

IDENTIFICATION OF SINGLE PARTS IN ASSEMBLIES BY 3D SCAN AND GEOMETRICAL SIMILARITY SEARCH



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STRUCTURE



- **Introduction Fraunhofer IPK**
- **Need for 3D models**
- **Research projects and use cases**
- **Test series and results**
- **Future potentials and outlook**

PTZ BERLIN – PRODUCTION TECHNOLOGY CENTER

Two Institutes – One Roof



Corporate Management



Virtual Product Creation



Production Systems



Joining and Coating Technology



Automation Technology

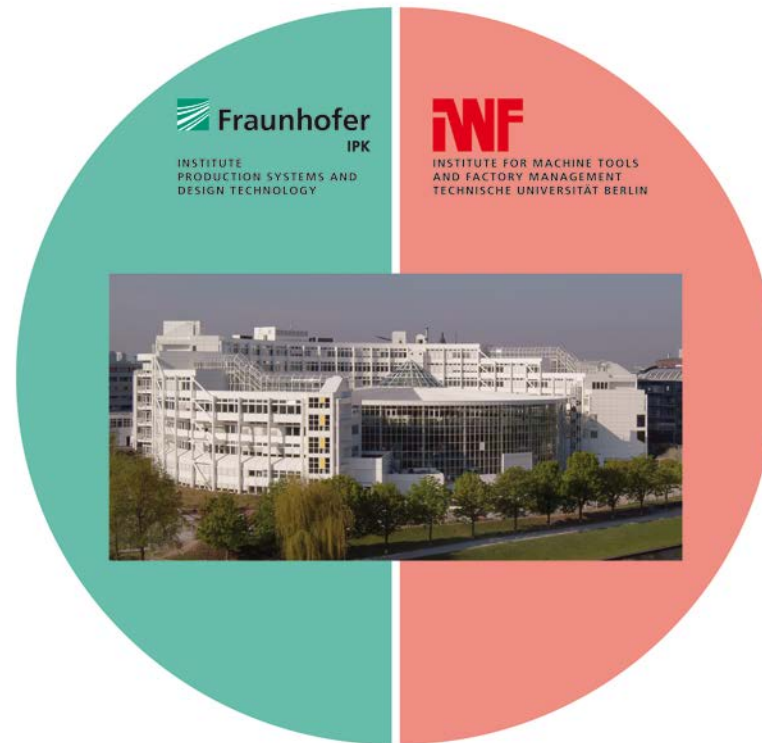


Quality Management



Medical Technology

PTZ Berlin



Assembly Technology and Factory Management



Industrial Information Technology



Machine Tools and facturing Technology



Joining and Coating Technology



Industrial Automation Technology



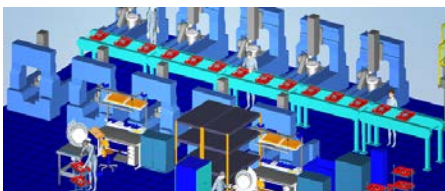
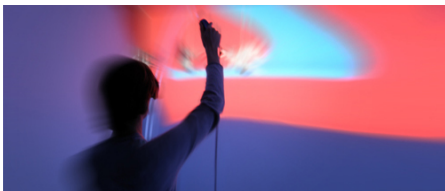
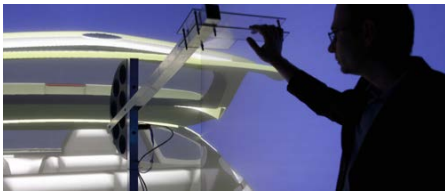
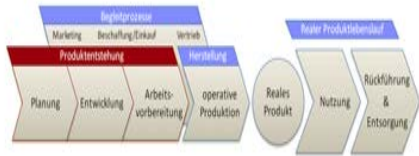
Quality Science



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RESEARCH DOMAINS

Division Virtual Product Creation



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1. Product development methods and processes

Analysis and composition of both product creation processes and sub-processes with regard to methodical and organizational aspects

2. Product modeling and functional validation

Modeling of product properties and characteristics (requirements, structures, functions, geometry generation incl. processing and repair, quality of digital data, ...)

3. Intuitive interaction with virtual prototypes

Context sensitive provision of information for various scenarios and players in product creation (developer, designer, manager, analyst etc.)

4. Information management for product creation

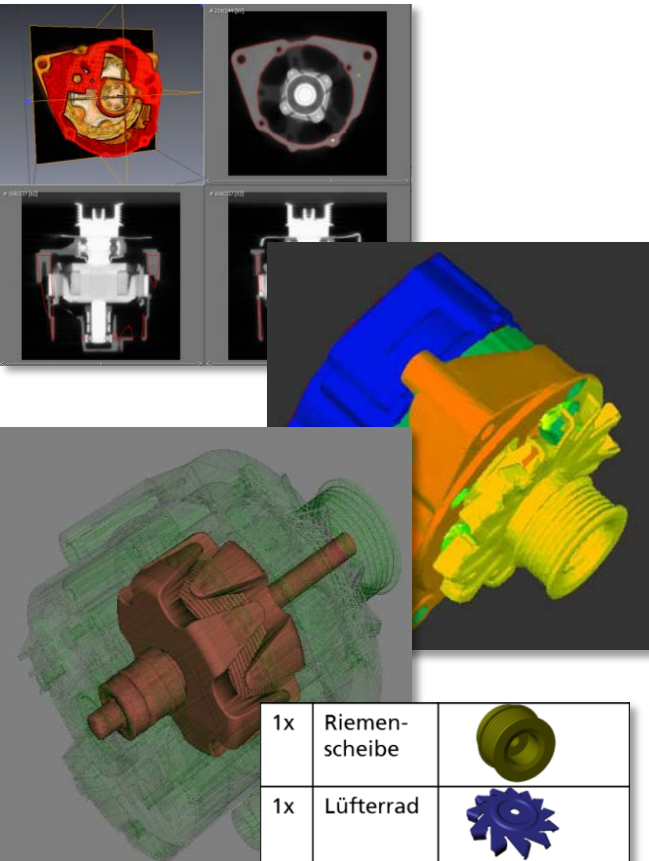
Collection, administration, processing and provision of information, which are generated in product life cycle and to be used for product creation





5. Digital manufacturing operations and factory processes

Modeling of manufacturing process features and characteristics (product, manufacturing/assembly process, equipment, factory layout, ...) in the context of product creation and reviewing of each production process with respect to the specific objectives

Focus Reverse Engineering

3D scan data processing



1x	Riemenscheibe	
1x	Lüfterrad	
1x	Generatorgehäuse	
1x	Lagerschild	
...

