Ostfalia
University of
Applied Sciences

3rd Edition

OSTFALIA I4.0 CATALOG

Demonstrators of
Industry 4.0 Technology

Created in context of the project **GrowIn 4.0 – Growing into Industry 4.0 · Accelerate Growth in Manufacturing SMEs**, funded by the Interreg North Sea Region programme resourced by the European Regional Development Fund.

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In order to show various technical possibilities how companies can take time-, resource- and cost-saving steps towards digitization, Ostfalia's "GrowIn 4.0" project team has compiled a catalog of demonstrators of several Industry 4.0 technologies, which is being continuously expanded.

The "Ostfalia I4.0 Catalog" is intended to illustrate the potential of digitization measures and also to encourage interested companies to have a look at the technologies in use and to talk about cooperation opportunities for their development.

CONTENTS

Production of Components and Industrial Prototypes with 3D Printing

More information:
www.ostfalia.de/en/forschung/research-centres/zaf

I4.0 application(s):
Rapid Prototyping, Rapid Tooling, Rapid Manufacturing

I4.0 technology(-ies):
Additive manufacturing, simulation/compensation of thermal distortion

Functional description:
Manupulation of different materials like e.g. AlSi10Mg, PA12, PA6 with carbon short fibers, DM20 (bronze-based metal powder), PLA, ABS, PEEK and many more in a layer-by-layer process.

Possible problem-solving/process optimization:
Prime example for the complete digitization of the process chain, application is only possible by means of digitization. Construction of tools and components in small batches (beginning at quantities of 1), construction of (functional) prototypes.

The waste of material by faulty prototypes (possibly made of the target material) is reduced, which results in resource-saving development. The development of products is accelerated, production costs are considerably reduced (especially when compared to outsourced production).

Technical structure:
Existing 3D printing methods:
selective Laser melting (metal),
selective Laser sintering (plastics),
stereolithography (synthetic resin),
fused layer manufacturing (plastics, also with fiber reinforcement),
polyjetting (plastics)

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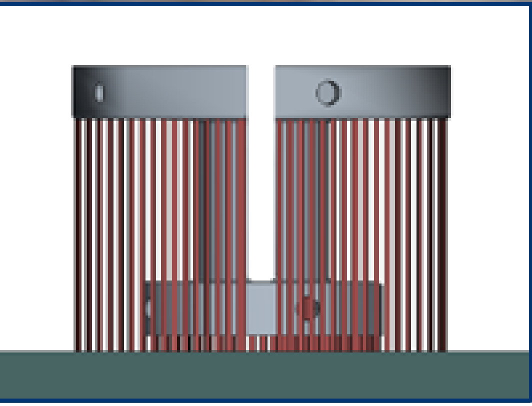
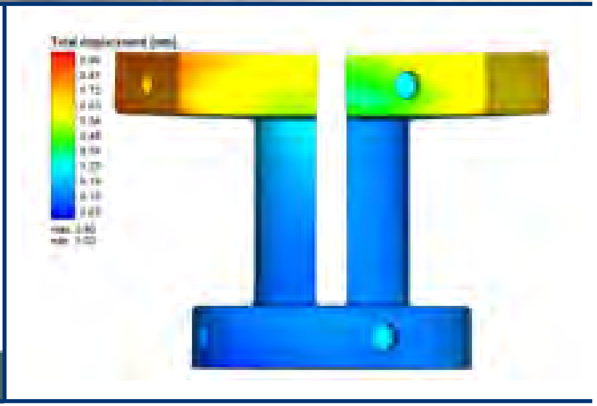
Virtual Dimensioning of Additively Manufactured Components

More information:
www.ostfalia.de/ipt





I4.0 application(s):
Rapid Prototyping, Rapid Tooling, Rapid Manufacturing

I4.0 technology(-ies):
Topology opt., simulation/compensation of distortion, use of construction space

Functional description:
The "Siemens NX" software is used to optimize the topology of metal and plastic components depending on the effective force flow and with "Simufact Additive" the mechanical simulation of various metallic materials such as AlSi10Mg is carried out; for thermomechanical simulation further material parameters are required. Finally, "Materialise Magics" is used to adapt support structures for minimum material use and to optimise the alignment and positioning of components in the construction space in such a way that maximum utilisation of the production facilities and efficient use of materials prevails.

Possible problem-solving/process optimization:
The process chain is completely digitalized. The measurement (optical, tactile) of manufactured components contributes to the gain of information and the validation of the preceding process steps. In this way it will be possible to proceed according to a best practice in the future. Production resources are conserved, less material is wasted due to defective components and superfluous support structure. Output is significantly increased.

Technical structure:
Siemens NX (to create the model), Materialise Magics (to calculate the component incl. support structure/"component anchors") and Simufact Additive (to simulate the warpage and recalculate it accordingly for compensation) are used. A 3D scanner/coordinate measuring device measures the sintered test objects to an accuracy of a hundredth of a millimeter (mechanical approach).

