integrated Business Solutions
- Engineering and Development
- Calibration and Repair

For more information visit **www.mksinst.com**
or call **+49 6151 708-0**.

mks | ESI® | Newport™ | Ophir® | Spectra-Physics®

COLLABORATIVE RESEARCH ON COLLABORATIVE ROBOTS

Within Industry 4.0 robots have been transforming from big industrial machinery (e.g. to produce cars) into cobots that can operate safely within the proximity of humans and perform multiple tasks with minimal leadtime. For the past six years, the Mechatronics and Robotics research group of Fontys University of Applied Sciences has been focusing on the subject of cobots and many research projects have been executed in this field. This article highlights the scope of two of these projects, dealing with a warehouse application and human-robot interaction, respectively.

MICHIEL VAN OSCH AND MARIJKE DE GEUS

Introduction

Until recently, automation and robotisation within the manufacturing industry were only achieved in high-volume production lines with little variation. Only large companies had the budget for this type of automation, for instance within the automobile industry. Within SME companies the volume of products is typically much lower while the variation of products is larger. These companies could not afford a robot costing 50,000 euros for a task that is only performed for a few hours per month.

In the past decade there has been a boom in modernisation and automation for manufacturers. This has been made possible by the push ensuing from the Industry 4.0 initiative and a number of technological breakthroughs, such as the availability of low-cost robot arms and autonomous mobile robots (AMRs); advances in usability and programmability of these robots, building on software systems like ROS (Robot Operating System) [1] [2]; and advances in path-planning technologies and sensing.

Within this period, the Fontys Mechatronics and Robotics research group has been focusing its research on these new technologies. Many projects have been executed in the fields of flexible manufacturing, mobile robotics and safety. In this way, Fontys has been able to develop and transfer new technologies to industry and prepare students for technologies that will be common in the future. For the past four years, Fontys has been a participant in the Fieldlab Flexible Manufacturing [3], which is located at the Brainport Industries Campus (BIC) [4]. Fontys has recently opened a location for education at the BIC so that students can be in close contact with new technologies and the needs of industry.

This article highlights two projects of the Fontys Mechatronics and Robotics research group [5]. The first project is part of our effort to develop new innovative systems for automation within the manufacturing industry. This research is part of larger subsidised research projects, including the Fieldlab Flexible Manufacturing and the SIA RAAK-mkb project "Let's Move IT" (SIA is the Dutch Taskforce for Applied Research, *Nationaal Regieorgaan Praktijkgericht Onderzoek*). The project described in this article concerns the development of a Smart Storage system that can automatically deliver warehouse containers to an AMR. The AMR can transport these containers to a robot cell or a human worker.

The second project concerns our ongoing research on intuitive collaboration between robot arms or AMRs and human workers as conducted within the SIA RAAK-mkb project "Close Encounters with Robots". If a robot arm moves and behaves intuitively from a human perspective, it will most likely be perceived as a more reliable and acceptable co-worker to humans and can therefore be more effective in performing its task.

Smart Storage system

The rise of AMRs was accompanied by applications for them. One of these applications is picking items from a warehouse and delivering them for packaging or assembly. To get items onto the AMR there are two options. Either the AMR is equipped with a collecting system to pick items from a shelf or the shelf is robotised and can place items on the AMR. Within Fontys a so-called Smart Storage system has been developed that can place boxes (e.g. containing screws) on the AMR.

AUTHORS' NOTE

Michiel van Osch is head of Mechatronics and Robotics Research and Marijke de Geus is a researcher/teacher, both at Fontys Engineering University of Applied Sciences in Eindhoven (NL).

michiel.vanosch@fontys.nl
www.fontys.nl/robotica


1

The Smart Storage system.

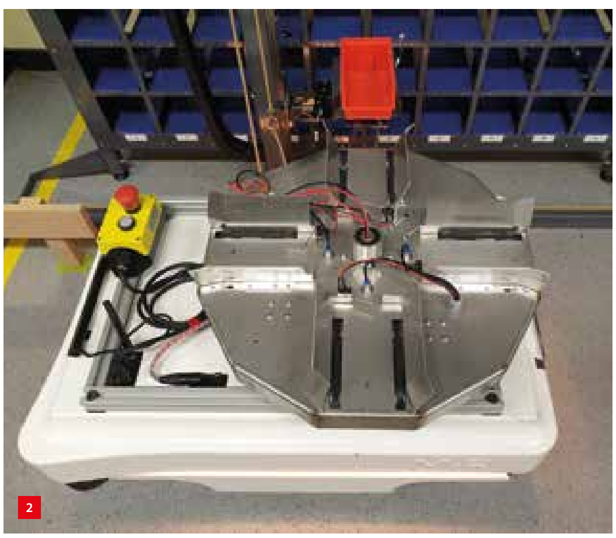
Similar applications already exist, such as the medicine-dispensing robot at pharmacies. This robot takes the medicines from a closed-off cabinet and delivers them to the location where the pharmacist can pick them up. However, such a system did not exist for picking boxes filled with components in manufacturing lines. During assembly, workers may have to walk hundreds of meters to pick up parts and as there is no tracking of which parts are available in the storage, this can lead to unwanted delays in production. Hence, there is a need for automation of these storage cabinets.

The first generation of the Smart Storage system (Figure 1) contains a grid of 10x10 storage locations for standard warehouse containers. A robot arm that can move linearly up and down, as well as to the left and right, is able to pick a storage container from any location by grabbing the handle of the container. Three storage locations of the Smart Storage system are equipped with pressure sensors so that the containers can be weighed. If a container is too light, meaning that it is almost empty, a signal for a refill can be given.

The Smart Storage system can feed containers to an AMR. A custom turntable (Figure 2) has been developed by students of Fontys for the MIR robot [6] so that it can receive a maximum of four containers from the Smart Storage system. The robot arm of the Smart Storage system is not protected and therefore that side of the system is not safe for humans. However containers can be resupplied from the rear of the system. Taking out containers manually is prohibited to secure the tracking of which containers are in storage. A human operator is allowed to take out a container by selecting the required item through the system after which the robot arm offers the container to the human.

The content of a container is scanned using a barcode scanner. The low-level control (sensing and motors) is implemented via a Nucleo-144 microcontroller. A Raspberry Pi is used to keep track of the content of the storage system via a MySQL database, to implement the user interface and to communicate with other devices like the MIR AMR.

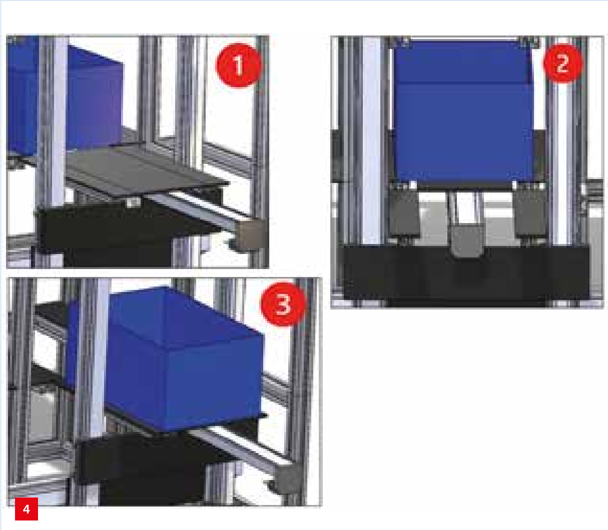
A new version of this Smart Storage system was required for several reasons. The downside of the previous system was that the arm could only pick up one container type from one specific supplier. However, there are many suppliers of these warehouse containers and the handles of the containers slightly vary in size. The first system was not fully developed and hard to operate. The communication with the MIR robot was specifically developed as a proof of concept and was not usable for other devices. Within the Fieldlab Flexible Manufacturing a demand emerged for the building of a cabinet that could accommodate larger boxes and was capable of communicating with other devices.


2

Delivering a storage container to an AMR with a custom turntable comprising four container positions.


3

The new Smart Storage system.



Sliding mechanism of the new Smart Storage system, for picking boxes in three steps.

In addition, the robot arm of the previous system suffered from slippage and required recalibration after a certain period.

In the spring of 2020, a new Smart Storage system (Figure 3) has been designed that can hold twelve larger containers. This storage system uses a linear sliding mechanism to pick boxes in three steps (Figure 4). The robot moves in lateral and vertical direction and can position itself in front of a box (1). The robot slides its arm below the box, like a pizza spade that can be used to pick up pizzas from an oven (2). The robot pulls the box to take it out of storage (3). The new storage system is controlled by a Siemens Simantic PLC and equipped with NEMA24 stepper motors. The new version of the Smart Storage system is also capable of weighing boxes. It is currently located at the Brainport Industries Campus within the Fieldlab Flexible Manufacturing.

Showing intention in robot movement

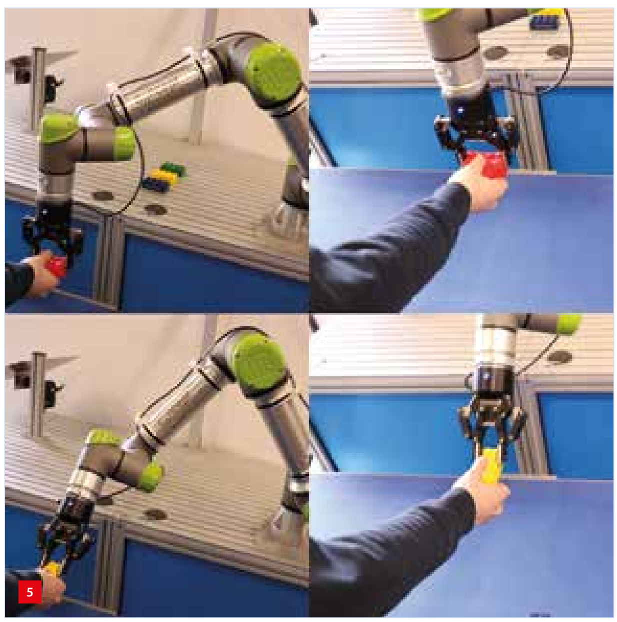
As robots enter applications where they operate around and with humans, it is important to consider the way in which the robot's physical actions are interpreted by people around them. For human-robot collaborations to work successfully, robots can no longer be considered merely as functional tools. This shift requires a design strategy where robots are seen as self-reasoning artificial agents. In this way, more efficient robot deployment is achieved.

So far, human-robot interaction has been studied mainly in the field of social robotics, which focuses on advanced interactions that future social robots might engage in. For industrial robots, there is a lack of practical knowledge on how to make them suitable for human environments and have them engage in minor collaborations such as joint collision avoidance.

Literature shows that the predictability of the cobot's behaviour influences the perceived comfort and productivity of an employee who is working with an industrial cobot. Less predictable behaviour leads to discomfort [7] [8], decreased trust [9] and lower productivity [10]. This in turn leads to an ineffective and unpleasant collaboration. Like its predictability, the 'legibility' of a cobot, i.e. the degree to which a robot is intuitively understandable, is a defining factor for human-robot collaborations.

Within the SIA RAAK-mkb "Close Encounters with Cobots", two use cases are addressed in order to derive practical guidelines for human-robot interaction and collaboration in current industry settings, namely: 1) cobot manipulators, and 2) AMRs. Thus far, multiple prototypes have been built to study the feasibility, ease of implementation and effectiveness of the robot to sense and to communicate.

For the use case with cobot manipulators, behaviour decision trees are used to enable the cobot to adapt its behaviour easily when the current situation no longer corresponds to the expected situation. This approach allows for minimisation of sudden unexpected stops of the robot, which decreases unexpected behaviour from a human perspective. Cobot movement, specifically in hand-over scenarios, is studied to deduce accessible movement guidelines that enable a smoother workflow. As an example, the dynamic orientation of a cobot arm and the object it is handing over have a significant effect on the experienced



The effect of dynamic orientation of a cobot arm and the object it is handing over.
Top: a standard position for a robot to grab objects, resulting in an unnatural handover.
Bottom: a simple adaptation of the pose allows for a significantly more positive user experience.

predictability of the robot and its fluency of motion (Figure 5). Furthermore, the movement of specifically the gripper can indicate the timing of the handover for the operator.

For the second use case, with AMRs, several topics are studied, including the physical appearance of the AMR, ways for it to show its direction, means to separate detected people from other detected objects, as well as the possibility to steer people's behaviour to give or take priority when encountering an AMR to minimise congestions. The initial results confirm that it is possible to minimise congestions through the choice of trajectory and speed alone. It is also found that this behaviour can lead to a lower perceived safety of the robot when it is unclear whether the robot has seen the person or not.

The SIA RAAK-mkb project "Close Encounters with Cobots" is still ongoing until the beginning of 2021. The remainder of this project is dedicated to further quantification of the results and the comparison of different solutions to produce both accessible and practical guidelines for the implementation of cobots and AMRs amongst people in order to optimise workflow, efficiency and safety. Demonstrators of both use cases will be built to illustrate these guidelines and their benefits.

Conclusion

In this article two research projects on robotics in Industry 4.0 have been discussed. The first research project concerned the development of a robotised storage system that is able to deliver warehouse containers to an AMR, after which the AMR can automatically take the goods to a robot cell or other workstation. The second research project concerned a robot showing intent to a human so that they can more effectively work together. This increases productivity when humans and robot share the same work floor.

These two projects demonstrate the wide variety of applied research that is ongoing at the Fontys Mechatronics and Robotics research group within the field of Industry 4.0 and beyond. In the past we have also been involved in research on bin-picking applications, different types of grippers, tool changers and inter-robot communication, and we are currently involved in research projects involving digitisation, digital twinning, perception of safety by human operators and further research into internal manufacturing logistics through AMRs. Outside of Industry 4.0, we are also working on cleaning robots and robots that can help in coronavirus-related use cases, such as serving bar customers on a terrace and disinfecting rooms using UV-C light.

REFERENCES

[1] Robot Operating System (ROS), *www.ros.org*
[2] M. Quigley, B.P. Gerkey, K. Conley and J. Faust, "ROS: an open-source Robot Operating System", *Proceedings ICRA Workshop on Open Source Software*, 2009.
[3] Fieldlab Flexible Manufacturing, *www.flexiblemanufacturing.nl*
[4] Brainport Industries Campus, *www.brainportindustriescampus.com/en*
[5] Fontys Mechatronics and Robotics Research, *www.fontys.nl/robotica*
[6] MIR 100, *www.mobile-industrial-robots.com/en/solutions/robots/mir100*
[7] J.T. Butler and A. Agah, "Psychological Effects of Behavior Patterns of a Mobile Personal Robot", *Autonomous Robots*, 10, pp. 185-202, 2001.
[8] D. Bortot, H. Ding, A. Antonopolous and K. Bengler, "Human Motion Behavior While Interacting With an Industrial Robot", *Work*, 41 (Suppl. 1), pp. 1699-1707, 2012.
[9] K. Eder, C. Harper and U. Leonards, "Towards the Safety of Human-in-the-Loop Robotics", *IEEE International Symposium on Robot and Human Interactive Communication*, pp. 660-665, 2014.
[10] M. Koppenburg, P. Nickel, B. Naber, A. Lungfiel and M. Huelke, "Effects of Movement Speed and Predictability in Human–Robot Collaboration", *Human Factors and Ergonomics in Manufacturing & Service Industries*, 27 (4), pp. 197-209, 2017.

mikrocentrum

opleiden • ontmoeten • ondernemen

COURSE Geometric Dimensioning and Tolerancing

Product Manufacturing Information (PMI)

In ISO 16792 language this means the annotations and attributes contained in a 3D solid model that compliment the geometric definition and complete the digital data set. The process and accomplishment of applying PMI to a 3D solid CAD model is Model Based Definition (MBD).