Fields of application

- Inspection (3D measurement, deviation analysis)
- Spare part production (e.g. rapid manufacturing)
- Reengineering or redesign
- Quality control (deviation analysis)

Challenges

- 3D models are not available or do not represent actual product condition
- Lacking product documentation (BOM, product structure, electric plan, maintenance history)
- Lacking standards for Reverse Engineering processes

Activities and solutions

- Development of processes and software for Reverse Engineering of mechanical and electronic products
- Automated analysis and processing of geometry
- Studies for Use of 3D scanning technologies

STRUCTURE



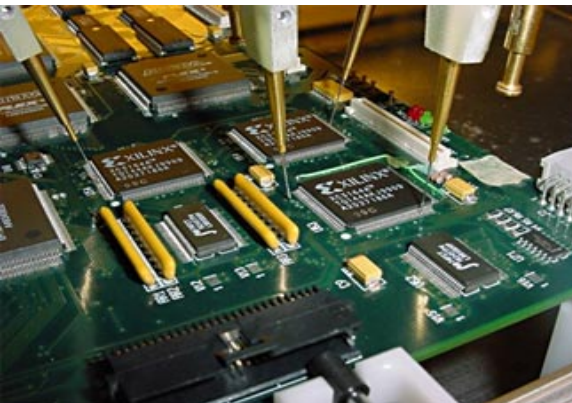
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Initial situation

Need for 3D models



Steam turbine (image source: Siemens)



Flying Probe Test (image source: SQC)

Rising maintenance requirements

- Increasing product complexity and design variety
- High design variety and unpredictable failures

Missing data and information

- OEMs keep back information to protect their design knowledge
- Service provider act without access to 3D models, BOMs, electric plans and other technical descriptions...
- Actual state of a product is often unknown

Little standardization and high manual effort

- Long term practical knowledge is needed
- Small degree of process automation

Knowledge of actual and desired product condition is fundamental for a robust planning, operation, and automation of MRO processes

Solution: 3D scanning and Reverse Engineering

Need for 3D models



Inspection

- Deviation analysis
- MRO planning

Quality control

- Check of bought-in parts

Reengineering/remanufacturing/retrofit

- Modification of geometry models
- Additional design into existing structures

Production

- Own production of spare parts
- Obsolescence management

Industries

- Turbo machinery (gas- and steam turbines, jet engines)
- Transport (e.g. air and rail)
- Plant manufacturing
- Machine tools
- Engines

Image source: Power-technology.com, Hommel, MAN

Challenges of Reverse Engineering

Need for 3D models

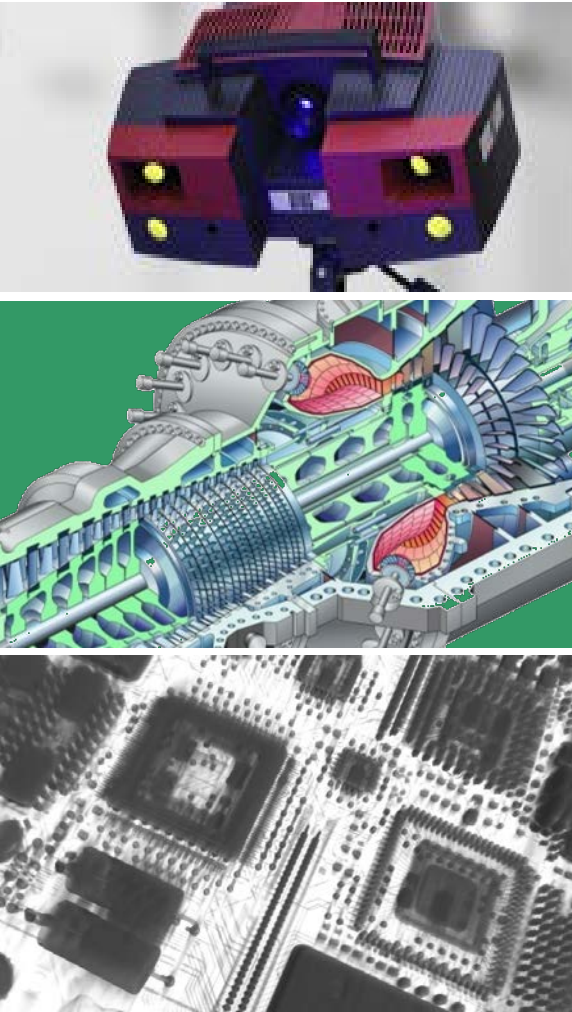


Image source: GOM, Siemens, Fraunhofer IPK

Selection of adequate technology

- Fast development processes of 3D scanners
- Complex post processing software

Reduction of disassembly effort

- In situ 3D scans of single parts
- Identification of single parts

Identification of product structure

- Configuration und change management in PDM-systems

Standardized process from scan to manufacturing (CAD/CAM)

- Automated parameterization
- Conclusion of target geometry

Reconstruction of electric plans

- Low degree of automization
- Error prone results of actual RE principles

STRUCTURE



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Condition based digitalization for MRO processes

Project COSDIMRO



Content

- Development of an reverse engineering process for automated generation of three-dimensional assembly models of complex machines and facilities
- Facilitating the subsequent use of the 3D-models by means of information technology for MRO-planning- and -assistance systems

Challenge

- MRO-planning requires – especially in case of an unknown product state – a time-consuming diagnose process
- Restricted automation potential due to nonexistent or not updated product models

Solution Approach

- 3D scanning of products
- Separating the parts of the digital model
- Deducing the product structure
- Enabling data compatibility for IT-systems

All departments,
Development project

Client:



Runtime: 12/2009 – 05/2012

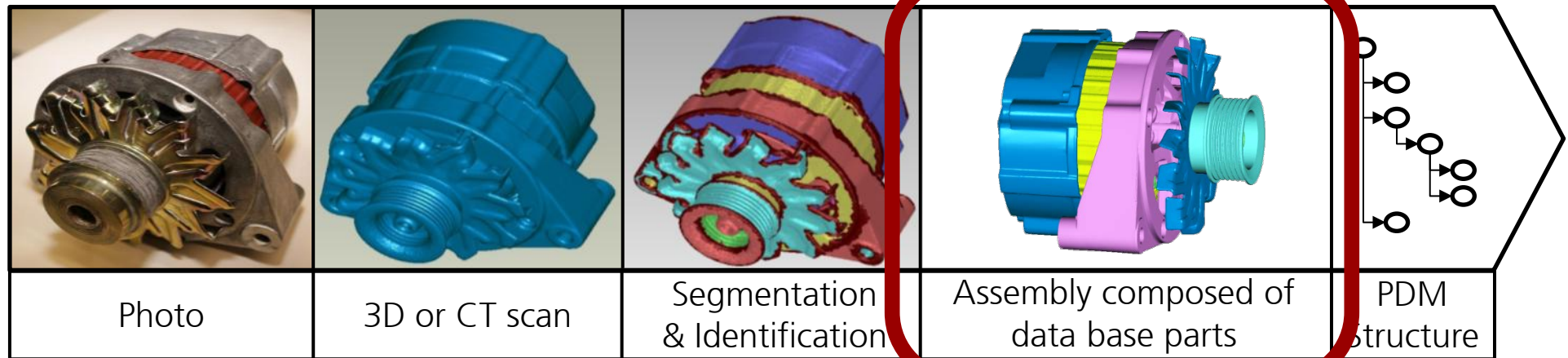
Image source: Siemens, MAN

Process for digitization of assemblies

Project COSDIMRO

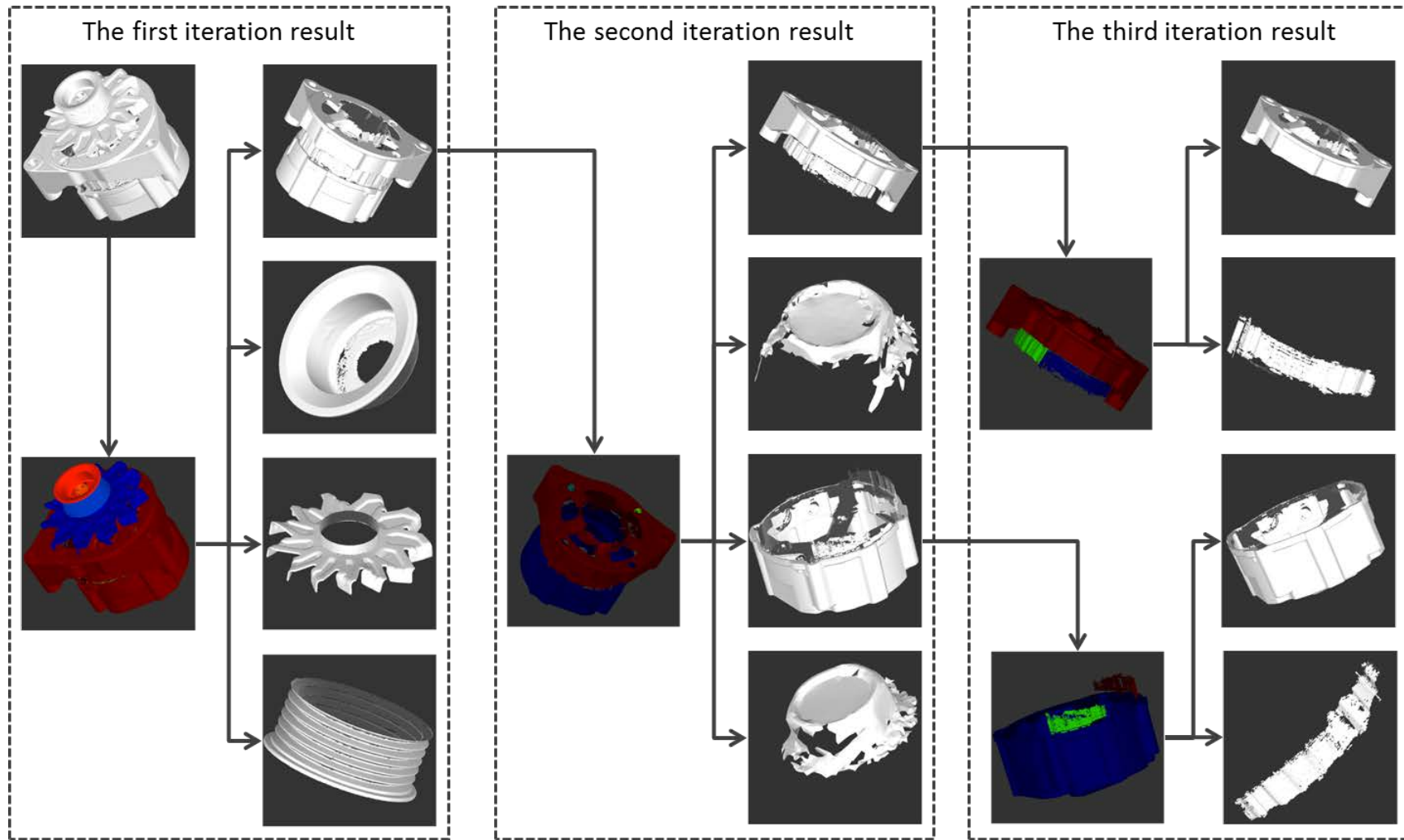
- Development and prototypical implementation of a RE method for effective and efficient support of MRO processes
- Semi-automatic generation of digital models of complex products and facilities
- Identification of parts and assemblies as well as their relationships
- Subsequent processing for PLM and MRO planning and assistant systems

Test object: electric generator



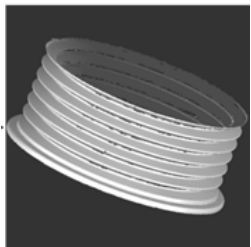
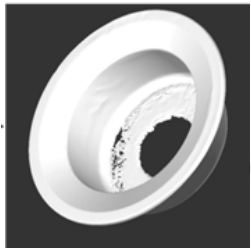
Segmentation result

Project COSDIMRO



Part identification

Project COSDIMRO



Segmented parts

Suchoptionen

Ordner: /Kataloge | Text- und Variablen | Skizze (2D) | Geometrie (3D) | Topologie

Geometrische Suche ausführen

Markiertes Teil als Suchkriterium benutzen

- Luefterrad
- fan

3D-Datei als Suchkriterium benutzen

ers/tipp/Desktop/Testfalle/segmented_cloud0-9.stl ... anzeigen

Einheit der Datei: mm

Suchergebnisse unter: 70 % ausblenden

Maximale Anzahl der Suchergebnisse: 100

Suche starten

Suchergebnisse

Rang	Ähnlichkeit	Vorschau (...)	Firmenlog...	Katalog	Name	Beschreibung	Datum	X (SIZE)
1	77%			Alternator	Luefterrad.stl		02.09.2...	134.19...





Geometrical similarity search with CADENAS PARTsolutions

1x	Belt Pulley	
1x	Fan Impeller	
1x	Generator Housing	
1x	Bearing Shield	
...