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Digital Assistance Systems in (Warehouse) Logistics

More information:
www.ostfalia.de/h/forschung/forschungsprojekte/projekt-digassla

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I4.0 application(s):
Intelligent Commissioning, Intelligent Process Support in the Warehouse

I4.0 technology(-ies):
Pick-by-Scan, Pick-by-Light, Pick-by-Vision, Augmented/Digital Reality

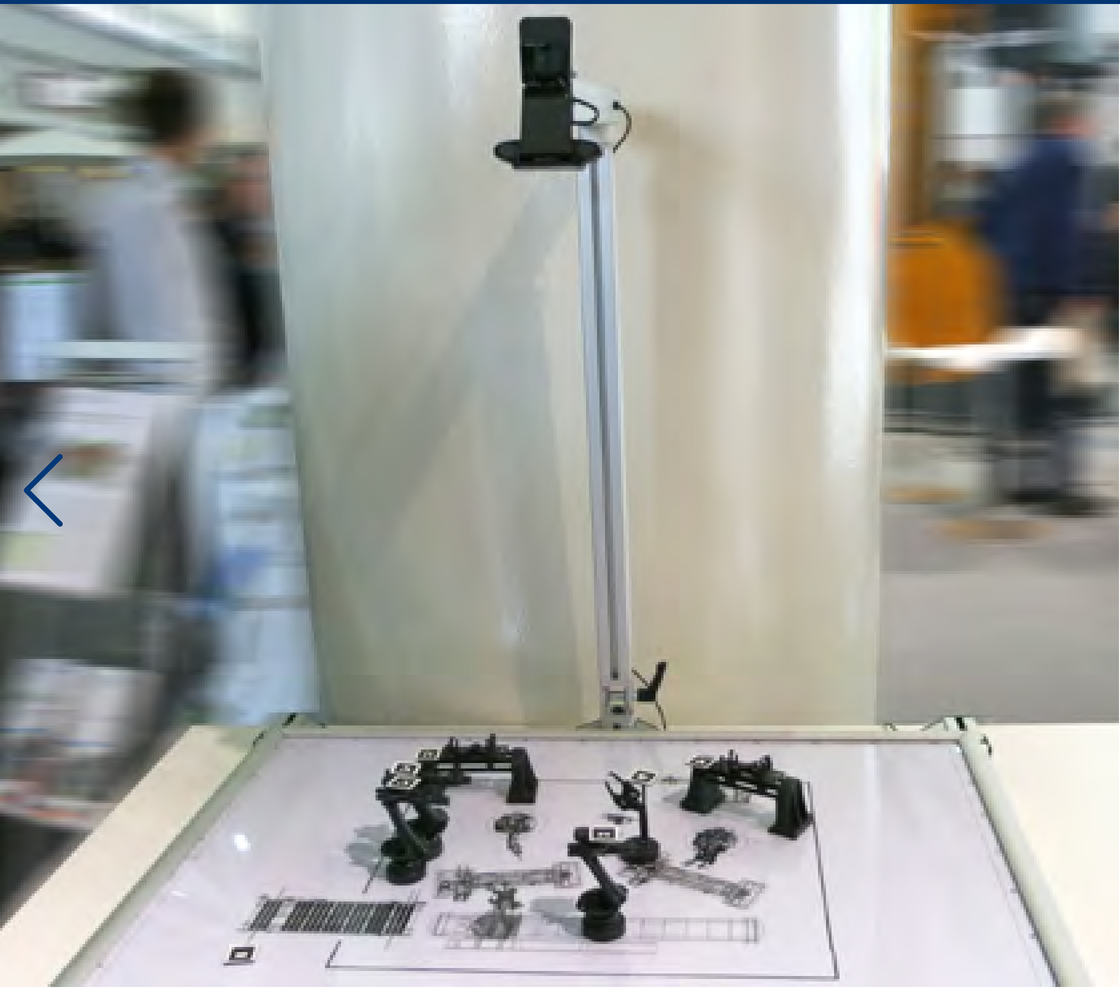
Functional description:
Companies that already maintain an inventory management system with real-time inventory lists of the warehouse can make use of the picking technologies Pick-by-Scan (the use of a handheld scanner for storage, removal and transfer), Pick-by-Light (sequential assembly of commissioning orders) and Pick-by-Vision (use of data glasses for the same operations). While Pick-by-Scan requires searching the shelves using the available information (e.g. shelf and compartment number), the Pick-by-Light system guides the operator to the required location by illuminating compartment indicators. If Pick-by-Vision is used, the worker is guided to the storage location by the data glasses.

Possible problem-solving/process optimization:
In direct comparison with Pick-by-Scan, which already simplifies inventory control and speeds up stock-taking processes, the use of Pick-by-Light and Pick-by-Vision also supports workers in finding their way around the warehouse. Search times for requested parts are shortened to a minimum, and throughput times in commissioning are reduced. The use of these technologies enables potential savings for operations and ensures increased process reliability thanks to error-free processes.The pick-by-light system also supports assembly processes by providing the specialist with required objects in the correct sequence via the light display. Due to radio-controlled displays, this technology can be used flexibly for changing processes.

Technical structure:
Inventory management system, handheld scanner / gateway with display / data glasses, in-house WiFi, local control computer / server or cloud-based system (Internet connection required).

Digital Planning Table

More information:
www.youtube.com/watch?v=dfG3GiL-YXY



I4.0 application(s):
Visual Layouting: Modeling of production environments

I4.0 technology(-ies):
Marker recognition with ARTToolkit, 3D printing (miniatures), simulation

Functional description:
A miniature of a production machine or any other equipment on production level is created via 3D printing. A marker is placed on that miniature, which is linked to its virtual counterpart – to establish the link, the marker has to be positioned in front of the camera during a learning process. If the miniature is moved on the planning table, position and rotation of the marker are captured and the virtual model is positioned accordingly.

Possible problem-solving/process optimization:
A collaborative element is implemented into the planning process - the personnel, who is going to operate the equipment, can participate in the planning of the production level.
No software knowledge ist required for this, the layouting is done intuitively, while an increased visual thinking will be very helpful (on the future production site, where necessary, as the setup is portable).
As the layout is planned cooperatively, there are less iterations to be done (with external workforce) and costs can probably be reduced.