In the course Geometric Dimensioning and Tolerancing (GD&T) you will learn the most important methods of dimensioning and geometric tolerancing according to the latest ISO standards. Are you able to define or interpret correctly the tolerance requirements of a workpiece regarding function, manufacturability, measurability and costs?

Location, date & price:

Location	Start date	Sessions	Language
Veldhoven	26-11-2020	3	English
Veldhoven	27-11-2020	3	Dutch
Veenendaal	04-11-2020	3	Dutch
Veldhoven	25-01-2021	3	English

For more information and registration for this course, visit www.mikocentrum.nl

Mikrocentrum uses all-inclusive rates. All mentioned rates are exclusive of VAT and include course materials and package costs. Members of the Mikrocentrum High Tech Platform enjoy a 10% discount.

GD&T steps towards 3D PMI MBD

- Learn basic or advanced GD&T according the latest standards
- Learn how drawing based practices evolve into model-based product definition
- Learn to create 3D data for effective downstream consumption

For more information, please contact:

Mart Mijnsbergen, m.mijnsbergen@mikrocentrum.nl or by phone at +31 (0) 40 296 99 33

Mikrocentrum, De Run 1115, 5503 LB Veldhoven, The Netherlands

HAND IN HAND

Festo's BionicSoftHand simulates the human hand. Using artificial intelligence (AI), it gradually learns to grip and move objects. Together with the BionicSoftArm it is opening new applications for the collaborative working spaces of the future. In order to carry out the movements realistically, compact valve technology, sensor technology, electronics and mechanical components are integrated in the tightest of spaces.

In 2006, Festo set up the Bionic Learning Network, comprising universities, institutes, development companies and private inventors. The goal was, and still is, to learn from natural phenomena that can be relevant for everyday tasks in automation technology, such as gripping, moving and positioning goods as well as controlling processes – nature performs all of these tasks instinctively, easily and efficiently. Gripping has always played an important role in the Bionic Learning Network. Numerous bionic gripping applications have already been developed in the interdisciplinary research work of the network.

It took around 400 million years for the fin to evolve into the hand. Today, we use our hands as a matter of course for the most diverse tasks and move our fingers without even thinking. A virtuoso pianist can hit the keys 24 times per second. Talent, practice, and above all the ingenious design of the fingers and their dexterity are what make such feats possible.

The thumb plays an important role in gripping because of its opposable position, in the human hand as well as in the bionic pneumatic robot hand. The BionicSoftHand was designed for use in collaborative working spaces, for example in combination with the modular pneumatic lightweight robot BionicSoftArm or the BionicCobot, both of which are Bionic Learning Network 'products' as well. Unlike conventional robot grippers, the BionicSoftHand is not pre-programmed for a specific application. It is able to learn.

EDITORIAL NOTE

This article was contributed by Festo's Bionic Learning Network. Festo is a leading worldwide supplier of automation technology and provider of industrial training and education programmes.

www.festo.com/bionic

Within the framework of the Bionic Learning Network, the BionicSoftHand was designed for use in collaborative working spaces.

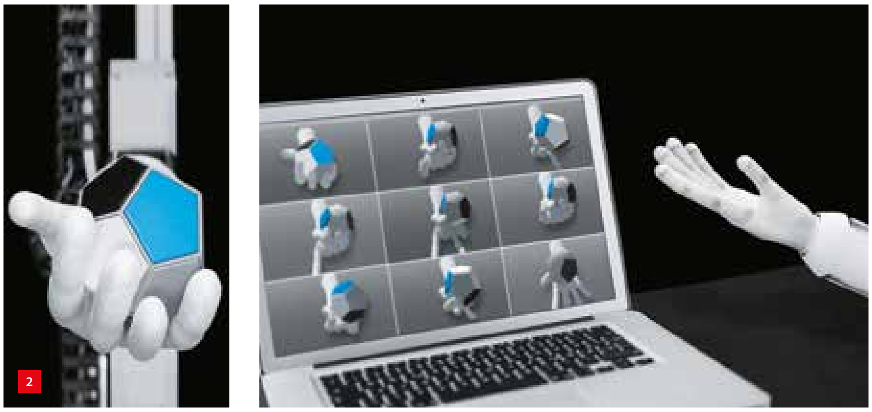
Virtual training

A baby learns at a very early age how to grasp and move an object correctly through a process of trial & error. With a thumb and index finger that can move laterally thanks to a swivel module, the BionicSoftHand – having a total of twelve degrees of freedom – can accomplish the same feat in a fraction of the time using AI. The BionicSoftHand learns to grip and turn objects using the reinforcement learning method and massively parallel learning. Instead of having to imitate a concrete action, the hand is given a goal, which it tries to achieve through trial & error. Based on the feedback received, the hand gradually optimises its actions until it can finally solve the task successfully.

Using positive and negative feedback, the AI can classify its actions and learn from them. Massively parallel learning ensures that this happens quickly. Digital simulation models – also known as digital twins – accelerate the training process significantly. The acquired knowledge is shared with all virtual hands, which then continue to work with this new knowledge. Each mistake is therefore only made once, and successful actions are immediately available to all online models. After the controller has undergone virtual training, all knowledge is transferred to the real BionicSoftHand

Flexible bellows and textile cover

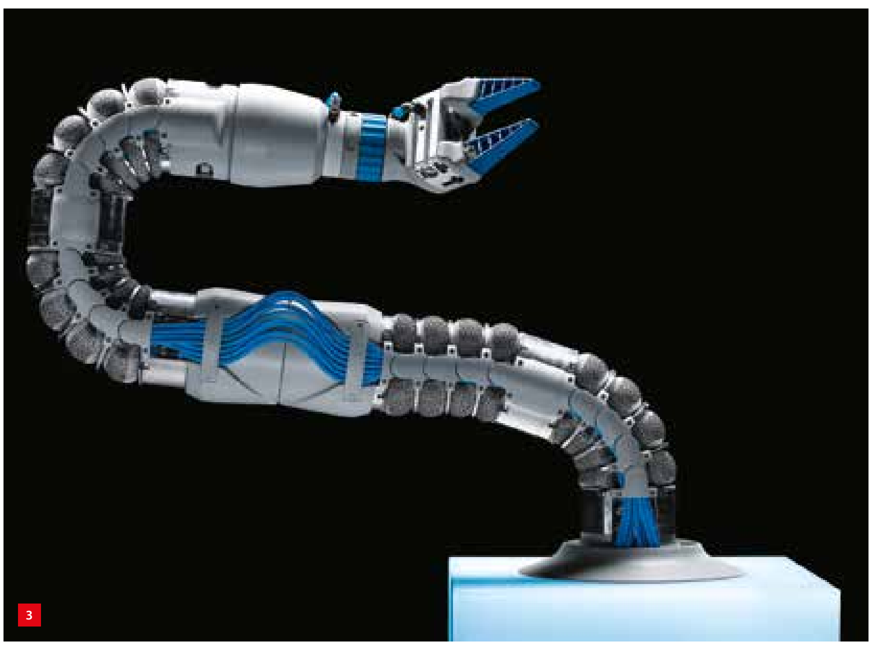
The BionicSoftHand controls its movements via the pneumatic structures in its fingers; see the video [V1]. They consist of flexible rubber bellows (instead of bones) with air chambers and soft materials. This makes the hand light, flexible and sensitive, yet capable of exerting strong forces. The developers overcame the challenge of keeping tubing to a minimum with a compact, digitally controlled valve terminal on the wrist. This means that the tubes for controlling the fingers do not have to be pulled through the entire robot arm. The BionicSoftHand can be quickly connected and operated with only one tube each for supply air and exhaust air. The compact valve terminal comprises 24 proportional piezo valves for precisely pressurising and exhausting the gripper fingers and controlling the swivel modules, which provide additional degrees of freedom for lateral movement.



With the aid of digital twins, which train in parallel in a virtual world, the BionicSoftHand hand can learn, for example to turn an object (in this case a dodecahedron) so that a previously defined side is facing upwards at the end.

The gripper fingers of the BionicSoftHand are moved over a bellows made of robust elastomer. The two chambers are pressurised with compressed air, which makes them particularly flexible. When both air chambers are completely empty, the gripper fingers remain stretched. When they are filled with air, the gripper fingers bend. This is enabled by the interaction between the elastic outside of the gripper fingers and a strap on the inside of the gripper fingers, which limits their extension.

The elastomer bellows are covered in a 3D textile material made from elastic and high-strength fibres. This design determines at which points the structure can move. Flexible printed circuit boards with a meander structure are applied to the knitted fabric on which the inertial and tactile force sensors are located. The wafer-thin printed circuit boards are flexible and do not impair the movements of the gripper fingers.



The largest possible version of the BionicSoftArm, with seven pneumatic actuators and just as many degrees of freedom.

Flowing arm movement

Combined with pneumatic lightweight robots such as the BionicSoftArm, the BionicSoftHand makes direct and safe collaboration between people and robots possible; see the video [V2]. The BionicSoftArm is a compact further development of the BionicMotionRobot. Thanks to its modular design based on several pneumatic bellows segments and rotary drives, it can move freely and flexibly. Depending on the requirements, the length of the BionicSoftArm can be varied with up to seven actuators. This makes it very easy to implement applications that are difficult to realise with a standard robot. And thanks to its flexibility, the BionicSoftArm can also be used in very tight spaces.

Like its two predecessors, the Bionic Handling Assistant and the BionicMotionRobot, the BionicSoftArm is inspired by the movements and functionality of the elephant's trunk. With its pneumatic bellows structures, the BionicSoftArm effortlessly masters the flowing motion sequences of its natural role model. Depending on the desired action, the bellows can bend and extend as required. To achieve this, they are covered with a special 3D woven fabric that allows the bellows structure to expand in the required direction of movement. The modular robot arm can be used for a wide variety of applications, depending on the design and mounted gripper, such as the BionicSoftHand. Thanks to its flexible kinematics, the BionicSoftArm can interact directly and safely with people.

VIDEO

[V1] BionicSoftHand, *www.festo.com/group/en/cms/13508.htm*

[V2] BionicSoftArm, *www.festo.com/group/en/cms/13527.htm*

A SIMULATOR FOR DEPTH ESTIMATION

A stereo-vision system that was developed for application in mobile robots turned out to lack depth resolution in the background of the pictures. A simulator was built to gain understanding of the parameters that influence depth estimation in stereo vision. In this article we will explain how these properties influence depth resolution and provide a link to the webtool that was made to interactively observe and evaluate the resulting depth resolution when the parameters are varied. This tool makes it possible to find the correct hardware that provides the resolution required, or to determine the resolution for specific hardware.

VICTOR SLUITER

Introduction

Stereo vision is widely used in robotics, in applications where robots need to orient themselves in 3D to pick & place items, but also in applications where mobile robots need to recognise and avoid obstacles. When stereo vision is needed in an application, the system designer can either buy an existing solution, such as the widely used Intel® RealSense™ cameras, or leverage open-source solutions to build a stereo-vision system that meets their needs.

FireBot

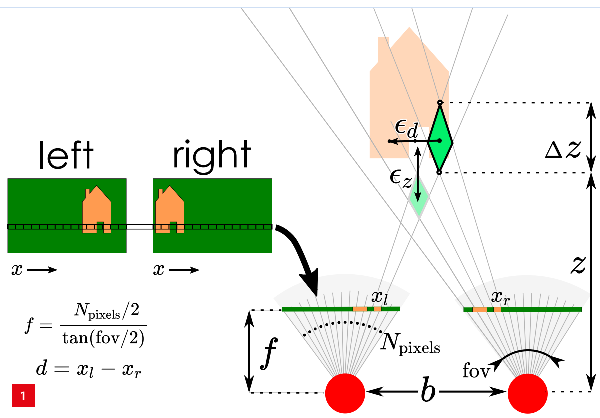
The application that piqued our interest in stereo vision is the *RAAK Publiek* FireBot project, funded by SIA, the Dutch Taskforce for Applied Research (*Nationaal Regieorgaan Praktijkgericht Onderzoek*). In this project, the Mechatronics research group at Saxion University of Applied Sciences (project coordinator) collaborates with the University of Twente, three companies and four Dutch fire brigades to improve the abilities of their unmanned reconnaissance robots. One of the research topics is to create a 3D map while driving in an environment that is filled with warm, dense smoke. Regular RGB vision (3D) systems are not suitable due to high scattering of the light by the smoke and water particles. Therefore, research was carried out using thermal cameras, detecting long-wavelength infrared.

While designing the system, we needed to select a thermal camera and choose the right resolution value and lens. One of the requirements was the depth resolution, so we had to determine what depth resolution could be achieved at a particular distance from the cameras and which parameters influence the resolution and the depth quantisation effects. The depth resolution is the smallest possible difference in depth that can be measured at a certain depth, and determines what level of detail can be observed. The quantisation is a result of having discrete pixels, and results in objects close to each other being assigned the same depth value.

Although the application with thermal cameras might be specific to our application, the methods and analysis described below are generic for all kinds of stereo-imaging systems including visible light.

Making depth estimations

Before any calculations are made on stereo resolution, the most common depth estimation algorithms make a few assumptions: the images do not have lens deformation and the cameras are perfectly coplanar. In most real-life situations a calibration is needed to correct for lens deformation and non-ideal camera placement. This is achieved by image undistortion and rectification based on a set of pictures made

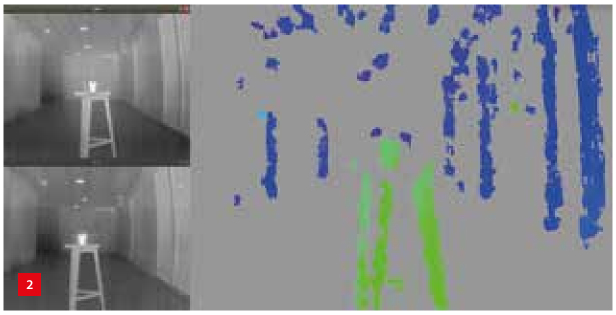


Schematic representation of depth estimation. The house is pictured by both cameras; a feature that is seen in both images leads to a depth by triangulation of the pixel coordinates (x_l and x_r) and the baseline distance b. The green diamond shows the area that is formed by the intersection of the two pixels.