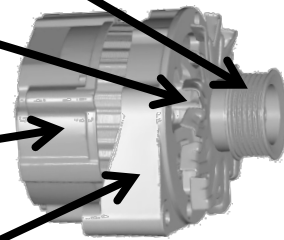
Identified parts from data base

Assembly building

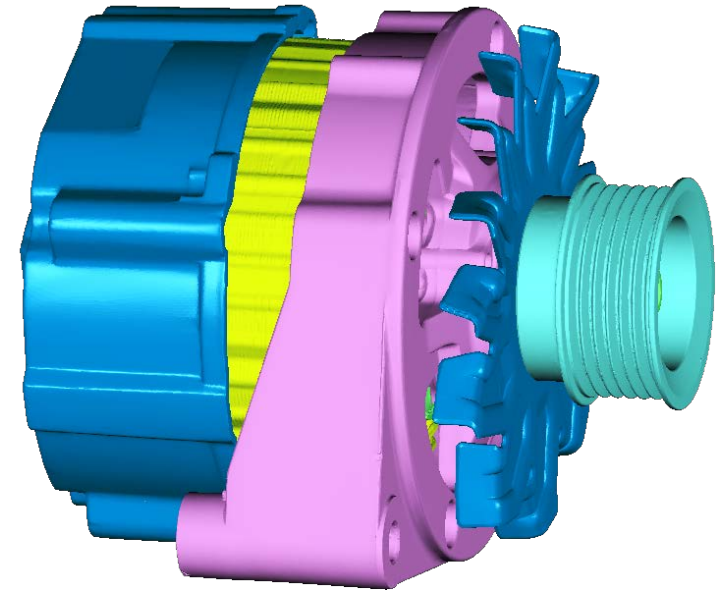
Project COSDIMRO

1x	Belt Pulley	
1x	Fan Impeller	
1x	Generator Housing	
1x	Bearing Shield	
...

Identified parts from data base



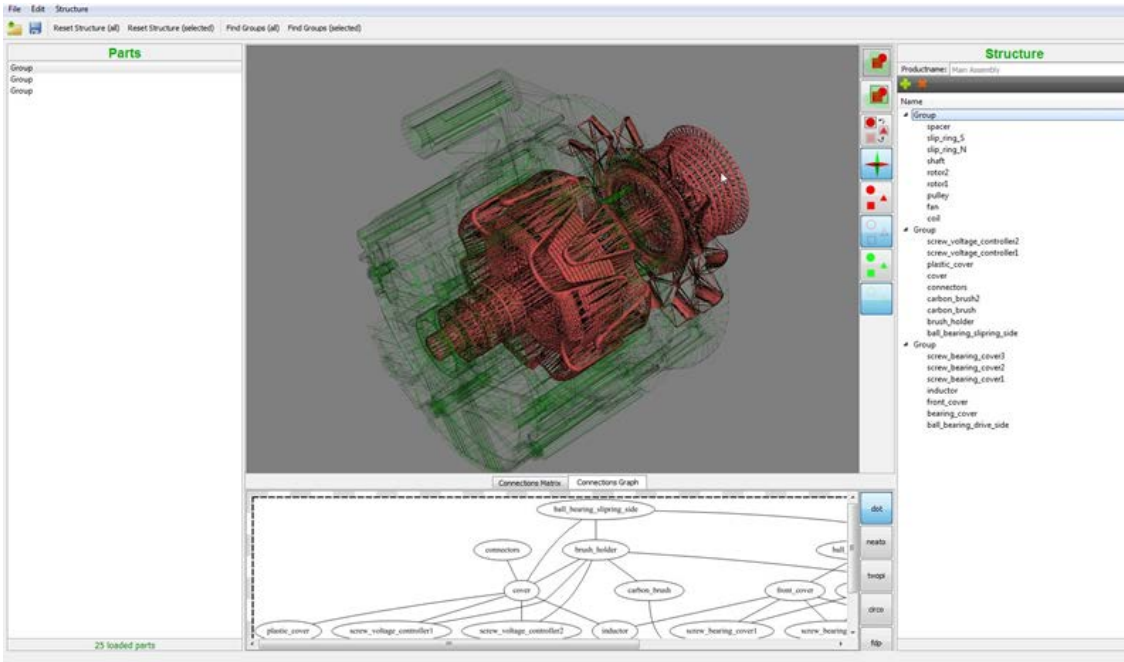
Fitting of single parts into point cloud



Reconstructed assembly

Derivation of product structure

Project COSDIMRO



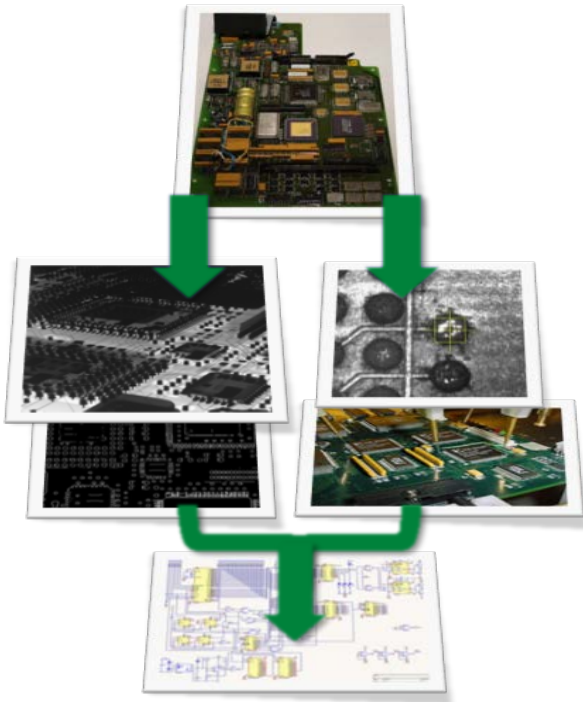
GUI of structure generator

Implementation of a Structure Generator

- Import of assemblies (single parts in STL format)
- Contact analysis of single parts by graph theory approaches
→ contact graph
- Proposal of product structure
- Possibility of manual rework
- Visual user support through integrated GUI

Maintenance information recovery for electronics

Project LangzEI



Client:



Run time: 01/2010 – 05/2011

Content

- Automatic generation of circuit diagrams for electric devices to support maintenance operations
- Analysis of Reverse Engineering (RE) methods to create a process chain

Challenge

- Missing information: Missing electric circuit plan and bill of material, no digital plan of board layout available
- Lack of product data/information hinders diagnose and repair of PCBs* (even of those with reduced complexity)