Technical structure:
Table and camera arm made of item profiles, FullHD USB camera (upgrade to 4k resolution is planned), pc and software: Siemens Process Designer

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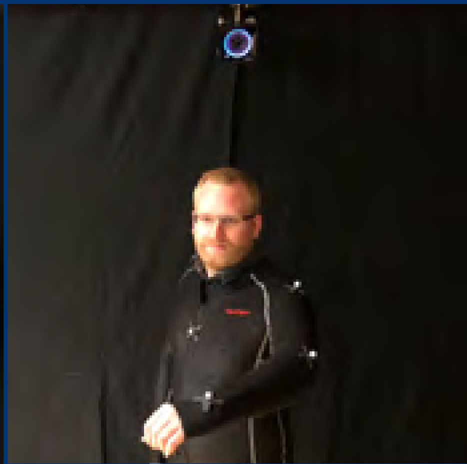
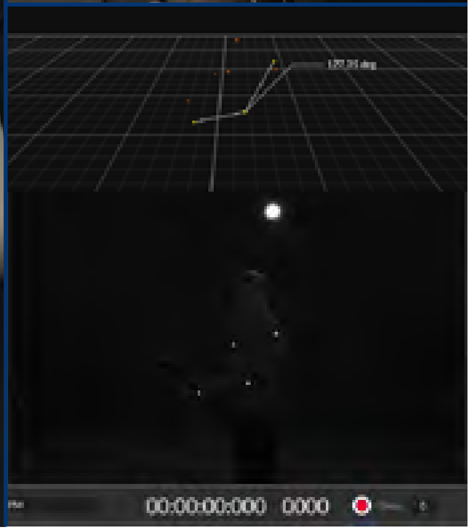
Augmented/Virtual Reality

Motion Tracking with Machine Learning

More information:
www.ostfalia.de/i/fakultaet/institute/imi





I4.0 application(s):
Factory 4.0, Virtual Reality, Ergonomics Computer Models

I4.0 technology(-ies):
Optical Tracking, VR Analytics, Neural Networks

Functional description:
Eight cameras with infrared emitters detect movements of people. A system with "markers" is available, that is, infrared reflectors that are attached to body joints. In this way, all possible degrees of freedom are mapped. The scenes recorded in this way are digitized and transferred to a 3D model. The model can be viewed from all sides on the computer. With the help of machine learning with artificial neural networks, scenes can be interpreted in various application areas.
- Process optimization in production: (How) do people e.g. interact with cobots or with each other?
- Nursing / medical technology: Has a person fallen?
- Working environment / sports: Are movement sequences ergonomically correct?

Possible problem-solving/process optimization:
The transfer of real situations to a digital 3D model is thus possible in a memory-efficient way.The data to be processed per motion sequence can be reduced to a few vectors - although this will still be several gigabytes (up to 360 images/second of 8 cameras with "x" captured vectors), the memory requirement is significantly lower compared to video data with the same recording duration. Subsequent computing operations also run more resource-efficiently.

Technical structure:
Eight OptiTrack Prime 17W cameras connected to a server via Gigabit Ethernet, a suitable network switch is required (purely local application). On the server, the accruing data is collected and interpreted using the OptiTrack Motive software.

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Visualization of Process and Product Data with Augmented Reality

More information:
www.ostfalia.de/ipt

I4.0 application(s):
Maintenance, diagnosis, etc.

I4.0 technology(-ies):
Augmented Reality, Cyber-Physical Systems

Functional description:
The Augmented Reality (AR) glasses insert information on processes and/or products based on server data into the user's field of view, e.g. energy consumption levels of production machinery, material flow or CAD models of the product in creation.

Possible problem-solving/process optimization:
Maintenance and repair processes can be accelerated, if the necessary information are shown directly in an overlay, instead of being searched for in documents, databases or manuals.

Technical structure:
Microsoft HoloLens, server and networking infrastructure

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Self Learning Neural Controllers through Machine Learning

More information:
www.ostfalia.de/en/forschung/research-areas/digitization

I4.0 application(s):
Neural controllers, controller design

I4.0 technology(-ies):
Artificial Intelligence, Machine Learning, Reinforcement Learning

Functional description:
Using neural networks with machine learning and reinforcement learning, a neural controller is developed that independently learns to control a nonlinear technical system – for example in the form of an inverse pendulum.

Open source libraries such as TensorFlow and Keras are used on the Nvidia Jetson edge computer.

Possible problem-solving/process optimization:
The AI-based approach to controller design with machine learning allows controllers to be designed without the human expert effort usually associated with the design process.

Compared to the use of conventional controllers, the layout is done faster and specialist knowledge of control engineering is not absolutely necessary. Also, the edge computer used is less expensive and more versatile than conventional systems for real-time control

Technical structure:
The neural controller is operated on an edge computer like Nvidia Jetson and controls an inverse pendulum in this application example.

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Blockchain in Internet of Things – Application Areas, Properties and Alternatives

More information:
www.ostfalia.de/pws/schiering

I4.0 application(s):
All applications, where integrity and authenticity is important

I4.0 technology(-ies):
Blockchain, merkle trees, communication in IoT networks

Functional description:
Authenticity and integrity of communication in IoT networks is an important requirement. The guarantee of supply chains in Supply Chain Management, secure communication of sensor data in Industry 4.0 and the smart city are a few examples. The aim is to show the properties of an implementation with blockchain technologies.

Possible problem-solving/process optimization:
Blockchain technologies are one way to implement IT security requirements in IoT communications. In addition, this technology also allows to integrate various partners within a workflow or service, as in the smart city or in supply chain management. On the other hand, when deciding on a blockchain or alternative technologies, aspects such as the required computation time for cryptographic operations, the need for storage space and power must also be taken into account.

Technical structure:
IoT blockchain demonstrator, implemented by means of a series of Raspberry Pis and a screen.