AUTHOR'S NOTE

Victor Sluiter is a research engineer in the Mechatronics research group of Saxion University of Applied Sciences, located in Enschede (NL).

v.i.sluiter@saxion.nl
www.saxion.nl/onderzoek/smart-industry/mechatronica



A disparity map (right image) is generated from two thermal images (left) for a stool with a hot cup of coffee on top of it. Depth is rainbow-colour-coded from red (close) to purple (far away). Only green to purple are visible in this picture. Note how it is possible to observe that the middle leg is darker green and hence pointing backwards, something which cannot be deduced from either of the two thermal images.

of a known calibration object. More information can be found on Wikipedia [1] and the OpenCV (Open Source Computer Vision Library) website [2].

Figure 1 explains how depth is estimated. The two cameras (red circles) both see the house. A 'block matching' algorithm searches each pixel row for corresponding features in the left and right images. In this case the wall to the right of the door was found in both pictures. Since the baseline b and the focal length f (expressed in number of pixels; the relation with the field of view, fov, is shown in Figure 1) are fixed parameters in the set-up, the depth can be calculated: $z = f / (b \cdot d)$. Here, d is the number of pixels the feature has shifted between both images, also known as the disparity. Now the depth z is derived by triangulation.

In Figure 2 it can be seen how the visualisation algorithm from OpenCV shows the disparity as a colour map.
A large disparity (features far away from each other when comparing the left and right image) means the object is relatively close to the camera, and when a feature is further away, it will be in almost the same location in both images. The resulting disparity image is rainbow-colour-coded and shows the nearest objects in this image as green/blue and objects in the background as purple. In the grey area no corresponding features could be found and no disparity could be calculated.

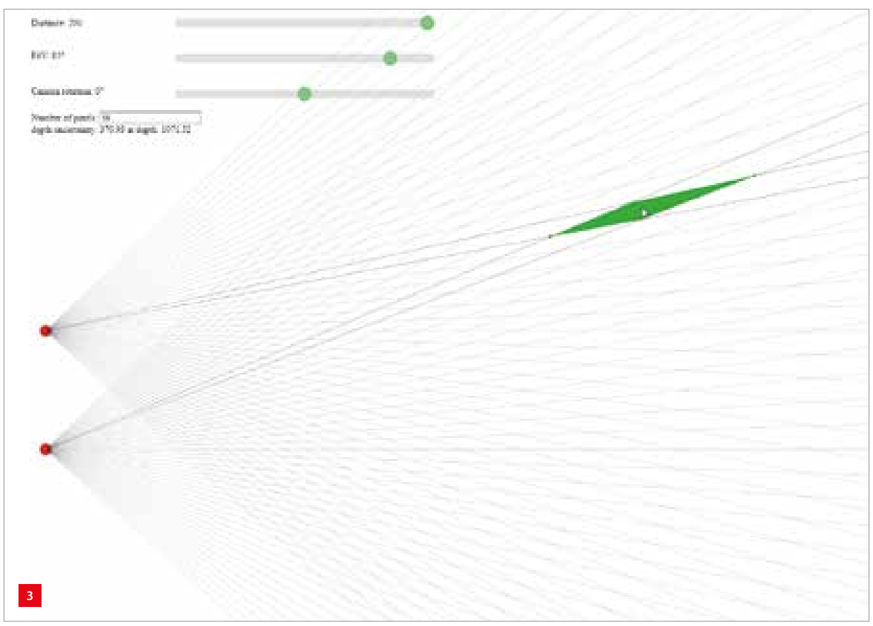
Note: Due to occlusion of part of the hind leg by one of the front legs, the disparity image can show only (the other) part of the hind leg. However, the region where the two legs 'overlap' is partly grey, which unjustifiedly suggests that the legs are separated (no occlusion). This is because here the disparity can not be determined due to the occlusion: one camera 'sees' the hind leg, but the other camera (the left one, in this case) does not.

One of the observations we made was that the depth resolution degrades progressively with increasing distance. From literature [3] we already know that there is a quadratic increase in depth error ϵ_z for a given distance z, caused by a disparity error ϵ_d:

$$\epsilon_z = (z^2 / f \cdot b)\, \epsilon_d$$

The disparity error ϵ_d (error in number of pixels) is caused by the block matching algorithm finding the wrong pixel as a feature match in the row (i.e. the wrong x_l or x_r, in this case because of erroneously selecting the wall to the left of the door as the relevant feature in one of the two images). This effect is illustrated in Figure 1, where a wrong match is shown with a dim green diamond. Although this explains depth error due to matching error, the artefacts we noticed in our disparity images were a very clear quantisation effect; objects close to the camera could be imaged with great detail in depth, but further from the camera all objects that had clear features would all get assigned the same depth. We saw the same depth, i.e. a 'binning' of depth values.

To better understand the theory behind stereo vision we developed a simulator. This simulator shows graphically what the implications of design choices are, for example what the nearest point is where the two images have overlap (from this point on, disparity and hence depth can be determined). What also appeared clearly when using the tool is that the depth quantisation (binning) error becomes larger for objects further away; the quantisation effect is also quadratic. From Figure 1 it can be deduced that the match of two features results in the green diamond-shaped area where the feature originated from. With fewer pixels, a smaller baseline or larger field of view, the diamonds become larger and the real object generating the image



Screenshot of the simulator. The intersection of camera pixels under the mouse cursor is highlighted and depth z and size of the bin Δz are given. Note the change in area of the intersections of pixels.

feature can be anywhere within that diamond. The size of the depth bin Δz can be approximated by:

$$\Delta z = 2\,(z^2 / f{\cdot}b)$$

Online tool

The simulation tool [4] is publicly accessible and can be used to perform some quick calculations and especially to obtain an intuitive understanding of how camera set-up parameters affect performance. This gives a better understanding of how vision set-up parameters influence the depth estimation in stereo-vision applications.

Parameters that can be entered are the baseline distance, number of pixels per row, horizontal field of view and camera rotation. The visualisation updates 'live' while changing parameters, showing the 'binning' of the possible depth values, but also the overlap of camera view. When moving the cursor across the screen, the depth value z and the size of the depth 'bin' Δz are shown for the area the mouse is hovering over. In this way, trade-offs can be made, for example between longer focal length for better resolution and shorter focal length for imaging closer by. Although we consider this a valuable tool, some disclaimers have to be made. First of all, the calibration discussed above will introduce artefacts in the image, so the angular field of view per pixel in the rectified and 'undistorted' image will probably be slightly different from the angular field of view per pixel of the 'raw' image. Secondly, we show the distance z and the size of the depth 'bin' Δz. It is disputable whether the depth should be represented as a depth in the centre of the diamond with a possible positive and negative deviation, because the larger the depth, the more distorted the diamond gets and hence the less meaning the 'centre' has). For clarity of presentation we decided to use the representation shown in Figure 3.

REFERENCES
[1] *en.wikipedia.org/wiki/Image_rectification*
[2] *docs.opencv.org/4.4.0/d9/db7/tutorial_py_table_of_contents_calib3d.html*
[3] D. Gallup et al., "Variable baseline/resolution stereo", *IEEE Conference on Computer Vision and Pattern Recognition*, 2008, *ieeexplore.ieee.org/document/4587671*
[4] *tiny.cc/disparity*

ALIGNMENT IN ACTION

To support the growing transition from electronic to photonic integrated circuits (PICs), TEGEMA has developed a modular platform for the micro-assembly processes of integrated photonics. This modular approach enables a faster time-to-market for automatic and precise alignment systems, while increasing throughput tenfold with respect to currently available solutions. A first photonic demonstrator machine has been proven to perform fast, high-accuracy active alignment of components. The modular approach allows for a machine that is customised to a client's current demands, while leaving plenty of room for the customisation of different components and upgrades, and to integrate the machine into an assembly line.

VICTOR HOEKSEMA, ARNO THOER AND GUUS HOLLANDER

Industrial growth of photonic integration

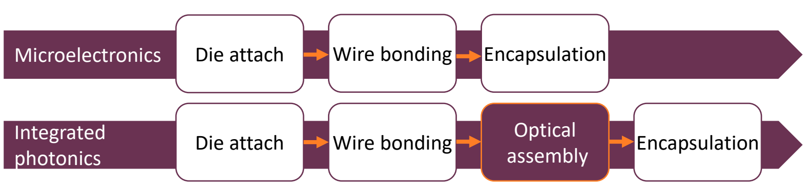
Photonics is the physical science of light (photon) generation, detection and manipulation through emission, transmission, modulation, signal processing, switching, amplification and sensing [1] [2]. Applications of photonics can be used to satisfy the exponentially growing demand for data transport across the globe. Optical fibre cables are being implemented to communicate data more quickly over longer distances, while requiring significantly less electrical power. However, the use of fibre optics for long-distance communication alone will not be enough to meet the increasing demand for additional, energy-saving and faster data communication.

The next step requires replacing electronics with photonics in data centres and other computing hotspots. Currently, incoming optical signals are converted to electrical signals used for processing and converted back to outgoing optical signals. These conversion steps introduce latency, which can be solved by integrating additional photonics. Unfortunately, the adoption of photonic integrated circuits (PICs) is hampered by the high investment costs necessary for the additional step that is required in integrated photonics assembly (Figure 1). These costs need to be comparable to the actual technology standard of the electronic counterparts. Another issue is the scarcity of essential infrastructure for producing these applications. These are the core challenges in the assembly and packaging of PICs, in particular the precise sub-micron alignment of components.

AUTHORS' NOTE

Victor Hoeksema (mechanical engineer), Arno Thoer (director project solutions) and Guus Hollander (lead engineer) all work with TEGEMA, a multidisciplinary system integrator located in Son (NL). Recently, TEGEMA was acquired by Etteplan, an equipment, engineering, software and documentation solution provider for the manufacturing industry, headquartered in Espoo (Finland).

www.tegema.nl
www.etteplan.com



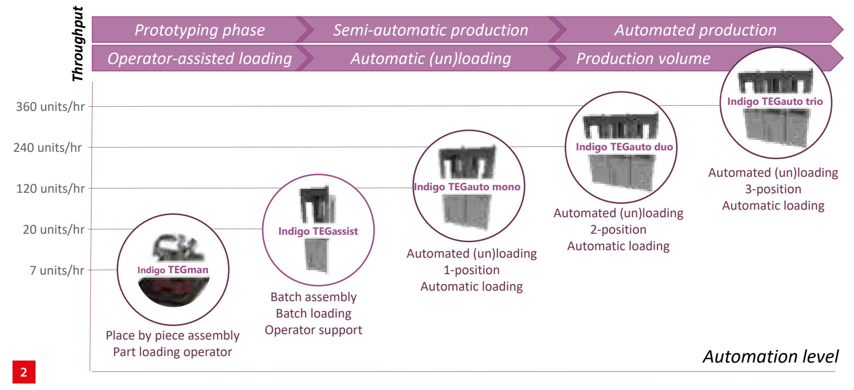
1 *Additional step in integrated photonics assembly, as compared to microelectronics production.*

Modular approach

The modular micro-assembly platform is Tegema's answer to the challenge of assembling and packaging PICs cost-effectively. The modular approach is based on Tegema's extensive knowhow in high-precision/accuracy alignment and joining & bonding. The photonics modular system offers a platform on which two optical elements are bonded with sub-micron alignment. This solution allows for several levels of automation to grow along with the production volume demand: from operator-assisted to semi-automatic to fully automated production of photonic devices (Figure 2). The machine can be upgraded from supporting low volumes in the research phase to fully automatic production

Key features of the modular platform

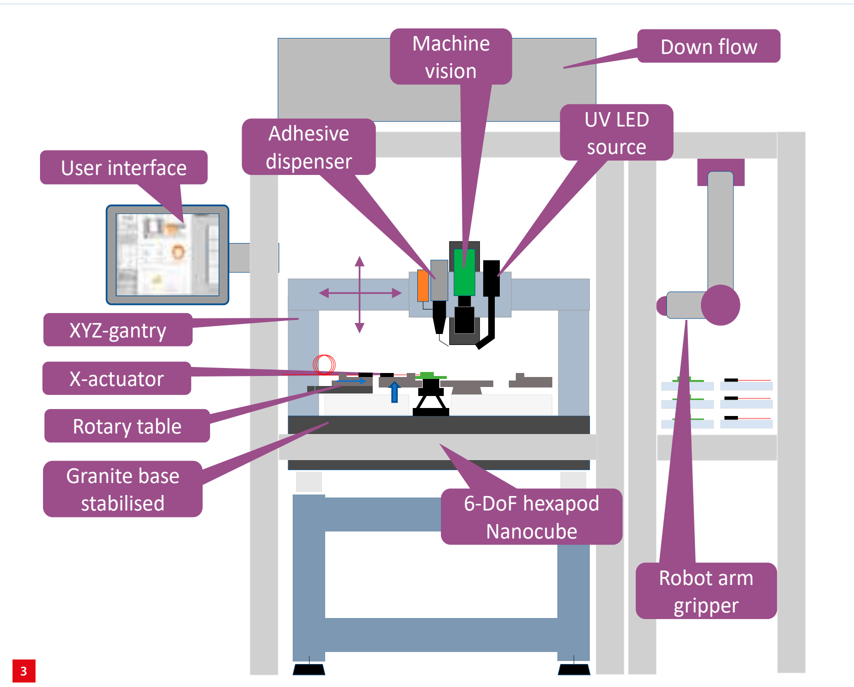
- Cycle time: 27-54 seconds (fully automated).
- Sub-micron active alignment: < 100 nm / 17 μrad (typically 0.02 dB).
- Small footprint: 1.1 m^2.
- Flexibility (short changeover time for tooling).
- Fully manual to semi-automated machine versions.
- Configurable closed-loop active alignment.
- Data/media logging and reporting function (for statistical process control).
- In-field upgrading options.
- Individual machine configurations with application-specific process modules.
- Bonding technologies, adhesive bonding (UV curing, thermal curing), soldering, solder reflow, laser welding and thermal compression.