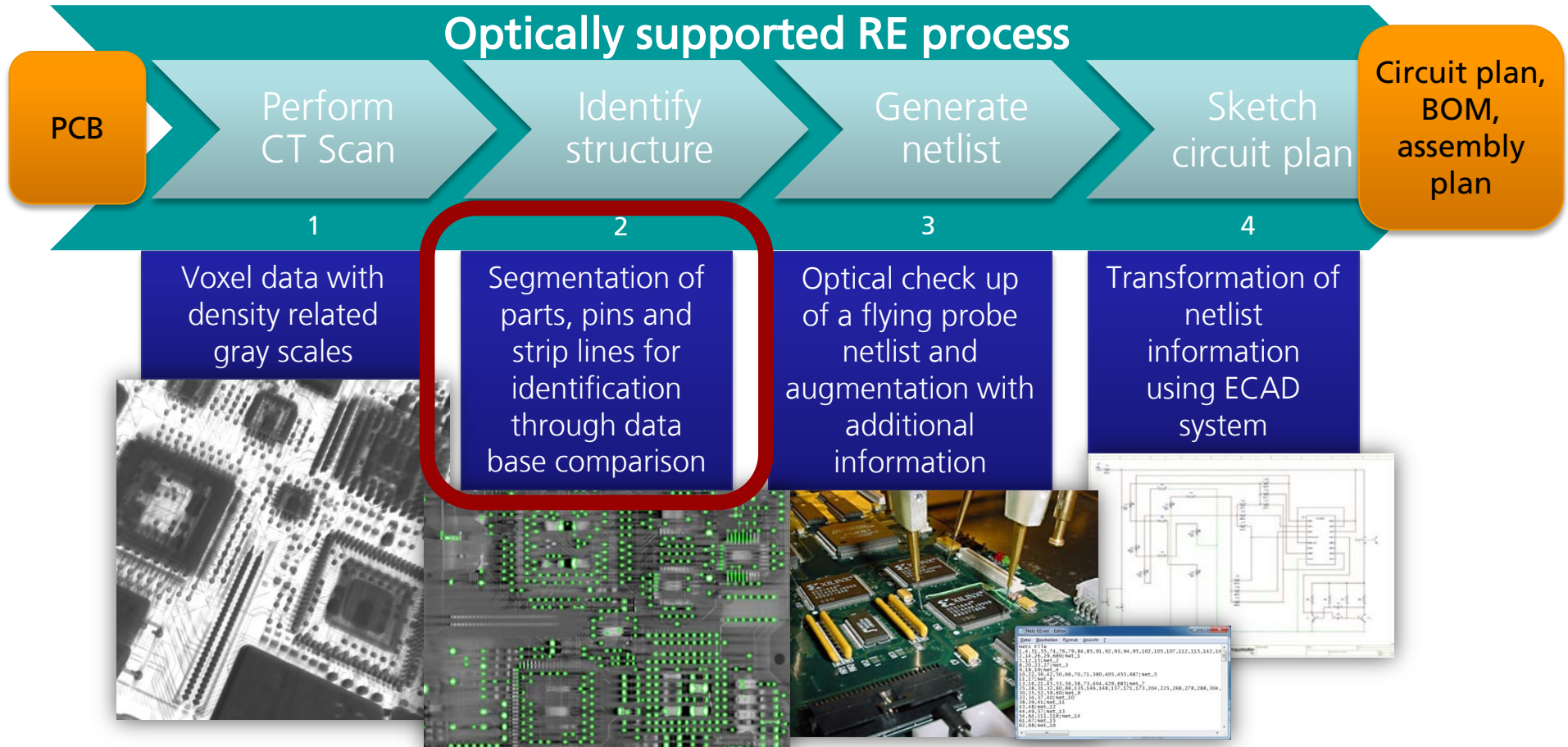
Solution Approach

- Digitalization of products with Reverse Engineering technologies
- Definition of a new Reverse Engineering process for PCBs*
- Application of optical and electrical technologies
- Automated generation of circuit plan, bill of material and board layout plan
- Interface implementation to ECAD system

*PCB: Printed Circuit Board

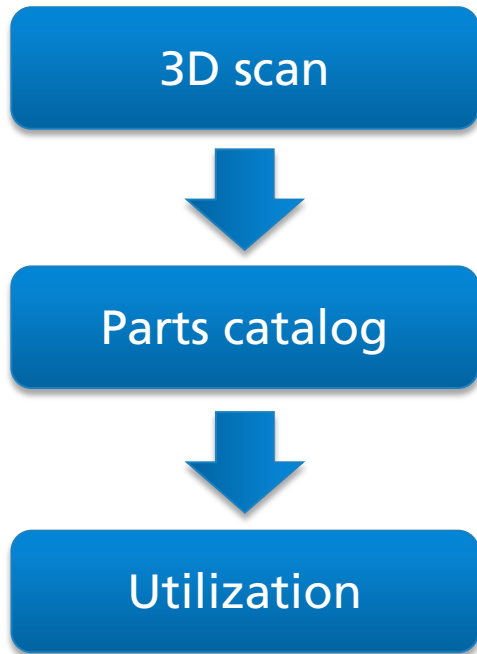
Hauptphasen des Prozesses

Project LangzEI



Use cases for geometrical similarity search

Precondition: 3D scan data and parts catalog



Inspection

- Execution of deviation analysis

Renovation

- Surface treatment and recovery of original product state

Usage of spare parts

- 3D measurement for choice of appropriate spare parts

Reengineering

- Automated building of original assemblies
- Accurate fitting of reworked components