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Dynamic Machine to Machine Real Time Communication with Time-Sensitive Networking

More information:
www.ostfalia.de/pws/wermser/forschung-und-entwicklung

I4.0 application(s):
Real Time Communication, Machine to Machine (M2M) Communication

I4.0 technology(-ies):
Time-Sensitive Networking, OPC/UA (Pub/Sub) or MQTT as M2M protocol

Functional description:
Time-Sensitive Networking enables reliable real-time communication at a constant, low latency in Ethernet-based networks.

By means of different standards for time synchronization and traffic scheduling, network traffic is divided into different classes. One or more time slots, in which data transfer is guaranteed, is assigned to every class. A central coordinating instance controls the configuration dynamically.

Possible problem-solving/process optimization:
Dynamic real-time capable data traffic relations between industrial machines can be established and terminated, additionally they can be adapted to changing requirements. Thus, the communication at a production line can be reconfigured to the production criteria of another product in a minimum amount of time.

Technical structure:
TSN-Bridge (e.g. InnoRoute TrustNode, NXP LS1021ATSN or TTTech DE-Switch Akro 6/0 TSN), central coordinating instance, terminals

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Internet of Things Radio Networks in Example Testing- and Tab-Environments

More information:
www.ostfalia.de/en/forschung/research-areas/digitization/rg_iot

I4.0 application(s):
Internet of Things (IoT): Predictive Maintenance

I4.0 technology(-ies):
LoRa, LoRa Radio, LoRaWAN, Bluetooth 5.0, SigFox, WiFi

Functional description:
Transmitter and receiver (concentrator) modules enable efficient data exchange in 433 MHz / 868 MHz / 2,4 GHz bands, licensed (SigFox) or free, narrow-band or ultra-narrow-band at low transmission rates.

Possible problem-solving/process optimization:
Short range or medium range transmission of sensor data without difficult / expensive retrofitting, energy-saving operation of sensors (partly even battery operation for years).

Technical structure:
Several projects: ‚Feather' modules (433MHz band), WiFi modules, LoRaWAN modules (transmitters and concentrators), partly in test environments or in lab environments.

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M2M Communication with the Hermes Standard

More information:
www.ostfalia.de/ipt

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I4.0 application(s):
Machine-to-Machine (M2M) Communication

I4.0 technology(-ies):
Hermes Standard as M2M protocol, Ethernet

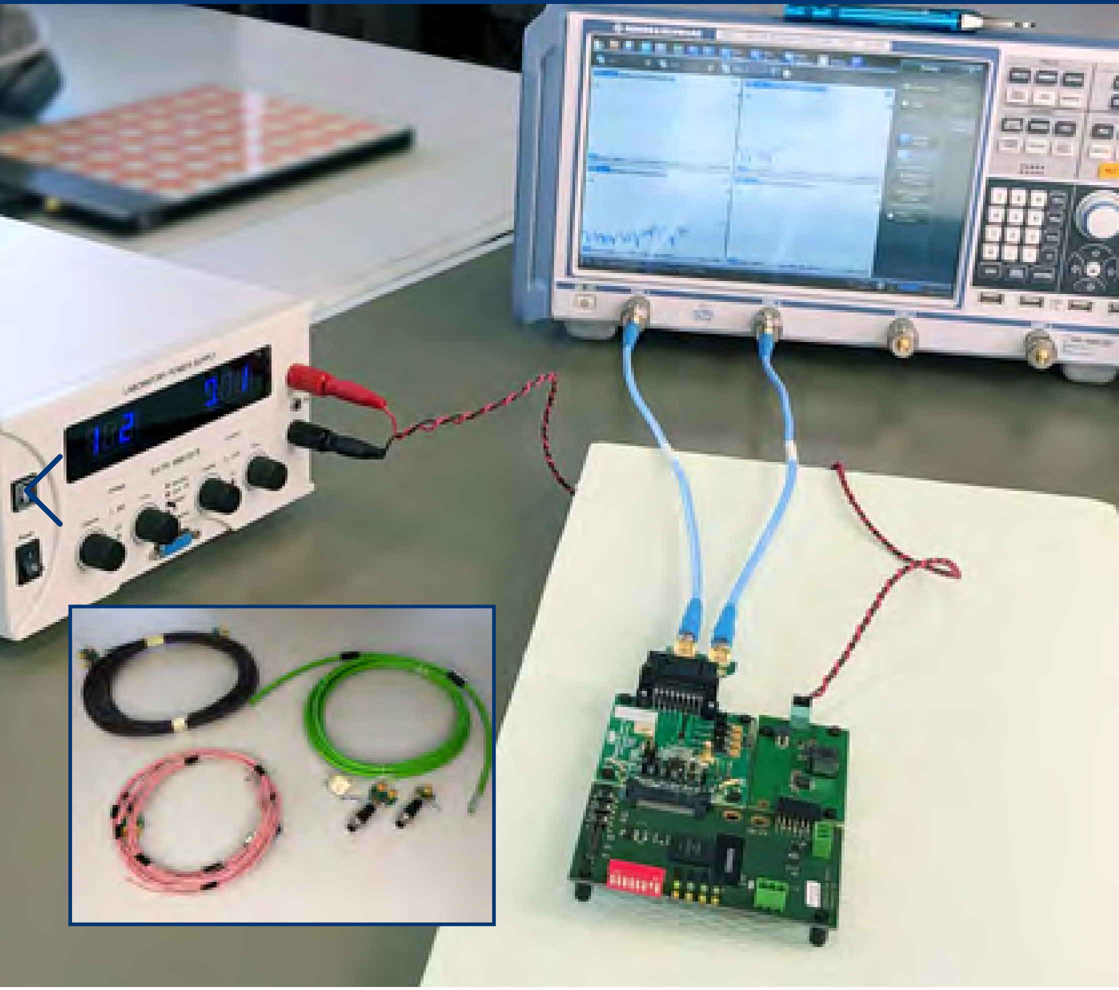
Functional description:
IPC-HERMES-9852 is an open source standard based on the well-known TCP/IP protocol. Via Ethernet, small amounts of data are exchanged in XML format between machines of a production line. The machines can either be connected directly (peer-to-peer) or via an existing network infrastructure. Each production machine establishes a connection to downstream machines and acts as a server for them. It likewise acts as a client for upstream machines.
In a simulated production line, Hermes controllers are inserted as software nodes, allowing conformance tests to be performed and error conditions to be simulated in order to test the hardware controller without the need for further machinery.