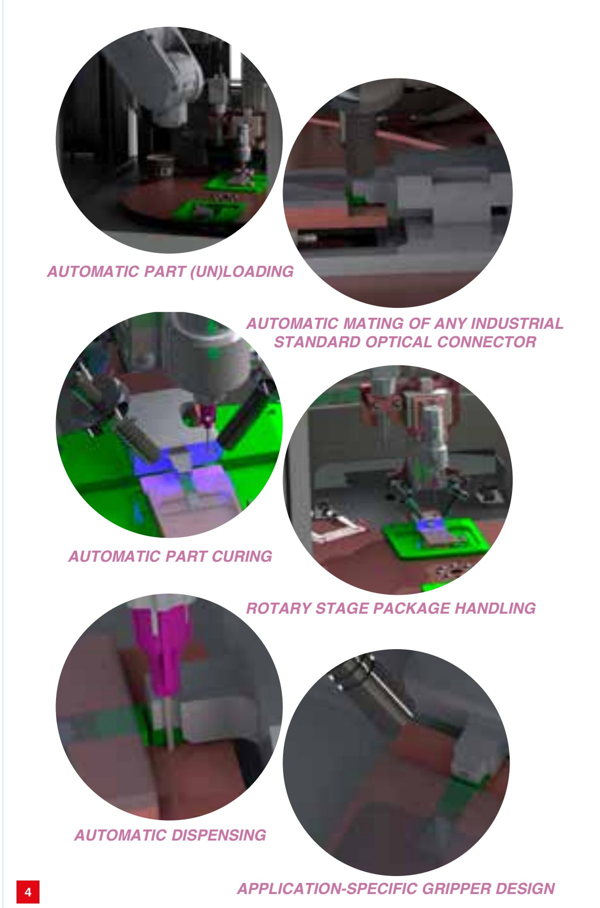
TEGEMA Indigo product line of automatic assembly solutions for operator-assisted, semi-automatic or fully-automated production of photonic devices. The Indigo TEGman provides a solution for piece-by-piece assembly in an R&D environment. The TEGassist provides a solution for low-volume production, where the operator loads the parts and the assembly is automated. When production volumes increase, the TEGassist can be upgraded to TEGauto by integrating it into a production line, with set-ups featuring one, two or three different automated alignment processes, using one robotic arm for component loading/unloading.

without having to invest in new equipment. Key features of the modular platform are presented in the text box.

The machine platform can be configured for chip-to-chip, lens-to-chip and fibre-to-chip alignment, among others. The core of the machine platform is an ultrafast, accurate, active alignment process in which the alignment of the optical components is optimised for (optical signal) coupling efficiency. This capability combined with flexible microgripper technology and accurate bonding technologies yields a versatile assembly platform suitable for a wide range of optical assemblies. The available processes include assembly of fibre-optic modules, microlenses,



Schematic overview of the demonstrator machine.



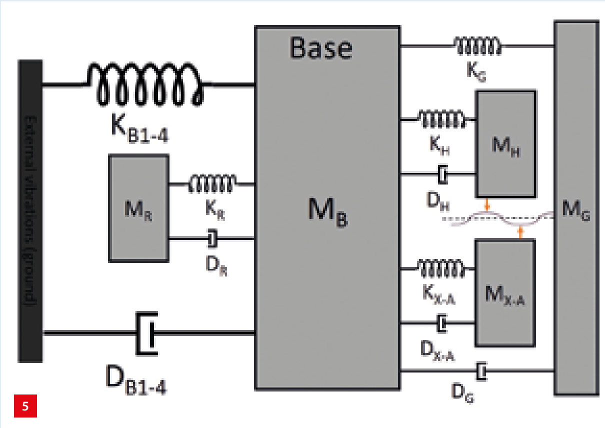
Overview of modules in the demonstrator machine.

photonic devices, camera modules, lidars, and optical interconnects for fibre optics and waveguides, as well as optical fibre pigtailing, planar waveguide coupling, and chip-to-chip alignment.

Modular platform demonstrator machine

To showcase the modular platform, Tegema built a demonstrator machine (Figure 3), set up for the sub-micron alignment and bonding of an optical fibre to an electronic chip; Figure 4 gives an overview of the available modules. Alignment is performed on a stabilised base that houses a 6-DoF (six-degrees-of-freedom) hexapod that holds the chip and an X-actuator that holds the fibre. The bonding of the fibre requires an XYZ-gantry system that holds the adhesive dispension, two UV-light sources and an optical camera. A rotary table transports products to and from the process position. A robot arm can be added to automate the (un)loading of products.

The hexapod aligns the chip with the X-actuator holding the fibre; this is done through active alignment based on optimising the data output of the fibre. Adhesive droplets are dispensed on both sides of the fibre using machine vision to determine dispense position. Both droplets are simultaneously UV cured to prevent displacement of the



Mass-spring-damper system model of the demonstrator machine. M = mass, K = stiffness, D = damping. Subscripts: B = Base, G = Gantry, H = Hexapod, R = Rotary Table, X-A = X-actuator.

fibre due to adhesive shrinkage. The optical fibre output is checked before, during and after processing to ensure high alignment quality.

Vibration tolerance analysis

As external and internal vibrations can easily disturb sub-micron alignment, it is important to categorise the necessary stiffness (K) and damping (D) of the internal and external connections; see Figure 5. The machine base is supported by four vibration mounts/external connections (K_{B1-4}, D_{B1-4}), with internal connections to the hexapod (K_H, D_H), X-actuator (K_{X-A}, D_{X-A}), XYZ-gantry system (K_G, D_G) and rotary table (K_R, D_R).

The target is that external vibrations meet the ISO2631-2 VC-B standard (Figure 6). This is a standard for optical microscopes up to a magnification of 1,000X and for lithography equipment (including steppers) to 3 micron line widths. The internal vibrations are a result of the acceleration rates of the XYZ-gantry, rotary table, X-actuator and hexapod. The sum of the amplitude heights determines the relative inaccuracy between hexapod and X-actuator with respect to chip and fibre alignment, respectively.

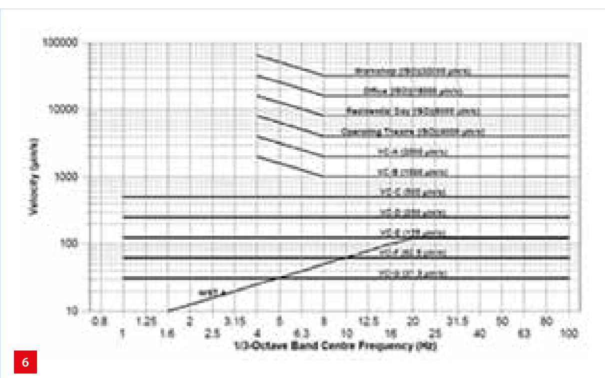
To reach the required vibration tolerance of 2 nm, the low-frequency signals arising from the rotary table movement require time to damp out. Mounting the rotary table on the base with a low-stiffness connection and additional damping enabled the trade-off between vibration damping and motion speed. The XYZ-gantry, hexapod and X-actuator were designed to have a high stiffness, as required for the active alignment process.

Active alignment

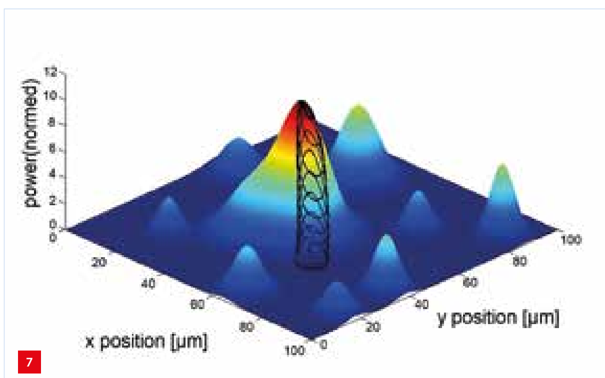
The large movement of the rotary table brings the chip above the hexapod. The hexapod moves up slightly in the Z-direction, lifting the chip; during this step it creates a vacuum between the chip and hexapod interface, ensuring the chip is fixed. The movement of the X-actuator brings the fibre to a fixed position that is close to the chip, and can release the fibre and retract after the active alignment and bonding is completed.

There are two steps in the active alignment: a coarse alignment followed by a fine alignment. The coarse alignment is performed based on optical camera information concerning the distance between the optical fibre and the chip; the hexapod will move in X, Y, Rz until a coupling signal ('first light') is detected. When a coupling signal can be read out, the software will perform the fine alignment. In this process the optimal coupling signal strength (and hence the optimal positioning of the fibre with respect to the chip) is determined by performing a digital gradient search (Figure 7). The hexapod moves the chip with small circular motions for each DoF, causing the coupling signal to vary; this variation in phase and amplitude can be analysed to determine the instantaneous gradient [4].

The algorithm measures the local instantaneous gradient with nanometer-scale exploratory motions of the alignment system. The routine is performed multiple times for all six DoFs of the hexapod, with an active limit on X-movement (based on optical camera distance information) to prevent the collision of fibre head and chip. The algorithm was



ISO2631-2 floor vibrations standards [3].



Gradient search method based on the coupling signal strength.


The Indigo TEGauto duo set-up for two different automated alignment processes, using one robotic arm for component loading/unloading. On the right, a close-up of the photonic demonstrator machine (without robotic arm).

provided by PI (see Partners text box) and programmed into the software. The unique PI approach allows multiple gradient search routines to proceed in parallel. This means that the optimisation of multiple DoFs can proceed simultaneously, which significantly reduces the fibre-to-chip alignment time.

Conclusion

The TEGEMA photonic demonstrator machine shows the benefits of combining a modular platform with state-of-the-art active alignment algorithms, providing a solution for PIC assembly and packaging (Figure 8). The machine enabled the optimisation of the active alignment process, adhesive dispension and curing, modularity, software integration and cycle time reduction. It also reached the specification goals with a fast cycle time of 30 s per product and a resolution of 4 nm. The modular platform approach allows the customisation of the machine to actual and future customers' needs. Short cycle times are achieved through the use of active alignment and automatisation, which results in cycle times that are ten times shorter than those of the currently available solutions.

REFERENCES

[1] "Understanding Wavelengths in Fiber Optics", *www.thefoa.org*, retrieved 16-12-2019.
[2] "Future Trends in Fiber Optics Communication", WCE, London, 2 July 2014, ISBN 978-988-19252-7-5.
[3] Wesolowsky, M.J., et al. "Human-induced vibrations in buildings", *International Journal of High-Rise Buildings*, Vol. 1 (1), pp. 15-19, 2012.
[4] Jordan, S., "Understanding Wavelengths in Fiber Optics", *www.physikinstrumente.com*, retrieved 14-9-2020.

Partners

The production of integrated photonic components, when compared to microchip manufacturing, has a decisive process step that is more complex: the coupling technology that connects optical fibre components, such as individual glass fibres or glass fibre arrays, chips, VCSELs (vertical-cavity surface-emitting lasers), lenses, diffractive elements or photodiodes to each other. This assembly and packaging technology contributes considerably to the total costs of photonic products. Therefore, system integrator TEGEMA has partnered with dedicated suppliers, such as PI, and integration specialists like CITC (Chip Integration Technology Center).

PI offers fast, high-precision positioning systems for the coupling step in manufacturing with special firmware routines built into the system controllers. These systems are already used worldwide for the development of photonic components, as well as in pilot production. The trend is towards increasing levels of automation, for example when handling photonic chips or applying and curing adhesives.

The growth of photonics is hampered mainly by the lack of standardisation in the back-end production of integrated photonics packages. That is why every new product demands an innovation in assembly and packaging. This leads to high costs and technological risks. By developing manufacturing processes and manufacturing equipment hand-in-hand through a highly flexible platform, CITC and TEGEMA aim to reduce development risks and costs. CITC is the Dutch non-profit innovation centre that specialises in heterogeneous integration and advanced packaging.

WWW.PHYSIKINSTRUMENTE.COM
WWW.CITC.ORG

SUPPORT THE

It would have been a big 'precision party' on 18 and 19 Novembe
in Den Bosch (NL) for a 'corona-proof' setting, had everything g
precision community. This time with a special touch, because it w
one and only meeting point for the Dutch – and increasingly also
innovation, relationship management and new business.

After extensive consultation with exhibitors and the authorities, t
Due to the special nature of the fair, with its impressive physical e
interactions, a digital version was not a viable alternative.

We accept this decision wholeheartedly and call on everybody to
hopefully next year, either as an exhibitor or a visitor. The spirit o

Hans Krikhaar,
president DSPE

Gerrit Kulsdom,
owner Sales & Services

Note:
The decision to cancel the Precision Fair 2020 was made just befo
in this issue, but there was not enough time to modify the adverti
and advertisers.

PRECISION FAIR

...r. The twentieth edition of the Precision Fair, moved to the Brabanthallen ...oing for it to become once again the 'high mass' of the international ...was the 20th anniversary of the fair that since 2001 has grown into the ... the international – precision community, with a unique focus on

...he organiser Mikrocentrum had no choice but to cancel the fair. ...exhibitions and the warm atmosphere full of planned and unplanned

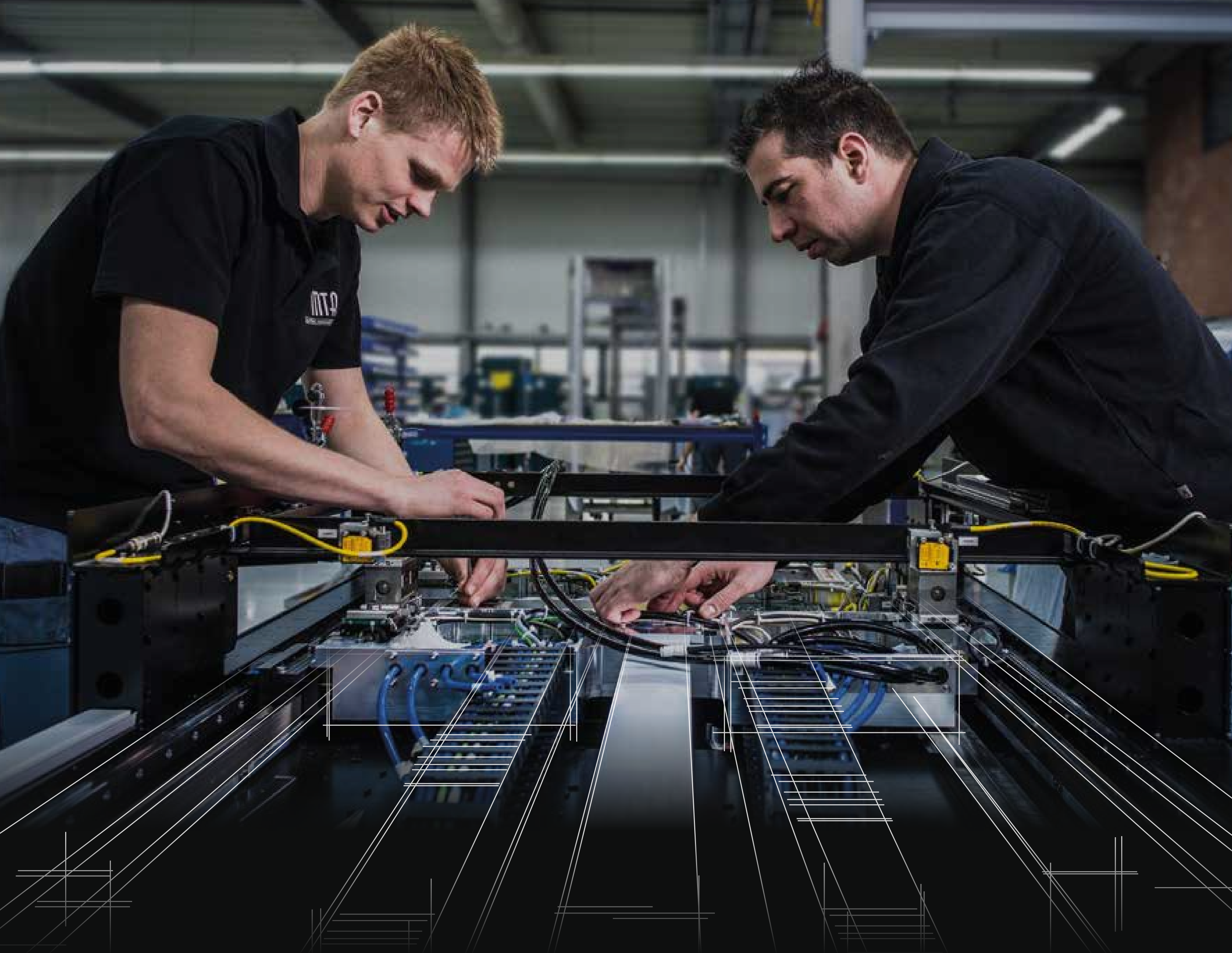
... support the Precision Fair and to participate in the next edition, ...f the Precision Fair lives on.