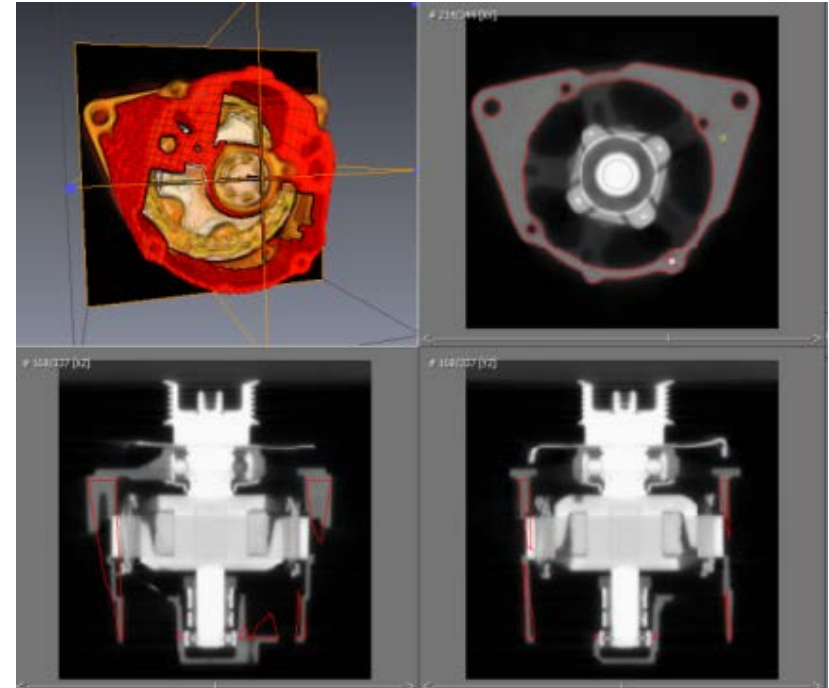
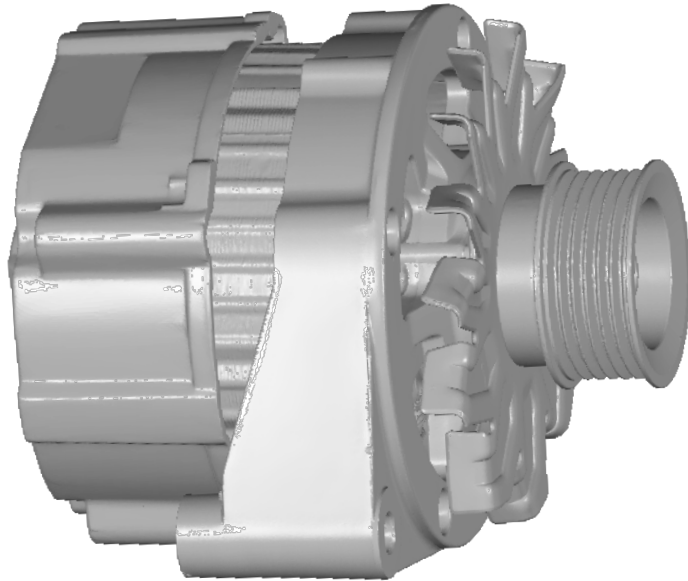
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Test data

Structured light 3D scan and computer tomography



- Scan of a GOM ATOS III structured light 3D scanner
- STL file (triangulated data)

- Scan of a X-ray system
- Complete capture of the entire model

Preparations

Development of the test case

- Creation of a parts catalog with CADENAS PARTsolutions
- Structured light scan of 8 alternator parts

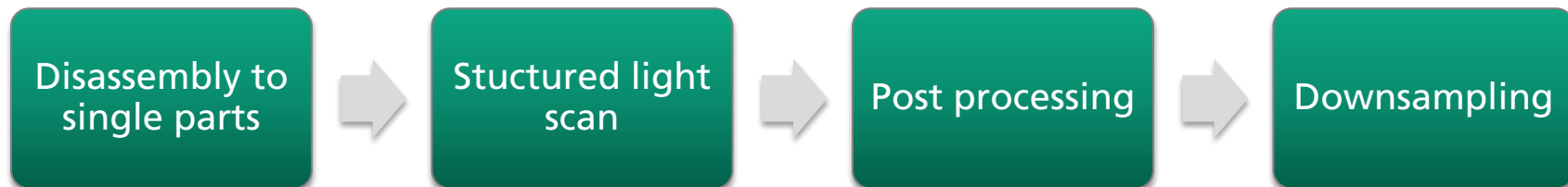
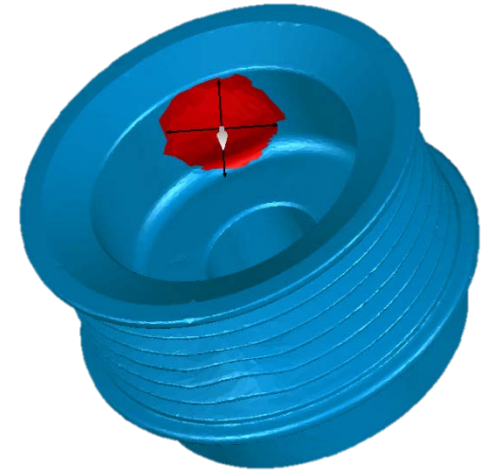


- New „quick search“ profile that works better with corrupted surfaces

Test series 1

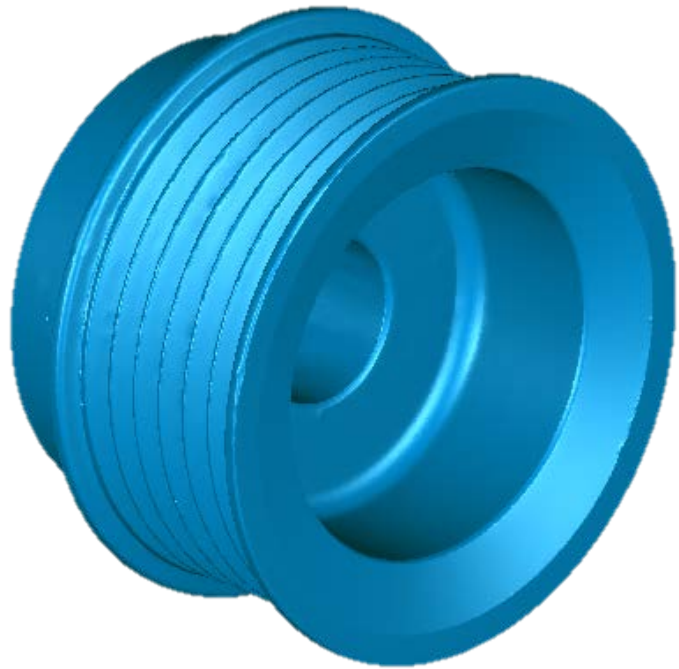
Preparations

- Structured light scan with a GOM ATOS III
- Parts were completely disassembled and scanned
- Digital deformation of parts to simulate signs of use
- Downsampling to 100k faces
- Search threshold set to 70%, search went over all cataloges (PN – EN – ISO & standard parts)