Possible problem-solving/process optimization:
The use of standard components saves costs that would otherwise be incurred by proprietary hardware and software solutions (“vendor lock-in”). The Hermes Standard enables manufacturer-independent communication between machines - shown here in the area of printed circuit board production - whereby low complexity and high transparency simplify implementation. Cost-effective retrofitting is possible by upgrading legacy systems.
A low-cost single-board computer can be used as a communication device on / in production machines (old or new).

Technical structure:
In the research environment: simulation computers on which Hermes controllers are emulated. A GUI is available for the visualization of the processes.

Signal Integrity in Single-Pair Ethernet in Industry

More information:
www.ostfalia.de/pws/hampe/forschung



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I4.0 application(s):
Machine-to-Machine (M2M) Communication

I4.0 technology(-ies):
Ethernet Transceiver, Multi-Gigabit Ethernet, Simulation: Modelling

Functional description:
Signal integrity measurements are performed on transmission lines used in industrial networks. The parameters are, for example (frequency-dependent throughout): "jitter" (accuracy fluctuation in the transmission clock), spectral power density (power of the signal), attenuation, characteristic impedance, propagation characteristic, reflection coefficients and mode conversion (a part of the useful signal, also called differential mode signal, becomes the interference signal or common mode signal). Conformity measurements for electromagnetic compliance are also advantageous / required. For cable and module, immunity to radiation and emission can be determined. Also: Sensitivity measurement against electrostatic discharge (ESD).

Possible problem-solving/process optimization:
Simulations of signal routing can be used to develop an optimal transmission path, subsequent measurements on the test setup validate the design (validation measurement / conformity measurement) or show potential for improvement, for example if the reflected part of the signal is still too high. The result is an efficient and interference-free line, and the falsification of data on the transmission path is avoided.

Technical structure:
A Rohde & Schwarz ZNB-8 vector network analyzer is used in addition to calibrated test cables; reflection and mode conversion are measured. The three-part board (power supply, controller and signal generator) supplies a test signal - different modes are available. Various measurements with different measuring devices are possible.

Monitoring of Tree Populations in Municipal and Forestry Applications with 5G and mMTC

More information:
www.ostfalia.de/forschung/forschungsfelder/digitalisierung/smart_country

I4.0 application(s):
Environment Monitoring, Smart Forestry, Smart Farming

I4.0 technology(-ies):
IoT, massive Machine Type Communication (5G mMTC), LPWAN Infrastructure (given here: LoRaWAN), NB-IoT

Functional description:
Environmental sensors equipped with an LPWAN transmitter unit are mounted on trees whose direct environment is monitored - for example, for humidity in the air and soil, air and soil temperature, CO2 levels and photosynthesis levels. Once transmitted via an IoT radio network, this data is stored and processed in a cloud environment.

Possible problem-solving/process optimization:
The transmission of sensor data from the tree population makes work easier for forest owners as well as cities and municipalities. Monitoring the environment 24/7 becomes possible. Until now, checking the tree population has often involved several hours of walking - instead, the vital signs of the trees can be retrieved at any time via the cloud. Timber harvesters can use the daily updated data to differentiate between timber qualities (securing and, where applicable, improving yields, targeted and sparing use of resources). Algorithmic analyses of the sensor data enable the implementation of location-based online early warning systems, allowing a rapid and targeted response to disturbance variables.

Technical structure:
Battery powered temperature, humidity, CO2 and photosynthesis sensors with Low Power WAN (LPWAN) radio module, public LPWAN infrastructure, cloud data storage and service for data processing/analysis and visualization.