Hans van Eerden,
editor Mikroniek

...ore Mikroniek went to press. Therefore we skipped the preview of the fair ...isements in which stand numbers are mentioned. Apologies to our readers

Precision Fair 2020

Wednesday 18th and Thursday 19th November 2020



INNOVATIONS

Oude Reimer

Coolant Box

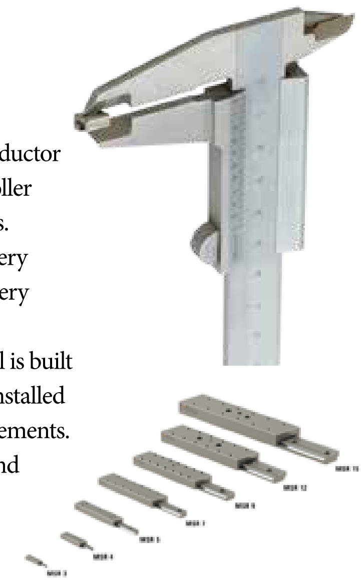
The new Coolant Box is an automatic mixing and maintenance system with high-end measurement system for cooling lubricants that are used by various machines as well as standard metalworking and polishing machines. It offers up to 25% reduction of cooling lubricant consumption. In addition, it facilitates online monitoring of the consumption of each machine. In 24/7 operation, the standard system covers up to six machines; extension is optional. The system prevents bacterial growth by means of a built-in ozone installation, provides extra chip filtration and removes stray oil. All in all, it achieves longer machine life due to better filtering and ensures a clean working environment for operators and machines. As a result, the Coolant Box increases process reliability at low cost.

WWW.OUDEREIMER.NL

PM

Miniature roller table MSR-3

As an extension of the MSR miniature roller-table family, the MSR-3 is introduced. With a height of only 3.2 mm and a width of 5.5 mm, the smallest family member offers maximum space savings. It comes in four different lengths (8, 15, 20 and 25 mm) and covers stroke lengths from 8 to 20 mm. The top and bottom table are made from one piece. This enables the best possible accuracy. High system stiffness is key in the design for precise positioning; depending on the size, process accuracies better than 3 microns can be achieved over the entire stroke.
The MSR-3 is the smallest roller table on the market with a crossed-roller cage and cage control. Especially with limited installation spaces, PM enables the user to utilise the advantages of crossed-roller bearings with anti-cage-creep mechanism even on a very small scale.
The slides of the MSR series are characterised by a high load-bearing capacity and stiffness and enable high accelerations. Since all components are made of stainless steel, the miniature slides are suitable for applications in semiconductor manufacturing and medical technology. The crossed-roller cage allows making precise and short lifting movements. The lubrication is distributed over the raceways with every movement. The slide is set free of play and guarantees very easy and smooth running.
A unique feature of the MSR cart is that the cage control is built into the design. This means that the MSR slide can be installed in any direction and is suitable for highly dynamic movements. The crossed-roller cage always remains in its position and does not migrate. The installation of MSR roller tables increases the reliability of miniature machines and guarantees a long service life.



The MSR-3 is the smallest member of the MSR family of miniature roller tables.

WWW.PM.NL

Precision Micro

Whitepaper: "Photochemical etching: precision without compromise"

Leading photochemical etching manufacturer, Precision Micro, has launched a new whitepaper to educate and inform design engineers unfamiliar with the process about its potential – including its ability to enhance quality, reduce lead times and cut costs, without compromise.

Almost every industry, from automotive and aerospace through to healthcare and electronics, requires complex precision components. Often created using traditional techniques such as laser cutting and stamping, these machining methods have limitations – such as thermal stress and burring – which can compromise the performance of these critical parts.

Providing a comparison of these techniques, the whitepaper (download from *bit.ly/3jJQ9fq*) is able to highlight the ability of photochemical etching to overcome common machining issues, making a case for the process across a variety of industries which rely on precision-etched components to deliver the highest levels of quality and safety in their products. Precision-etched components are at the heart of many safety-critical products, such as antilock braking systems and springs in satellites, as well as corrosion-resistant microfilters. That is why, when it comes to creating individual components, there can be no room for compromise in the quality of outputs.

WWW.PRECISIONMICRO.COM

SIOS (Te Lintelo Systems)

SP 5000 DI differential laser interferometer

The new SP 5000 DI ultrastable differential laser interferometer from SIOS Meßtechnik is characterised by its unique thermal stability and can be used for long-term measurements in research and development, such as for material testing. Thanks to its design, with an external reference beam, the measurement system can be placed at a larger distance from the measurement location without significantly affecting the resolution or stability of the measurement. The length resolution of the interferometer is 5 pm and this can be achieved even under normal laboratory conditions thanks to the differential principle of the measurement system.

The range for length measurement is several meters if tilt-invariant reflectors are used for the measurements. The system has a modular design and can therefore be adapted to specific measurement tasks, for instance in OEM configurations as feedback system.
Adjustments can be made simply and with long-term stability. The construction of multi-axis systems on the basis of the SP 5000 DI interferometer also allows multi-coordinate measurements.

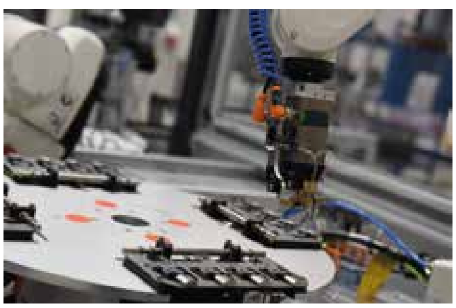
WWW.SIOS-DE.COM
WWW.TLSBV.NL

STT Products

QuickScan Production Optimisation

Many manufacturing companies sometimes lack the time, budget or attention for innovation and improvement of an existing production process. But with increasing demand and the growing shortage of skilled workers, it is inevitable that labour productivity will have to increase in the coming years. Improving or replacing manual operations by focusing on automation can yield major gains in terms of capacity, quality, efficiency and working conditions.
In order to optimise a production process, it is important to consider it in its entirety. And a fresh look can help to reveal bottlenecks that could otherwise go unnoticed. STT Products has been monitoring the production processes of manufacturing companies for over thirty years. STT now wants to use this experience, in combination with the available knowledge in the field of mechanical engineering, electrical engineering, software, and Lean, Six Sigma and QRM to advise manufacturing companies on how to produce future-proof. This advice is offered as a stand-alone service in the form of a quick scan, focusing on the capacity, quality, efficiency and working conditions of a production process. It regards the identification of manual actions that can be converted into an automated solution in order to increase efficiency. This could include increasing output, reducing waste, improving quality or working conditions, or simplifying the process.

WWW.STTPRODUCTS.NL



A robot gripper for automation of a manual assembly step.


Efficient Solutions for Precision Parts Cleaning
www.ucm-ag.com
Experience UCM at the Precision Fair 18-19 November 2020 at the Brabanthallen, 's-Hertogenbosch, Dommelhal Booth 336
UCM supplies machinery for ultrasonic precision parts cleaning applications. Its globally leading solutions help companies around the world in achieving highest cleanliness requirements. From the High Tech and High Purity industries, through manufacturers of optical and medical components to precision parts from the tools and automotive industries, UCM always offers the right solution. UCM's success is based on innovation, efficiency, sustainability and technology that inspires!
SBS ECOCLEAN GROUP
UCM
technology that inspires


Air Bearings for Motion Systems
Extreme precision. New design possibilities.
Visit us at:
Precisiebeurs 2020
Stand 555
IBS
Precision Engineering
www.ibspe.com


DSPE MIKRONIEK
DSPE MIKRONIEK

HIGH PRECISION, LOW ENERGY, NO HEAT

Whether machining sintered cutting inserts, coins or small parts for watches or jewels – the result always requires the highest precision and has to last for a long time. Start-up KLM Microlaser has developed the E1 laser machining centre for working with the hardest materials. The renowned Kern Evo machining centre serves as the machine base and an ultrashort-pulsed femtosecond laser is used as a high-tech tool, one which is perfectly suited to inserting highly precise and detailed shapes into small-format products such as stamps and pressing tools. In one case, the production time of sintered inserts was reduced from eight hours to two.

Introduction

The KLM E1, available since the beginning of 2020, is a modern high-tech laser machine that is of particular interest for the mould and tool and the watch and coin industries. When it comes to machining small parts, the KLM E1 excels in terms of productivity, long-term precision, freedom from wear, energy efficiency and usability.

System overview

Several key components in the KLM E1 (Figure 1) are crucial for this: the basic construction, including the axes and drives of the established Kern Evo milling machine; the use of a pulsed femtosecond (fs) laser source; a mirror-based laser beam guidance from Lightmotif; and software that makes operation easy, with a simple transfer of the CAD data to the machine control. With regard to manufacturing accuracy, two unique features have been developed: ASPM (Automatic Spot + Power Measurement) and Adaptive Machining.

A mineral cast stand in a monobloc construction and an X-Y cross-table, which is manufactured by Kern, are the solid basis of the E1. They ensure the highest precision in the sub-µm range, which is important for the positioning and measuring of the parts. A mirror construction from the laser source to the scanner, with mirrors that are attached to the machine frame, is used because optical fibres are not suitable for guiding fs lasers.

The power of the laser source is 20 W, which means that the E1 can process a wide variety of materials. When layers are removed, the short pulse duration ensures that little energy

1

The new KLM E1 laser machining centre, specially designed for processing small parts from hard materials, is equipped with a femtosecond laser.

EDITORIAL NOTE

This article was contributed by KLM Microlaser, based in Eschenlohe (Germany) and represented in the Netherlands bij Encoma. The company was founded in 2019 by Ekkehard Alschweig, engineer, co-owner and former head of Kern Microtechnik, bundling his mechanical engineering knowledge with the know-how of the Dutch laser specialists from Lightmotif, located in Enschede. KLM Microlaser develops and produces a new generation of triaxial laser machining centres called E1, with Kern Microtechnik taking over the mechanical engineering and service of the entire system.

www.klm-microlaser.com
www.lightmotif.nl
www.encoma.nl

2

A typical product for the E1, an unpolished stamp.

is injected with each pulse, thus preventing any heat penetrating into the workpiece, as heat could cause a change in the material structure. As with all fs laser systems, the removal depth of the E1 is low, usually between 0.3 μm and 2 μm per layer. This enables an extremely high precision.

Automatic calibration

ASPM (Automatic Spot + Power Measurement) is a system that makes the machine stable over the long term. As is every other machine, the E1 is subject to thermal and other influences that do not have an immediate but rather a creeping effect – that is, over a certain period of, typically, a few hours. As a consequence, workpieces are produced with less precision. These influences and resulting inaccuracies are minimal, but nevertheless have to be prevented. When working with fs laser machines, two main challenges with an effect on precision over a long term may arise.

Firstly, the zero point of the laser spot can shift from its originally calibrated X-Y position, just in the μm range, but this is enough to cause inaccuracies. The reason for this is that the light-guide mirrors for controlling the laser beam are mechanically attached to the machine frame. If heat is applied to the frame, the frame extends, the spot shifts and inaccuracies occur. As a result, the light-guide mirrors have to be re-adjusted.

Secondly, the power of the laser beam reaching the workpiece can vary. The output power of a laser is never really stable and, in the long term, contamination on mirrors and lenses can also cause small losses. This means that after a certain time, the laser power originally calculated is no longer available. As a result, the material removal rate can change.

With ASPM, the E1 has a simple and efficient solution for these two potential challenges. ASPM can be started automatically or with just the push of a button. ASPM then recalibrates the entire system within two minutes, which means that it can be done every time production starts or even once a day.

Depth accuracy

Another distinctive feature of the E1 is Adaptive Machining. The fs laser removes material in layers with an average depth of 1 μm, with exact values having to be defined in individual cases. Adaptive Machining optically measures the machined depth and compares the actual, measured values with the target values. The machine then adjusts the laser parameters accordingly and ensures that the target values are achieved.

Without Adaptive Machining, the depth accuracy depends on the total machining depth and is usually between +/–3% and +/–5% of the machining depth. At a typical depth of 0.5 mm, this results in an expected inaccuracy of around +/– 25 μm. With Adaptive Machining, the depth accuracy is independent of the machining depth. The E1 achieves accuracies better than +/– 10 μm and has even reached values of less than +/– 5 μm in many tests.

Production time reduction

Test runs have demonstrated the potential of the KLM E1, for example in producing stamps (Figure 2). In one instance, a manufacturer of sintered cutting inserts formerly worked with a combination of an electrical discharge machining and a milling process. Now they have converted the traditional process for press punches to produce blanks in green-state carbide. With the new KLM E1 they only run one process. The pressing tools that were previously produced within an average of eight hours now only take two (Figure 3).

3

A test customer reduced the production time of sintered inserts from eight hours (with classic electrical discharge machining and milling) to two hours (with the KLM E1).

WIM VAN DER HOEK (1924-2019) – A CONSTRUCTIVE LIFE

After the passing away of Wim van der Hoek, in early 2019, DSPE took the initiative to publish a book about the Dutch doyen of design principles. The presentation, originally planned at the 2020 Precision Fair (cancelled), will take place at an alternative (online) occasion. The book covers Van der Hoek's formative years, including World War II 'adventures', his career at Philips and Eindhoven University of Technology, where he developed his breakthrough ideas on achieving positioning accuracy and controlling dynamic behaviour in mechanisms and machines, and their reception and diffusion. It concludes with his busy retirement years in which he continued to tackle – technical as well as social – design challenges, believing that technology should support people.