Parts from test series 1

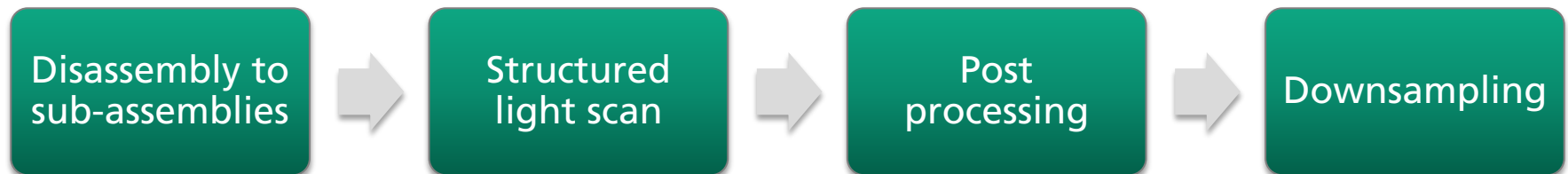
Detailed View



Test series 2

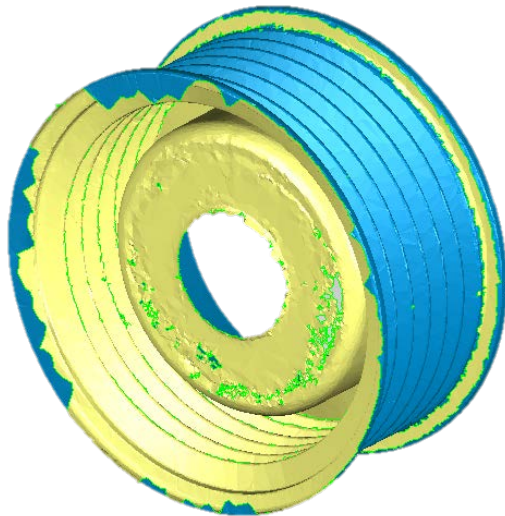
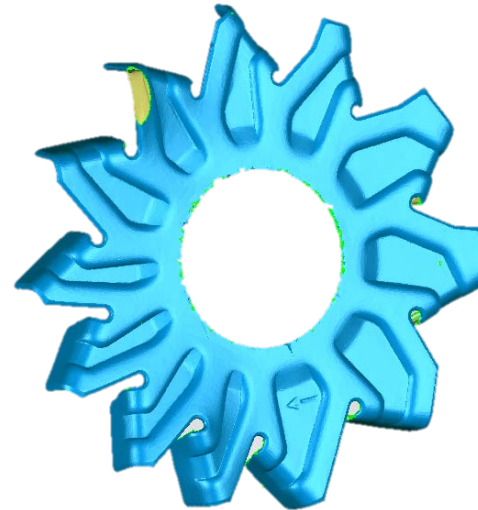
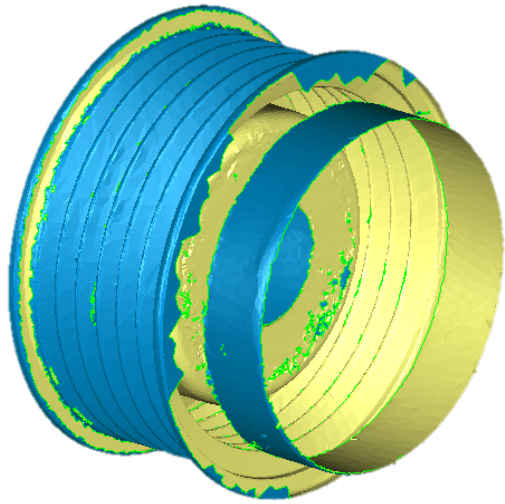
Preparation

- Structured light scan with a GOM ATOS III
- Alternator was disassembled in 2 sub-assemblies
- Parts were not entirely visible
- Test series 2a
 - Manual segmentation of single parts in sub-assemblies
- Test series 2b
 - Automatic segmentation through algorithm
- Downsampling to 100k faces
- Search threshold set to 70%, search went over all catalogues



Parts from test series 2a und 2b

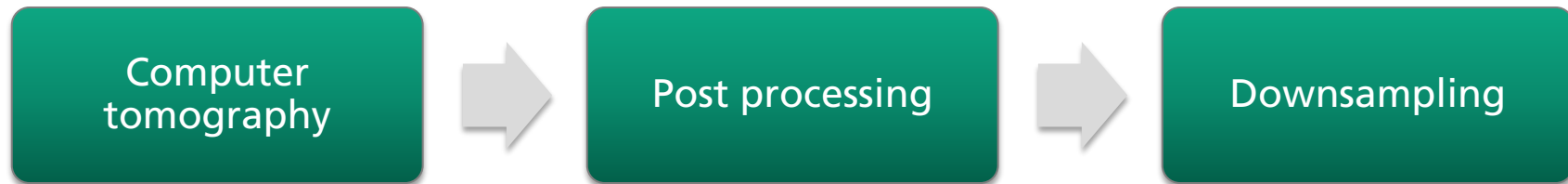
Detailed view



Test Series 3

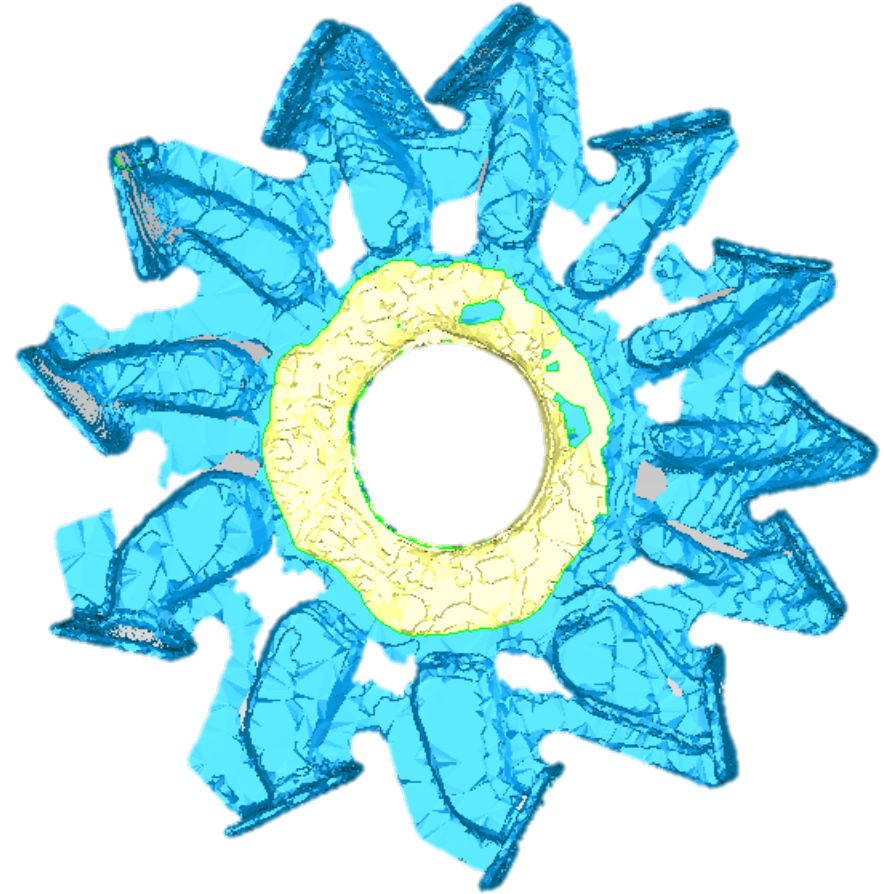
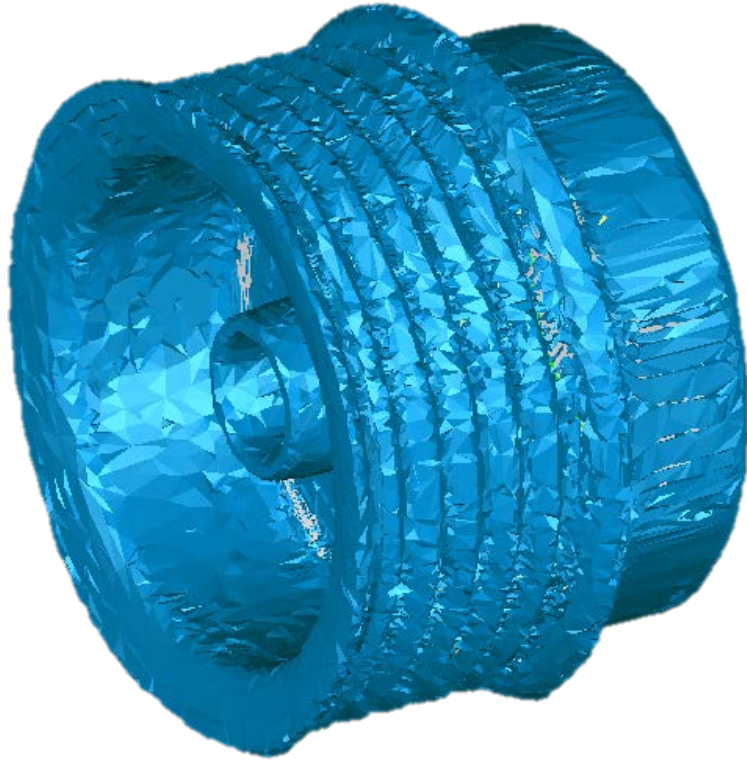
Preparation