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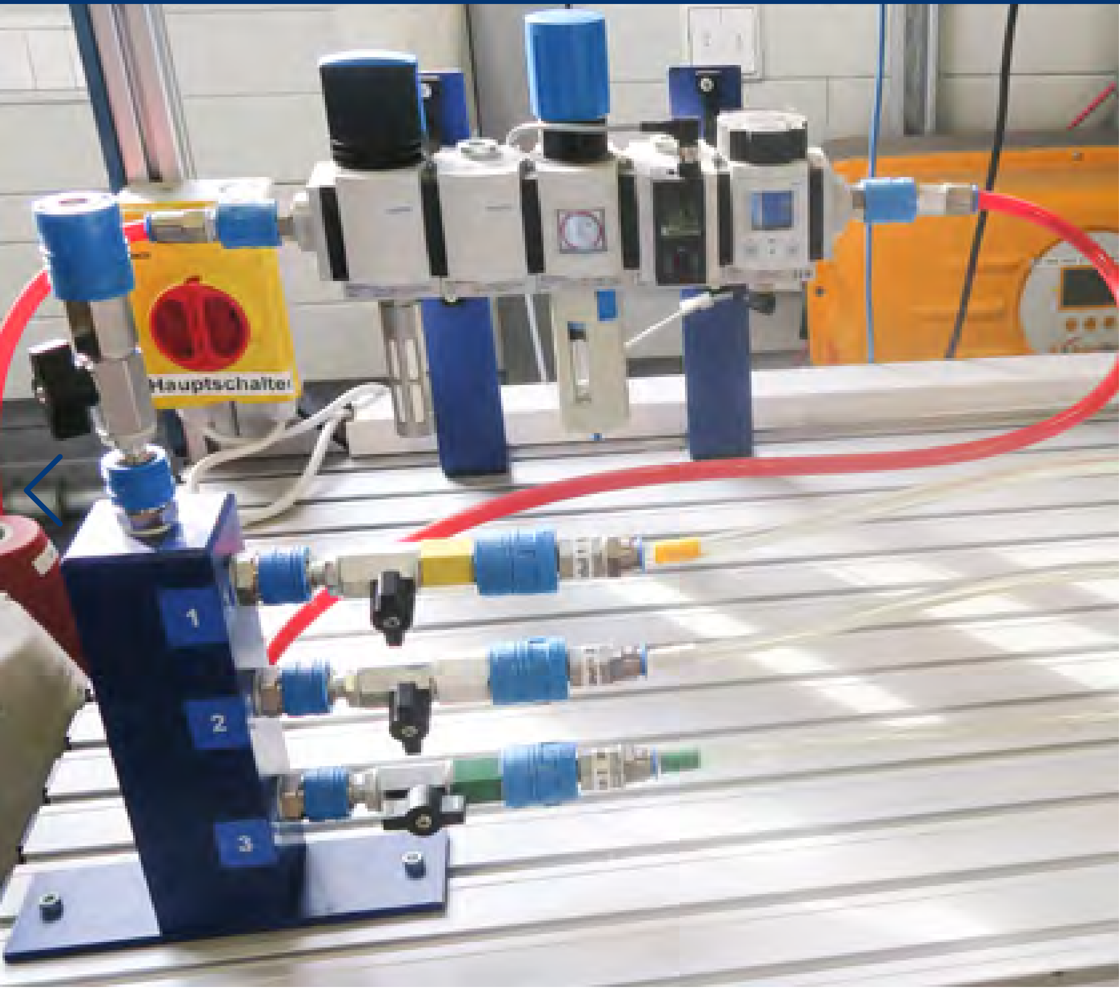
Digitization Measures for Resource Efficiency

More information:
www.nifar.de/themen.html



I4.0 application(s):
Energy and measurement data acquisition and evaluation (local and cloud based), smart maintenance, visualization

I4.0 technology(-ies):
Digital twin, AR/ VR, intelligent sensor technology

Functional description:
Measures for digitalisation, such as the introduction of energy management systems, the use of sensors (here on more than 25 devices with over 300 measured variables, such as pressure sensors for detecting leaks, see figure), strategies for networking and database connection or the use of AI applications have a great influence on resource consumption in companies. The right approach to the introduction of such digitalisation measures is crucial for the achievable savings, we offer training courses.

Possible problem-solving/process optimization:
Both the collection and the evaluation, maintenance and visualization of data are improved. Data can be processed in real time and thus reduce scrap and rework in manufacturing companies, for example. In development, for example, virtual products and systems are created ("digital twin"), optimizations are carried out and the worker is supported by visualization during production, which saves material, energy and thus costs.

Technical structure:
Intelligent sensors, Energy data acquisition (incl. measuring case), AR/ VR facilities like Microsoft HoloLens and Realwear HMT-1, Visualization, software like NX, MCD, PLCSIM-Advanced, Cloud connectivity, "Compressed air stand" (see figure) and "electrical stand"

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Energy Efficient Robot Operation

More information:
www.ostfalia.de/en/forschung/research-areas/digitization/rg_robotics

I4.0 application(s):
Reduction and management of energy needs

I4.0 technology(-ies):
Robotics, sensors, computer-aided measuring technology

Functional description:
The energy needs of a robot can be determined via measuring kit and PC, potential energy saving measures can be found in the broschure (see "URL"), for example optimizations in positioning, tracking points, beginning of movement, home position, velocity, acceleration, brake application time

Possible problem-solving/process optimization:
Implementing the recommended measures for energy efficient robot operation directly leads to energy saving and thus cost reduction. Furthermore, data about the energy requirements of the used equipment can be acquired, which may not have been collected before (implementation of energy monitoring).

Technical structure:
Used for this case study: KUKA KR210, KR120, KR60 (210, 120 and 60 kg load capacity). Suitable for recommended measures: all industrial robots with said load capacity. Programming environment: online (Pad)/offline (PC).

- where appropriate: loop in the measuring kit
- where appropriate: using simulations software, Siemens Process Simulate as tool for implementing/visualizing the optimization measures (e.g. KUKA source code can be loaded into ‚Siemens Process Simulate').

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Camera-based Object Recognition with Adaptive Gripping

More information:
[www.ostfalia.de/en/forschung/research-areas/digitization/rg_robotics]

I4.0 application(s):
Object recognition, pick-and-place, human-robot-collaboration, adaptive gripping

I4.0 technology(-ies):
Lightweight robotics, image processing, gripping systems, cobots

Functional description:
The camera system and the adaptive gripper are located on a ‚UR 10' by Universal Robots. The position of objects to be gripped is scanned and determined using the camera. In addition, already known objects are identified. The robot can grab objects and store them in a defined location based on this generated data. The adaptive gripping system allows the raising of objects of various geometries.

Possible problem-solving/process optimization:
The recorded camera images can be evaluated in many ways (object identification, quality assurance, avoidance of errors, ...). In addition, the overall concept is able to relieve employees of monotonous sorting operations and to be integrated as a semi-automated process into existing manual workplaces. Depending on the object viewed, ergonomic improvements can also be achieved.