The book, "Wim van der Hoek (1924-2019) – A constructive life / Design principles and practical learnings between criticism and creation", was researched and written by Lambert van Beukering, teacher, journalist and technology analyst, and Hans van Eerden, Mikroniek editor and freelance text writer. They received input from numerous sources, including Van der Hoek's family and former colleagues and students, Eindhoven University of Technology and Philips, as well as other high-tech companies that are indebted to his ideas.

Lambert van Beukering & Hans van Eerden (eds.), "Wim van der Hoek, 1924-2019, A constructive life – Design principles and practical learnings between criticism and creation", ISBN 978-90-829-6583-4, approx. 250 pages, € 39.50, published by DSPE.

The book starts with Wim van der Hoek's formative years in the Dutch (god-fearing) province of Zeeland, where he was born into a teachers' family, and his 'adventures' in World War II, when he was involved in reconnaissance work on the dreaded German V2 missile. After the war he studied mechanical engineering at Delft University of Technology and then joined industrial giant Philips in Eindhoven in 1949.

Unique combination of technical specialisations

At Philips, he became the leader of the Pre-development group at the *Apparatenfabriek*, later the main industry group RGT (Radio, Gramophone, Television), focusing on promising (manufacturing) technologies and functional elements. Soon, he started studying the dynamic behaviour and positioning accuracy of mechanisms and machines, as these machines for high-volume component production had to become increasingly more accurate and faster. His work was dominated by the ongoing miniaturisation and the rise of integrated circuits.

Starting as an engineer/designer, Van der Hoek developed to become an enthusiastic networker and advisor, right up to the board of directors. In that capacity, he was one of the founders of the Philips Centre of Manufacturing Technologies (*Centrum voor Fabricage Technieken*, CFT), which was established in 1968 as a "unique combination of technical specialisations". For ten years, he was discipline leader of Mechanics and Mechanisms and subsequently, in the years before his official retirement in 1984, he retired from managerial tasks to devote himself entirely to 'his' specialism, dynamic behaviour and positioning accuracy.

The Devil's Picture book

This very same specialism was the main subject of his part-time professorship at Eindhoven University of Technology, from 1961 to 1984. There, he undertook the endeavour to enthuse freshmen for the mechanical engineering profession and to teach fourth-year students (some 600, over the years) design as a confrontation between criticism and creation. In his lecture notes, he built on his research at Philips. He collected examples of designs that were lightweight, sufficiently stiff and play-free with regard to dynamics in his famous The Devil's Picture Book (*Des Duivels Prentenboek*, DDP), which he presented as a source of inspiration for upcoming and experienced designers.

Legacy

In his farewell lecture in 1985, Van der Hoek concluded that his attempts to teach students how to design had turned out to be a matter of trial & error, but satisfaction pre-dominated. Rightly so, because his lectures and supervision have made an indelible impression on many students. This impact can still be found in education at the three Dutch universities of technology and – since the onset of the current century – the universities of applied sciences, as well as in industry. Testifying to this, in the book some fifteen high-tech companies present their Wim van der Hoek stories accompanied by examples of their own DDP-worthy designs.

Busy retiree

At the age of 60, Van der Hoek retired. From a current perspective and – in retrospect – given the very advanced age of 94 that he reached, he was then still young and had a whole life ahead of him. He filled this with a variety of activities. His involvement with the mechanical engineering and manufacturing community remained and during an intermezzo of a study tour to Germany he even taught the participating students in a German shed, on the correct design of presses, a topic inspired by a company visit the previous day.

He advised renowned companies, such as ASML and in particular Van Doorne's Transmissie (VDT), on the reliable production of pushbelts for their continuously variable transmission. In addition, he immersed himself intensively in social problems outside his comfort zone and continued to enthusiastically pursue his two lifetime hobbies, painting and gardening. In 2004, he was overwhelmed by the surprise party, which some of his former students had organised on the occasion of his eightieth birthday, and the establishment of the Wim van der Hoek Award for young designers, presented annually since 2006, filled him with pride. In this way, his name as well as his design philosophy live on.

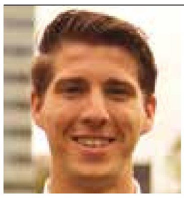
BOOK ORDER
INFO@DSPE.NL
WWW.DSPE.NL

Wim van der Hoek, 1924-2019.
(a) On the occasion of receiving his gymnasium diploma (1943).
(b) In front of the drawing board, at Philips CFT (undated, approx. early seventies).
(c) Delivering his farewell lecture at Eindhoven University of Technology (1985).
(d) Posing in front of the conference room named after him at JPE, the company founded by his former student Huub Janssen (2016).

EIGHT NOMINATIONS FOR
2020 WIM VAN DER HOEK AWARD

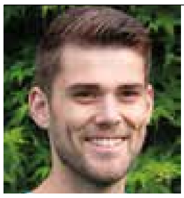
Mechanical design based on the design principles defined by Wim van der Hoek is very much alive. The Philips engineer and part-time professor at Eindhoven University of Technology passed away early last year at the age of 94, but his name lives on in the prize named after him and his ideas are still taught. The nominations for the Wim van der Hoek Award 2020 testify to this. The jury received a total of eight nominations from two universities of technology and two universities of applied sciences for students who applied existing or new construction principles in their graduation work. The award presentation, originally planned at the 2020 Precision Fair (cancelled), will take place at an alternative (online) occasion, under the auspices of DSPE.

Candidates



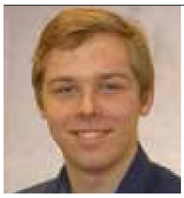
Jelle Elenbaas
(Fontys Engineering University of Applied Sciences)

Design of a multiple LED ring light for inspect positions of ADAT3-XF using AM
"Jelle has made an original design for an LED lighting ring that has to be able to take up two positions on Nexperia's ADAT3-XF die-bonder based on a bistable ('click clack') mechanism that should be realised by means of additive manufacturing (3D printing). Jelle shows excellent commitment, is flexible, takes initiative and is also critical of his own work (he reflects well). The value of Jelle's design for Nexperia is enormous. If the design meets expectations (the prototype has yet to be built), the result will be more functionality for a quarter of the current price."



Marijn van Houtum
(Fontys Engineering University of Applied Sciences)

Design of a positioning stage for Cryo samples
"Marijn is a very passionate, efficient and result-oriented designer. He also has sufficient self-confidence and is not afraid to ask questions. Despite the limitations of the corona crisis, he managed to make a design for Frencken Engineering within the set cost budget. This involved a complex positioning stage for cryogenic samples for an electron microscope. The result is a complete mechanical precision design, which includes all relevant sub-aspects (including design principles, choice of materials, error and cost budgeting, and technical product documentation including shape and position tolerances). In addition, the design was realised and assembled during the graduation period. Marijn shows excellent constructive insight with an eye for both theory and practice."

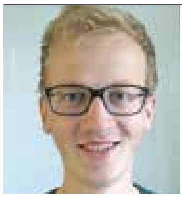


Joris Lammers
(Fontys Engineering University of Applied Sciences)

Het ontwerpen, optimaliseren en valideren van een 3D metaal geprint kruisveerscharnier
(Designing, optimising and validating a 3D metal printed cross-spring hinge)
"During his graduation project at MTA, Joris devoted himself fully to the design of a 3D metal-printed cross-spring hinge with a large stroke and high lateral stiffness. He iteratively went through the process of printing, testing behaviour, making improvements and printing a new design. He alternated his pragmatic approach with sifting through demanding papers in order to understand the theory and include it in his analyses. Joris has taken on the challenge of printing very thin metal structures, among other things. He investigated which materials, printer settings and post-processing treatments are most suitable for this. 'That design is so logical, it must already exist', one might think when one sees the end result. Apparently, it wasn't that simple after all, because the design didn't exist yet. MTA has now obtained a patent on it."

Bram Lomans
(Eindhoven University of Technology)

Mechatronic Architecture and Design for a Metrology Tool with Parallel Sensors
"Bram has been working on a new concept for small parallel sensors for application in future ASML Yieldstar metrology systems. He is very independent and goal-oriented. His graduation project was part of a broader study within ASML Research. During his graduation he was one of the few mechanics who held his own very well in a team mainly comprising opticians. He maps out his own route and knows how to include his environment. Bram is creative and analytically strong, and has good communication skills. To increase his 'bandwidth', he successfully supervised a bachelor's final assignment. He is a mechanical engineer in a broad sense with a focus on precision mechanics, both conceptually and on a detailed level."



Jochem Lutgerink
(Delft University of Technology)

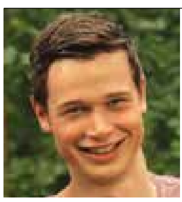
Design and Validation of a Collimator Alignment Assembly for a High-Power Bulk Multiplexer used in Ground-to-GEO Laser Communication

"Jochem graduated on the subject of satellite communication with light. His assignment at TNO was to design a compact, stable and high-precision alignment of the five lasers with different colours that form a high-power light source in the ground station. An assignment in which he could demonstrate his strengths: analytical skills, coupled with a critical attitude and confidence in his own skills, besides a thorough knowledge of optics as well as opto-mechatronics. He has developed a new alignment mechanism, using the well-known design principles and taking into account the requirements for (thermal) stability. In an original manner, he has combined 3D metal printing with the classic opto-mechanical alignment technology. He has also realised the mechanism and designed an optical measurement set-up for testing. During his graduation project, Jochem has grown in terms of knowledge and as a person, from a cautious techie to a budding system designer with confidence and pleasure in his profession and the drive to promote this profession."

Kas van Roekel
(Avans University of Applied Sciences)

Ibis Nest

"Kas has a broad interest in technology and his enthusiasm is very contagious. He is co-founder of the student start-up Stuval, a multidisciplinary development company that connects young talent with companies and develops ideas. Within Stuval he focuses on the application of Triz, the well-known method for inventive problem solving. Kas was looking for a graduation assignment with construction principles in the lead. At Settels he found a challenging question with complex boundary conditions. The final solution is elegant, because it is simple and well thought-out. He tries to keep the writing of reports to the minimum necessary, especially because he believes that you get to the essence of a problem faster if you experiment with 3D-printed models. He has shown that he has the potential to develop into a real engineer-designer."



Teun van der Sande
(Eindhoven University of Technology)

Design of a Retractable Imaging Device

"Teun showed his competences by tackling in-depth mechanical design issues while maintaining a clear overview at system level. During his assignment at Prodrive Technologies, he started with a system decomposition resulting in two major design issues to solve. In the first place, the design of a non-overdetermined support of the fragile sensor including its strict requirements on cooling. Secondly, the design of a linear-guidance-based retraction mechanism with a well-defined pretension and without end-of-stroke collision forces. Teun's analytical and experimental skills, enthusiasm and eagerness to learn, together with the ability to transfer newly obtained knowledge in a structured manner to team members, allowed him to solve both issues and to create a fully integrated product design as well."

Stan Smolders
(Fontys Engineering University of Applied Sciences)

Mitigation of disturbances on a linear stage, using FeedForward and Iterative Learning Control

"Stan is a social, attentive and passionate person. During his study he was always prepared to provide explanations to others and in this way he helped so many students. His analytical level far exceeds the level that can be expected of an HBO bachelor student. He has taken on a complex challenge during his graduation at MI-Partners: applying advanced, data-based ILC (Iterative Learning Control) solutions to a high-precision positioning system to reduce repetitive errors, while also seeking – based on system knowledge – basic functions for reducing, in conjunction with ILC, the tracking error in a more robust manner (with changing input signals). He compared all this with the traditional model-based feedforward control. Stan managed to master the necessary theory under challenging circumstances (a lot of working from home because of Covid-19)."


TeamNexperia
"Join TeamNexperia and become part of a leading company that supports, rewards and challenges you equally."
Martin from Hamburg – Senior Engineer
For our location in Nijmegen we are looking for:
Mechatronics Architect
Nexperia is a world-class company in semiconductor development and in-house production. We form a global network of talent, with passion and performance, perseverance and professionalism. Talk to us today and learn your true capabilities in an energetic company where you will develop and thrive, the Efficiency Company – Nexperia.
Get in touch with your future: www.nexperia.com/careers or contact joinourteam@nexperia.com.

Please check for any rescheduling, online reformatting or cancellation of events due to the coronavirus crisis.

Virtual event

29 October 2020

Technology for Automotive 2020

Organised by RAI AutomotiveNL and Mikrocentrum, combining the Automotive Congres and the AutomotiveNL Supplier Day. Topics include green & smart mobility, manufacturing & logistics and materials & design.

WWW.TECHNOLOGYFORAUTOMOTIVE.COM

Virtual event

4 November 2020

National Contamination Control Symposium

Event, organised by VCCN (Dutch Contamination Control Society), comprising a lecture programme, tutorials and an exhibition.

WWW.VCCN.NL

Virtual event

5 November 2020

Software-Centric Systems Conference

Devoted to complex software development. The keynote by TNO-ESI, Philips and Thales will be on interface modelling.

WWW.SOFTWARECENTRICSYSTEMS.COM

Virtual event

23-24 November 2020, Eindhoven (NL)

EAISI Summit 2020

First edition of this event, featuring the theme of 'Robotics & Interacting with Smart Machines', organised and hosted by TU/e Eindhoven AI Systems Institute, in partnership with High Tech Systems Center.

WWW.TUE.NL/EAISI

Virtual event

3-4 December 2020

International MicroNanoConference 2020

A wide range of technologies are presented, covering fields such as Health & Life science, Agro & Food, Sustainability & Energy, and Manufacturing & Engineering.

WWW.MICRONANOCONFERENCE.ORG

27-28 January 2021, Veldhoven (NL)

Food Technology 2021

Knowledge and network event about high-tech innovations in the food industry.

WWW.FOOD-TECHNOLOGY.NL

2 February 2021, Veldhoven (NL)

CLEAN 2021

This theme day, organised by Mikrocentrum, provides an expert's view on cleanliness, focusing on design, production, assembly and packaging.

WWW.MIKROCENTRUM.NL

10-11 March 2021, Södertälje (SE)

Lamdamap 2021

Fourteenth edition of this event, focused on laser metrology, coordinate measuring machine and machine tool performance. It embraces new topics, a new location and a new format as compared to the previous, UK-based editions.

WWW.EUSPEN.EU

29 March 2021, Düsseldorf (GE)

Gas Bearing Workshop 2021

Fourth edition of the initiative of VDE/VDI GMM, DSPE and the Dutch Consulate-General in Düsseldorf (Germany), focused on gas bearings as important components or integral technology of most advanced precision instruments and machines.

WWW.GAS-BEARING-WORKSHOP.COM

7-11 June 2021, Copenhagen (DK)

Euspen's 21th International Conference & Exhibition

The event features latest advances in traditional precision engineering fields such as metrology, ultra-precision machining, additive and replication processes, precision mechatronic systems & control and precision cutting processes.

WWW.EUSPEN.EU

9-10 June 2021

RapidPro 2021

The annual event showcasing solutions for prototyping, product development, customisation and rapid, low-volume & on-demand production.