Technical structure:
Lightweight robot UR 10 from Universal Robots,
Gripper from RightHand Robotics,
2D camera from Robotiq

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RID: Robot Input Device – Input Assistance for Positioning Simulations of Industrial Robots

More information:
www.ostfalia.de/en/forschung/research-areas/digitization/rg_robotics

I4.0 application(s):
Robot programming, possibly: Control/Teaching of industrial robots

I4.0 technology(-ies):
Simulation: digital twin

Functional description:
A miniaturized model of an industrial robot can transmit its positioning via a USB interface to a simulation environment, in which a virtual model reflects the positioning. The necessary data ist provided by rotary angle sensors in the axes. In principle, any number of degrees of freedom is possible (in the model shown: 6 degrees of freedom). In the simulation environment, motion processes can then be displayed.

Possible problem-solving/process optimization:
The Robot Input Device (RID) can be used as part of further training measures on robot function or for simplified input during simulations (ergo as input assistance). Planning of positioning with haptic elements facilitates visual thinking and encourages energy-efficient programming (resulting in operation of the industrial robot with the lowest possible energy consumption).

Technical structure:
Miniature of an industrial robot, with rotary encoders on its axes: Pewatron 7S series (resolution: 400 pulses/revolution, meaning < 1°). Transmission takes place via a serial transceiver, which in turn polls the values of the rotary encoders.

PC software: "Tecnomatix Process Simulate"

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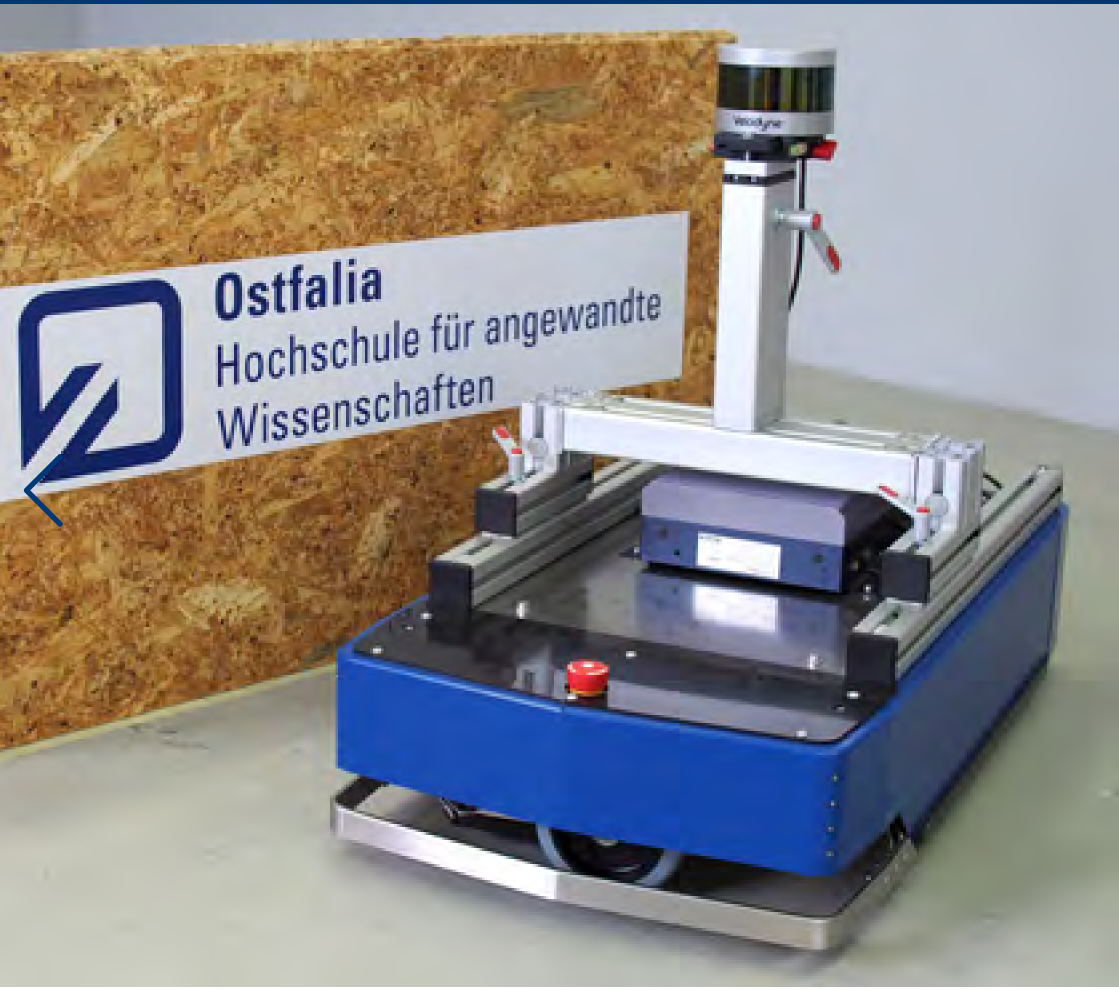
Self Learning Transport System (SeLeTraSys)

More information:
www.ostfalia.de/f/lff/forschung/seletrasys



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I4.0 application(s):
Automated Production Logistics, Machine-to-Machine (M2M) Communication

I4.0 technology(-ies):
A.I., Environment Recognition, Networked Sensors, Feature Map