WWW.RAPIDPRO.NL

ECP² COURSE CALENDAR

COURSE (content partner)	ECP² points	Provider	Starting date
FOUNDATION			
Mechatronics System Design - part 1 (MA)	5	HTI	12 April 2021
Mechatronics System Design - part 2 (MA)	5	HTI	8 November 2021
Fundamentals of Metrology	4	NPL	to be planned
Design Principles	3	MC	16 November 2020
System Architecting (S&SA)	5	HTI	16 November 2020
Design Principles for Precision Engineering (MA)	5	HTI	23 November 2020
Motion Control Tuning (MA)	6	HTI	23 November 2020
ADVANCED			
Metrology and Calibration of Mechatronic Systems (MA)	3	HTI	2 November 2020
Surface Metrology; Instrumentation and Characterisation	3	HUD	to be planned
Actuation and Power Electronics (MA)	3	HTI	16 November 2020
Thermal Effects in Mechatronic Systems (MA)	3	HTI	1 December 2020
Dynamics and Modelling (MA)	3	HTI	23 November 2020
Manufacturability	5	LiS	to be planned
Green Belt Design for Six Sigma	4	HI	1 February 2021
RF1 Life Data Analysis and Reliability Testing	3	HI	15 March 2021
Ultra-Precision Manufacturing and Metrology	5	CRANF	19 January 2021
SPECIFIC			
Applied Optics (T2Prof)	6.5	HTI	to be planned (Q1 2021)
Advanced Optics	6.5	MC	4 March 2021
Machine Vision for Mechatronic Systems (MA)	2	HTI	upon request
Electronics for Non-Electronic Engineers – Analog (T2Prof)	6	HTI	to be planned
Electronics for Non-Electronic Engineers – Digital (T2Prof)	4	HTI	to be planned
Modern Optics for Optical Designers (T2Prof) - part 1	7.5	HTI	to be planned (Q1 2021)
Modern Optics for Optical Designers (T2Prof) - part 2	7.5	HTI	to be planned (Q1 2021)
Tribology	4	MC	9 March 2021
Basics & Design Principles for Ultra-Clean Vacuum (MA)	4	HTI	2 November 2020
Experimental Techniques in Mechatronics (MA)	3	HTI	30 November 2020
Advanced Motion Control (MA)	5	HTI	11 October 2021
Advanced Feedforward & Learning Control (MA)	2	HTI	23 June 2021
Advanced Mechatronic System Design (MA)	6	HTI	to be planned (2021)
Passive Damping for High Tech Systems (MA)	3	HTI	17 November 2020
Finite Element Method	2	MC	29 October 2020
Design for Manufacturing (Schout DfM)	3	HTI	8 April 2021

ECP² program powered by euspen

The European Certified Precision Engineering Course Program (ECP²) has been developed to meet the demands in the market for continuous professional development and training of post-academic engineers (B.Sc. or M.Sc. with 2-10 years of work experience) within the fields of precision engineering and nanotechnology. They can earn certification points by following selected courses. Once participants have earned a total of 45 points, they will be certified. The ECP² certificate is an industrial standard for professional recognition and acknowledgement of precision engineering-related knowledge and skills, and allows the use of the ECP² title.

WWW.ECP2.EU

Course providers

- High Tech Institute (HTI)
  WWW.HIGHTECHINSTITUTE.NL
- Mikrocentrum (MC)
  WWW.MIKROCENTRUM.NL
- LiS Academy (LiS)
  WWW.LISACADEMY.NL
- Holland Innovative (HI)
  WWW.HOLLANDINNOVATIVE.NL
- Cranfield University (CRANF)
  WWW.CRANFIELD.AC.UK
- Univ. of Huddersfield (HUD)
  WWW.HUD.AC.UK
- National Physical Lab. (NPL)
  WWW.NPL.CO.UK

Content partners

- DSPE
  WWW.DSPE.NL
- Mechatronics Academy (MA)
  WWW.MECHATRONICS-ACADEMY.NL
- Technical Training for Prof. (T2Prof)
  WWW.T2PROF.NL
- Schout DfM
  WWW.SCHOUT.EU
- Systems & Software Academy (S&SA)

SAS joins the RoboValley community

Last month it was announced that SAS, a world leader in advanced analytics, has joined the community of RoboValley, the robotics ecosystem around Delft University of Technology (NL). RoboValley's aim is to drive the development of cognitive robotics that can contribute to addressing major societal problems, such as climate change, ageing societies, growing world population and food shortage. In addition, in manufacturing – through the application of artificial intelligence and intelligent machines – robotics can put an end to dull, dangerous and dirty jobs.
"Many initiatives in robotics – also within RoboValley – are mainly concerned with optimising for a specific task", Jaimy Siebel, managing director of RoboValley, declares. "Natural collaboration between people and robots tends to get less attention, but it could really improve wellbeing in the workplace. We call this symbiotic robotics. SAS may help robot developers, because data analytics can give you a handle on what actually happens during collaboration."

For entrepreneurial collaborations, SAS has initiated the D[N]A Lab, which is represented in Delft. The open-innovation platform for companies, start-ups and scale-ups with a positive impact on society supports projects in the domains of what they call 'Healthy Life, Healthy Planet', which includes agri-food and nutrition, sports and healthcare, and all climate-change-related fields like mobility, energy, waste, and water, in order to help innovations become 'enterprise-worthy' and 'scalable-ready'. SAS has already teamed up with the Delft student team Project MARCH. The goal is to use data analysis for creating feedback loops from the robot, in this case an exoskeleton, to the human pilot. This should enable the pilot to move more naturally and intuitively.

Project MARCH, part of the Delft robotics community and supported by SAS, has taken up the challenge to build an exoskeleton for people with a spinal cord injury.

WWW.ROBOVALLEY.COM
WWW.SAS.COM
WWW.PROJECTMARCH.NL

New Robotics master's programmes

Delft University of Technology has started a Robotics master's degree programme, at the intersection of mechanical engineering and artificial intelligence. The M.Sc. Robotics programme offers students a multidisciplinary education, allowing them to develop innovative and intelligent products and systems that meet today's challenges. The focus of the programme is on the interaction between humans and machines. Students will learn how to model, design, and control robotic systems, how to analyse, evaluate, and validate robotic systems in complex environments, and how to relate scientific knowledge to robotic systems, by critically considering their interaction with societal aspects. The future robotics engineer will supervise the transition towards further robotisation of society.

Meanwhile, University of Twente (UT) has started to offer a specialisation in Robotics, combining mechanical engineering with either electrical engineering, software programming or biomedical engineering. Within this specialisation, three topics are offered: Medical Robotics, Precision Robotics and Industrial Robotics. Students will be involved in the Twente Robotics programme, focused on human-centred robotics. As of September 2021, the UT offers a full Robotics master's programme.

Saxion University of Applied Sciences, located in Enschede (NL), plans to offer a new master's degree programme, Robotics Systems Engineering, also starting September 2021. Graduates will combine knowledge of robotics with skills in systems engineering. As 'investigative designers' they will contribute to the development of new robotic systems in various application areas. They will oversee engineering projects from a technical perspective and take the relevant business processes into account.

WWW.TUDELFT.NL
WWW.UTWENTE.NL
WWW.SAXION.NL

Flattening drives

To minimise installation requirements, drive specialist Faulhaber has extended its BXT flat motor series by adding corresponding gearheads and integrated encoders as well as speed controllers that are also exceptionally short in the axial direction. There are three sizes, which can solve many different drive challenges. In the case of a lower-arm prosthesis, for example, the smallest drive with a diameter of 22 mm would be ideal for the hand and the 16 mm long motor for the elbow. Other possible applications for the small compact drive systems are robot grippers, industrial automation, humanoid robots and even bio-robotics for motorised – i.e. power-assisting – hand exoskeletons. Thanks to their precise speed control properties, they are also suitable for e.g. dialysis machines or medical pumps.

The motors were developed based on the classic external rotor design. Thanks to innovative winding technology and optimised construction, the brushless DC-servomotors produce torques up to 134 mNm within a diameter of 22 mm, 32 mm or 42 mm, and deliver a continuous output of up to 100 W with a high level of efficiency. This means the compact motors significantly exceed the standards usual in this drive class. Particularly the ratio of torque to installation space and weight is much better than what is common on the market. Thanks to the high copper filling factor and the design of the pole shoes, the magnetic field is strong and the cogging torque very small. The motors, which operate at speeds up to 10,000 rpm, are available with or without a housing, which again extends the range of potential applications.

The compact, high-torque GPT metal planetary gearhead family is suitable for speed reduction of the flat motors, offering reduction ratios from 3:1 to 1,294:1 with extremely fine graduations in up to four stages. Each stage was optimised for high performance with respect to torque and speed. Depending on the diameter, the gearheads achieve continuous torques of 1, 8 or 18 Nm. Higher torques are also possible for a short period.

All BXT motors are equipped with digital Hall sensors for speed control and a magnetic encoder is available for precise positioning tasks. Thus, a wide speed range from 200 rpm to 10,000 rpm is available. The compact combination of motor and speed controller is ideal for space-critical applications and simplifies installation and commissioning.

WWW.FAULHABER.COM

Motor Control Blockset for algorithm development

To help designers in the aerospace, automotive and other high-end industries get the most out of their motor controller, for example to maximise powertrain efficiency, MathWorks has introduced Motor Control Blockset. This is an add-on product for designing and implementing motor control algorithms in Simulink, MathWorks' graphical environment for simulation and model-based design for multi-domain dynamic and embedded systems.

Now, motor control engineers can use reference examples (showing motor control with Hall and Quadrature Encoder sensors, as well as sensorless control) and Simulink blocks for developing field-oriented low-level control algorithms to spin brushless motors, such as surface-mount PMSMs (permanent-magnet synchronous motors), interior PMSMs, and induction motors. The blockset extends the set of Simulink products for motor control design, enabling engineers to test algorithms with each design change, generate fast and compact ANSI/ISO C code, and use simulation to validate software, reducing certification testing cycles.

Engineers can use simulation and code generation to catch errors earlier (i.e., preferably in the early design stages and definitely before physical testing) and speed up their motor control development projects, MathWorks claims. MathWorks is working with motor control hardware providers to develop reference examples that support their motor control kits, starting with several Texas Instruments kits based on their C2000 real-time microcontrollers. Engineers using these kits can automatically estimate motor parameters (from experiments with motor hardware, by deploying instrumented tests), generate application code, and spin motors in minutes (parameter estimation is set up with TI C2000, to which any motor can be connected). Additionally, Simulink Real-Time and the Speedgoat electric motor control kit enable rapid control prototyping, including field-oriented control autotuning.

WWW.MATHWORKS.COM/PRODUCTS/MOTOR-CONTROL.HTML

Precision podcast

Zygo Corporation has announced a new podcast series "Metrology Matters", on Spotify and Apple Music. It addresses relevant topics related to precision surface metrology, featuring independent thought leaders from both academia and industry.

WWW.ZYGO.COM

The first episode in the series is entitled "What is Metrology, and Why Does it Matter?"

Maxon and ANYbotics enter into a strategic partnership

Drive specialist maxon, renowned for its Mars motors, is joining forces with the robotics start-up ANYbotics and will in future supply the drive systems of the autonomous ANYmal inspection robot. The robot will soon be marketed in large quantities. ANYmal is an autonomous, four-legged robot that is capable of inspecting and monitoring industrial systems and is destined to also take on dangerous maintenance tasks in the future. The robot can even cope with difficult infrastructures such as stairs and inclines, and is used in a wide variety of industries. The cooperation will also benefit maxon, since ANYbotics provides important robotics know-how. ANYbotics, a 2016 spin-off from the ETH Zurich university of science and technology, recently won the Swiss Economic Award 2020 and has been chosen as the best young entrepreneur in Switzerland in the hightech/biotech category. The two Swiss partners want to create an energy-efficient and intelligent robotic drive. To further cement the partnership, the two companies are also getting closer geographically: maxon is opening a lab at the Züri.ch Campus in Zürich, in close proximity to ANYbotics.

ANYbotic's four-legged ANYmal robot was developed for inspecting and monitoring industrial systems and taking on dangerous maintenance tasks.

WWW.MAXONGROUP.COM
WWW.ANYBOTICS.COM

Etteplan takes over Tegema

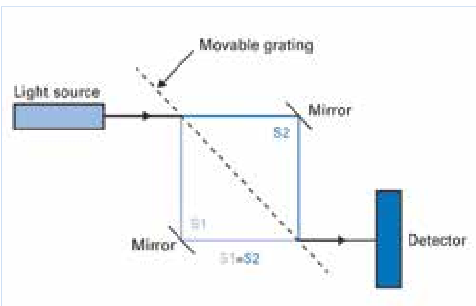
The Finnish company Etteplan has strengthened its production-related competences and know-how by acquiring Tegema. Etteplan is a leading engineering and software services company in Europe. As a production system integrator, Tegema, headquartered in Son (NL), provides production solutions, production cells and equipment for customers in the field of semiconductors, electronics, mobility, photonics and medical. The acquisition is another step in Etteplan's international growth and marks its start for engineering services in the Netherlands. After the acquisition, Etteplan employs some 200 people in the Netherlands in five different locations. Here, Etteplan started its operations in 2012 through the acquisition of Tedopres technical documentation business. In 2019, Etteplan acquired technical documentation specialist Triview Technical Communication from Soesterberg.

WWW.ETTEPLAN.COM
WWW.TEGEMA.NL

Nanoprecision over large travel ranges

Piezo-stepping drives or magnetic drives enable high-precision positioning over large travel ranges. However, high resolution and linearity over large travel ranges can only be achieved with highest resolution measuring systems and methods. For conventional nanopositioning with piezo actuators and travel ranges up to 1 mm, capacitive sensors achieve a resolution in the sub-nanometer range and very high stability and linearity.
However, capacitive measuring systems reach their limits for measuring ranges from approx. 1 mm; resolution and linearity decrease or the size of the active sensor area increases and thus also the required installation space. Incremental position sensors are therefore used for larger travel ranges. However, the linear encoders available on the market are often insufficient for the requirements of nanopositioning mechanics. Therefore, PI developed the PIOne incremental position sensor. Its sensor head contains a Mach-Zehnder interferometer, where the optical paths are equalised and fully symmetrical, compensating for environmental influences such as temperature and humidity. The sensor achieves a resolution of 20 picometers and better, thanks to its small signal period of 0.5 µm and optimised signal processing. In this instance, interpolation with a factor of 4,000 is possible without any noise.

The PIOne high-resolution linear sensor developed by PI ensures a position resolution of far less than one nanometer with adequate measurement analysis. Travel ranges are preferably > 1 mm, the accuracy class of the grating is 150 nm/30 cm.



Schematic diagram of a Mach-Zehnder interferometer with equalized beam paths. A beam coming from a laser diode is split into two optical beam paths when passing between two gratings and then united to a single beam again. The created interference pattern is detected by a photodiode and then processed further.