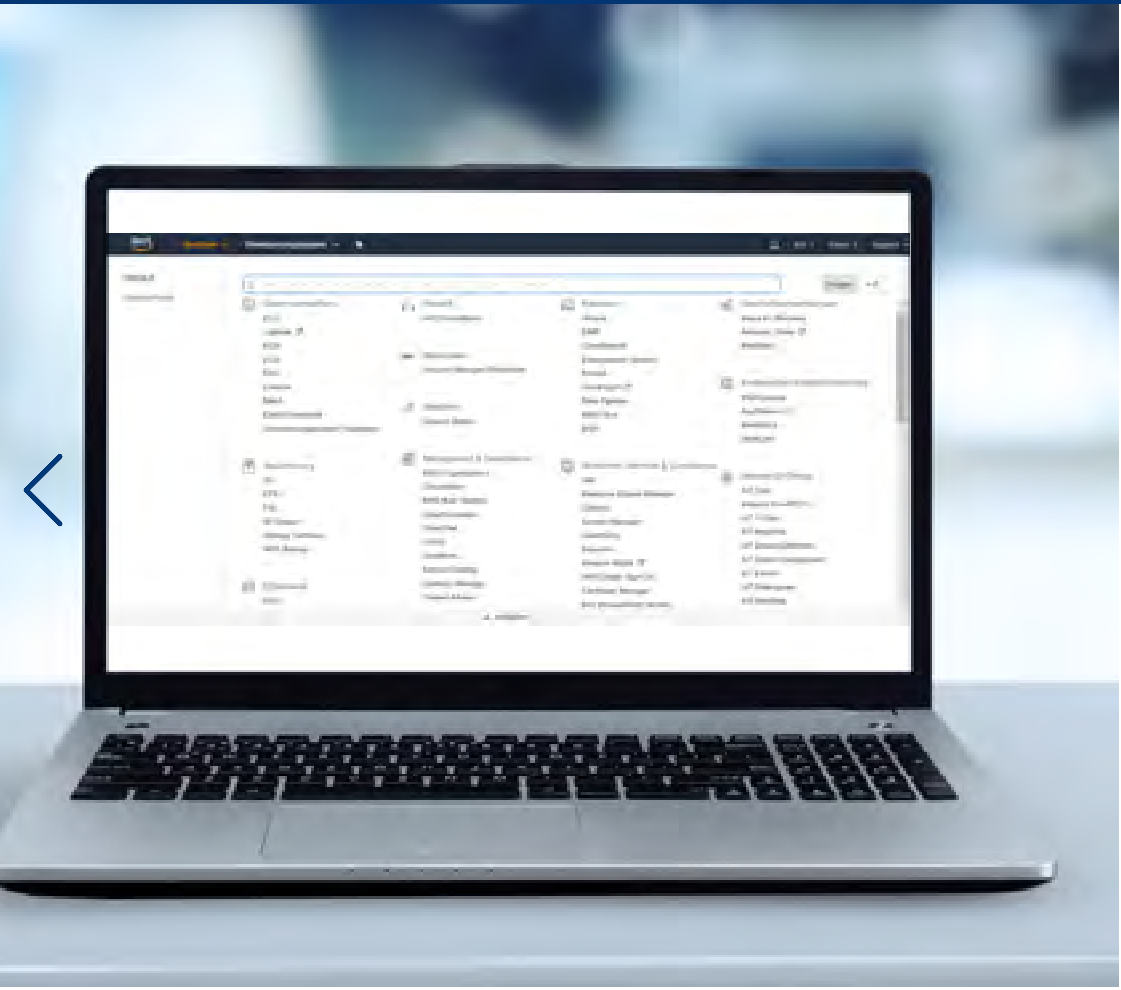
Functional description:
A computer acts as a control centre, which receives environment perception data from several transport vehicles and generates a digital map ("feature map") of the warehouse or production environment, which is then delivered to the transport vehicles. These vehicles plan the route to their destination automatically based on the digital map. Environment perception includes obstacle detection and object classification. In addition, each transport vehicle transmits its own location (based on camera and lidar data) as well as odometry and e.g. state of charge, which are used as tactical information. Points of interest (PoI) can be specified in the feature map, such as charging bays and fixed loading points (logistics nodes, parcel transfer points).

Possible problem-solving/process optimization:
Current transport systems work with physical "lane markings", which proves to be inflexible, especially with induction loops in the ground. If route changes become necessary, the infrastructure must be adapted at great expense. The given transport system works independently of existing infrastructure and is able to mark and avoid obstacles in real time. Except for charging cycles and maintenance schedules, no interruptions in operation are necessary. With the self-learning transport system, personnel can be supported or can dedicate themselves to more complex tasks in parallel. The logistics processes in production and warehouse are accelerated. In addition, it offers an optimization of ergonomics at the workplace: the physical strain on employees can be reduced.

Technical structure:
Central computer (control center): conventional computer or virtual machine (VM) with UNIX-based operating system. Control computer on transport vehicle: industrial PC "Advantech MIC-7700", environmental sensors: lidar, industrial greyscale camera, infrared sensors (currently not used), vehicle sensors: steering angle and speed sensors. The communication between control center and transport vehicles is wireless via WiFi.

Services in the Cloud

More information:
www.ostfalia.de/en/forschung/research-areas/digitization/rg_iot



I4.0 application(s):
Internet of Things (IoT) applications in industry, pharmaceutical, medicine, agriculture

I4.0 technology(-ies):
AWS (Amazon Web Services); MQTT, hybrid automation

Functional description:
Data from IoT sensors is transmitted to IoT clouds via Machine-to-Machine (M2M) protocols and can there be processed with a multitude of different software modules. Besides classic data storage and analysis, many innovative software functions are available as services, IoT-related functions in particular.

Possible problem-solving/process optimization:
Low cost compared to conventional automation solutions, standardized and vendor-independent solutions, short implementation time for innovative solutions, for applications like e.g.: predictive maintenance, preventive maintenance, smart monitoring, hybrid automation, basis for the use of Artificial Intelligence (A.I.) for automation purposes, dynamic, event-based visualization, open interfaces, e.g. for connection to ERP, high availability device management

Technical structure:
In this showcase data from various IoT sensors (e.g. temperature, movement, air pressure, humidity ...) is transferred to an IoT cloud via IoT radio technologies. For this purpose gateways are used to translate the sensor data from IoT radio protocol to classic IP-based communication. Afterwards the sensor data is sent to the IoT clouds via cellular router, where they lastly get processed by IoT applications from reusable software modules.

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