New touch probe for grinding

Heidenhain has developed the highly accurate and robust TS 750 workpiece touch probe specifically for grinding machines as a means to ensure in-process quality. Featuring very compact dimensions with a diameter of only 25 mm, it achieves an excellent probing repeatability of $2\sigma \leq 0.25$ µm. The probing speed of up to 1 m/min makes it possible to inspect parts quickly without lengthy non-productive times. The TS 750 offers extremely homogeneous probing accuracy over 360° and features particularly long-lasting pressure sensors for several million probing procedures as well as numerous mounting options.

WWW.HEIDENHAIN.COM

Down to 2.5 nm resolution

The VIONiC encoder series, now available in resolutions down to 2.5 nm, is Renishaw's highest performing incremental optical encoder. It provides direct digital position feedback with superior metrology, fast speeds and high reliability, according to Renishaw. The VIONiC readhead integrates Renishaw's filtering optics and advanced interpolation technology. This provides ultralow sub-divisional error (SDE) and excellent dirt immunity, and eliminates the need for additional adaptors or separate interfaces. VIONiC readheads are compatible with a wide range of linear, partial arc and rotary scales, from low-expansion ZeroMet to high-accuracy REXM rings. This makes it a versatile product suitable for a wide variety of applications. Designed with intuitive auto-calibration mode, VIONiC readheads are easy to install. An optional Advanced Diagnostic Tool ADTi-100 is available for real-time encoder data feedback during installation or for in-field diagnostics.

WWW.RENISHAW.COM

Additive Manufacturing / 3D metal printing

Raytech
Dirk Martensstraat 3A
8200 Brugge
Belgium
T +32 (0)50 45 44 05
E info@raytech.be
W www.raytech.be

Raytech offers 3D metal printing (titanium & aluminium) with a strong focus on small and accurate components. Optional treatments after 3D printing: laser welding – laser engraving – cleaning – polishing.

Automation Technology

Festo BV
Schieweg 62
2627 AN DELFT
The Netherlands
T +31 (0)15-2518890
E sales@festo.nl
W www.festo.nl
Contact person:
Mr. Michiel Deen

Festo is a leading world-wide supplier of automation technology and the performance leader in industrial training and education programs.

member DSPE

Cleanrooms

Brecon Group
Droogdokkeneiland 7
5026 SP Tilburg
T +31 (0)76 504 70 80
E brecon@brecon.nl
W www.brecon.nl

Brecon Group can attribute a large proportion of its fame as an international cleanroom builder to continuity in the delivery of quality products within the semiconductor industry, with ASML as the most important associate in the past decades.

Brecon is active with cleanrooms in a high number of sectors on:
* Industrial and pharmaceutical
* Healthcare and medical devices

member DSPE

Connect 2 Cleanrooms BV
Newtonlaan 115
Zen Building
3584 BH Utrecht
Nederland
T +31 (0)30 210 60 51
E info@connect2cleanrooms.com
W www.connect2cleanrooms.nl

Developing the most appropriate cleanroom to transform your production is our passion. Our scalable and connected cleanrooms have been delivering regulatory compliance to our clients since 2002. We innovate to overcome your contamination control challenges – resulting in a new generation of scalable cleanrooms that set an unprecedented benchmark in the industry.

member DSPE

Development

TNO
T + 31 (0)88-866 50 00
W www.tno.nl

TNO is an independent innovation organisation that connects people and knowledge in order to create the innovations that sustainably boosts the competitiveness of industry and wellbeing of society.

member DSPE

Development and Engineering

Segula Technologies Nederland B.V.
De Witbogt 2
5652 AG Eindhoven
T +31 (0)40 8517 500
W www.segula.nl

SEGULA Technologies Nederland BV develops advanced intelligent systems for the High Tech and Automotive industry. As a project organisation, we apply our (engineering) knowledge to non-linear systems. This knowledge is comprised of systems architecture and modelling, analysis, mechanics, mechatronics, electronics, software, system integration, calibration and validation.

member DSPE

Education

Leiden school for Instrumentmakers (LiS)
Einsteinweg 61
2333 CC Leiden
The Netherlands
T +31 (0)71-5681168
E info@lis.nl
W www.lis.nl

The LiS is a modern level 4 MBO school with a long history of training Research instrumentmakers. The school establishes projects in cooperation with industry and scientific institutes thus allowing for professional work experience for our students. LiS TOP accepts contract work and organizes courses and summer school programs for those interested in precision engineering.

member DSPE

Electrical Discharge Machining (EDM)

CVT precisie draadvonken

CVT BV
Heiberg 29C
5504 PA Veldhoven
The Netherlands
T +31 (0)497 54 10 40
E info@cvtbv.nl
W www.cvtbv.nl

Partner high tech industry for wire EDM precision parts. Flexible during day shifts for prototyping. Outside office hours low cost unmanned machining. Call and enjoy our expertise!

member DSPE

terhoek edm & precision solutions

Ter Hoek Vonkerosie
Propaanstraat 1
7463 PN Rijssen
T +31 (0)548 540807
F +31 (0)548 540939
E info@terhoek.com
W www.terhoek.com

INNOVATION OF TOMORROW, INSPIRATION FOR TODAY
Staying ahead by always going the extra mile. Based on that philosophy, Ter Hoek produces precision components for the high-tech manufacturing industry.

We support customers in developing high-quality, custom solutions that can then be series-produced with unparalleled accuracy. That is what makes us one of a kind.
It is in that combination of innovative customization and repeated precision that we find our passion. Inspired by tomorrow's innovation, each and every day.

member DSPE

Lasers, Light and Nanomotion

LASER 2000

Laser 2000 Benelux C.V.
Voorbancken 13a
3645 GV Vinkeveen
Postbus 20, 3645 ZJ Vinkeveen
T +31(0)297 266 191
F +31(0)297 266 134
E info@laser2000.nl
W www.laser2000.nl

Laser 2000 Benelux considers it her mission to offer customers the latest photonics technologies available.
Our areas of expertise are:

- Lasers, scanners and laser machines for industry and research
- Light metrology instruments for LED and luminaire industries
- Light sources for scientific applications
- Piezo- and stepper motion products for nano- and micro positioning
- Inspection and research grade high speed cameras
- Laser safety certified products

TLS te lintelo systems bv
photonics. our passion!
35 YEARS

Te Lintelo Systems B.V.
Mercurion 28A
6903 PZ Zevenaar
T +31 (0)316 340804
E contact@tlsbv.nl
W www.tlsbv.nl

Photonics is our passion!
Our experienced team is fully equipped to assist you with finding your best optical business solution. For over 35 years TLS represent prominent suppliers in the photonics industry with well-educated engineers, experience and knowledge.
Over the years we became the specialist in the field of:

- Lasers
- Light metrology,
- Opto-electronic equipment,
- Positioning equipment
- Laser beam characterization and positioning,
- Interferometry,
- (Special) Optical components,
- Fiber optics,
- Laser safety

Together with our high end suppliers we have the answer for you!

member DSPE

Mechatronics Development

SIOUX TECHNOLOGIES

Sioux Mechatronics Competence Centre
De Pinckart 24
5674 CC Nuenen
T +31 (0)40 2635000
E info.ccm@sioux.eu
W www.sioux.eu

Sioux Technologies is a global technology partner that supports or acts as the R&D department for high-tech companies. We help leading companies with the development, industrialization and creation of their products, from concept stage to a prototype and/or delivery of series production. Commitment, motivation, education and skills of our employees are the solid basis for our business approach. Together with the customer, we bring high-tech to life.

member DSPE

MTA creating machines together

MTA B.V.
Maisdijk 12
5704 RM Helmond
T +31 (0)492 474992
E info@m-t-a.nl
W www.m-t-a.nl

MTA is an high-tech system supplier specialized in the development and manufacturing of mechatronic machines and systems.
Our clients are OEM s in the Packaging, Food, Graphics and High-tech industries.

member DSPE

Mechatronics Development

MI-Partners
Habraken 1199
5507 TB Veldhoven
The Netherlands
T +31 (0)40 291 49 20
F +31 (0)40 291 49 21
E info@mi-partners.nl
W www.mi-partners.nl

MI-Partners is active in R&D of high-end mechatronic products and systems. We are specialised in concept generation and validation for ultra-fast (>10g), extremely accurate (sub-nanometers) or complex positioning systems and breakthrough production equipment.

member DSPE

Metal Precision Parts

Etchform BV
Arendstraat 51
1223 RE Hilversum
T +31 (0)35 685 51 94
F info@etchform.com
W www.etchform.com

Etchform is a production and service company for etched and electroformed metal precision parts.

member DSPE

Micro Drive Systems

maxon benelux
Josink Kolkweg 38
7545 PR Enschede
The Netherlands
F +31 53 744 0 713
E info@maxongroup.nl
W www.maxongroup.nl

maxon is a developer and manufacturer of brushed and brushless DC motors, as well as gearheads, encoders, controllers, and entire mechatronic systems. maxon drives are used wherever the requirements are particularly high: in NASA's Mars rovers, in surgical power tools, in humanoid robots, and in precision industrial applications, for example. To maintain its leadership in this demanding market, the company invests a considerable share of its annual revenue in research and development. Worldwide, maxon has more than 3000 employees at nine production sites and is represented by sales companies in more than 30 countries.

member DSPE

Micro Drive Systems

FAULHABER Benelux B.V.
Drive Systems
High Tech Campus 9
5656 AE Eindhoven
The Netherlands
T +31 (0)40 85155-40
E info@faulhaber.be
E info@faulhaber.nl
W www.faulhaber.com

FAULHABER specializes in the development, production and deployment of high-precision small and miniaturized drive systems, servo components and drive electronics with output power of up to 200 watts. The product range includes brushless motors, DC micromotors, encoders and motion controllers. FAULHABER also provides customer-specific complete solutions for medical technology, automatic placement machines, precision optics, telecommunications, aerospace and robotics, among other things.

Physik Instrumente (PI)
Benelux BV
Hertog Hendrikstraat 7a
5492 BA Sint-Oedenrode
The Netherlands
T +31 (0)499-375375
F +31 (0)499 375373
E benelux@pi.ws
W www.pi.ws

Stay ahead with drive components, positioners and systems by PI. In-depth knowledge, extensive experience and the broadest and deepest portfolio in high-end nanopositioning components and systems provide leading companies with infinite possibilities in motion control.

member DSPE

Motion Control Systems

Aerotech United Kingdom
The Old Brick Kiln
Ramsdell, Tadley
Hampshire RG26 5PR
UK
T +44 (0)1256 855055
F +44 (0)1256 855649
W www.aerotech.co.uk

Aerotech's motion control solutions cater a wide range of applications, including medical technology and life science applications, semiconductor and flat panel display production, photonics, automotive, data storage, laser processing, electronics manufacturing and testing.

Motion Control Systems

Newport Spectra-Physics B.V.
Vechtensteinlaan 12 - 16
3555 XS Utrecht
T +31 (0)30 6592111
E netherlands@newport.com
W www.newport.com

Newport Spectra-Physics B.V. is a subsidiary of Newport, a leader in nano and micro positioning technologies with an extensive catalog of positioning and motion control products. Newport is part of MKS Instruments Inc., a global provider of instruments, subsystems and process control solutions that measure, control, power, monitor, and analyze critical parameters of advanced processes in manufacturing and research applications.

member DSPE

Physik Instrumente (PI)
Benelux BV
Hertog Hendrikstraat 7a
5492 BA Sint-Oedenrode
The Netherlands
T +31 (0)499-375375
F +31 (0)499 375373
E benelux@pi.ws
W www.pi.ws

Opt for state-of-the-art motion control systems from the world's leading provider PI. Developed, manufactured and qualified in-house by a dedicated and experienced team. Our portfolio includes a wide and deep range of components, drives, actuators and systems and offers infinite possibilities in motion control on a sub-micron and nanometer scale.

member DSPE

Optical Components

Molenaar Optics
Gerolaan 63A
3707 SH Zeist
T +31 (0)30 6951038
E info@molenaar-optics.nl
W www.molenaar-optics.eu

Molenaar Optics is offering optical engineering solutions and advanced products from world leading companies OptoSigma, Sill Optics and Graticules Optics.

member DSPE

Piezo Systems

HEINMADE BV
Heiberg 29C
NL - 5504 PA Veldhoven
T +31 (0)40 851 2180
E info@heinmade.com
W www.heinmade.com

As partner for piezo system solutions, HEINMADE serves market leaders in the high tech industry. Modules and systems are developed, produced and qualified in-house.

member DSPE

Piezo Systems

Physik Instrumente (PI)
Benelux BV
Hertog Hendrikstraat 7a
5492 BA Sint-Oedenrode
The Netherlands
T +31 (0)499-375375
F +31 (0)499 375373
E benelux@pi.ws
W www.pi.ws

High-precision piezo systems and applications that perform on a sub-micron and nanometer scale: world leader PI develops, manufactures and qualifies these in-house. With a broad and deep portfolio with infinite possibilities in components, drives, actuators and systems at hand, our experienced team is dedicated to find the best solution for any motion control challenge.

member DSPE

Precision Electro Chemical Machining

Ter Hoek Vonkerosie
Propaanstraat 1
7463 PN Rijssen
T +31 (0)548 540807
F +31 (0)548 540939
E info@terhoek.com
W www.terhoek.com

As Application Centre we possess the required knowledge to support our clients in every phase of development and process selection.
With our own PEM800 machine we can also use PECM in-house for the benefit of our clients.

member DSPE

Ultra-Precision Metrology & Engineering

IBS Precision Engineering
Esp 201
5633 AD Eindhoven
T +31 (0)40 2901270
F +31 (0)40 2901279
E info@ibspe.com
W www.ibspe.com

IBS Precision Engineering delivers world class measurement, positioning and motion systems where ultra-high precision is required. As a strategic engineering partner to the world's best manufacturing equipment and scientific instrument suppliers, IBS has a distinguished track record of proven and robust precision solutions. Leading edge metrology is at the core of all that IBS does. From complex carbon-fibre jet engine components to semiconductor chips accurate to tens of atoms; IBS has provided and engineered key enabling technologies.

member DSPE

ADVERTISERS INDEX


HEIDENHAIN
Can exact positioning
be effortless?
Putting a thread through the eye of a needle is a real challenge even for a very steady hand and a keen eye. After all, it requires grasping very small objects with pinpoint accuracy, moving them through space without collision and then placing them exactly. To succeed at such complex tasks and procedures, articulated robots need to move up to seven synchronized servomotors very dynamically and accurately. With HEIDENHAIN rotary encoders for motor feedback and additional HEIDENHAIN angle encoders as position encoders, your success is indeed effortless.
HEIDENHAIN NEDERLAND B.V.
6716 BM Ede, Netherlands
Phone 0318-581800
www.heidenhain.nl
Angle Encoders + Linear Encoders + Contouring Controls + Digital Readouts + Length Gauges + Rotary Encoders