- computer tomography
- Alternator was captured completely without disassembly
- Single parts were segmented using an algorithm according to material density (gray scale segmentation)
- Post processing (Removal of unnecessary faces, separation of connected parts)
- Results have an edged surface as they were generated from voxels
- Downsampling to 100k faces
- Search threshold set to 70%
- Search went over all cataloges



Parts from test series 3

Detailed view



Test series 3

Results

Summary

Results of test series

	Test series 1	Test series 2	Test series 3
Scenario	3D scan of single parts	3D scan of assembly + segmentation	CT of product + segmentation
Measurement method	Structured light	Structured light	X-ray
Data acquisition	Ca. 30 min	Ca. 40 min	Ca. 1 day
Preprocessing	10 min	15 min	Several days
Postprocessing	Ca. 60 min	Ca. 60 min	Ca. 1 day

- High matching rates across all test series
- Matching rates at complete three-dimensional captured parts nearly perfect
- Very good matching rates for segmented parts
- Indicated correlation between geometrical completeness and matching rate

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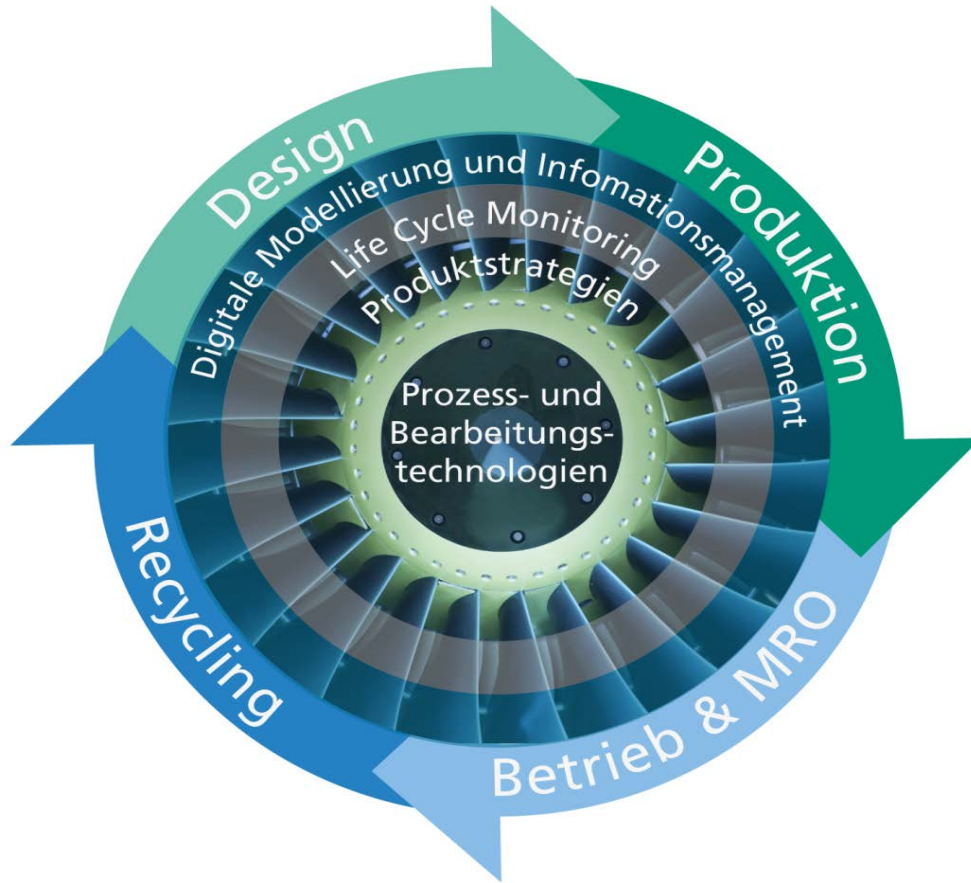
Future development potentials

From 3D scan to CAD model

- Improvement of robustness of geosearch
 - Strength/weakness analysis of geosearch for specific geometry properties and quality levels of 3D scan data
 - Specific improvement of search algorithms (possibly search directly in point cloud)
- Automated geosearch of 3D scanned parts
 - Interface to software for surface reconstruction of point clouds
 - Use of search results for automated deviation analysis
- Integration of geosearch into a reverse engineering process for automated generation of CAD assembly models
 - API-access onto search results
 - Connection to a segmentation principle for part separation in 3D assembly scans or “pattern matching” in any point clouds
 - Matching of found parts with existing product structures

Innovation cluster Life Cycle Engineering (LCE)

Outlook of new topics



Development of life cycle oriented engineering processes, methods, tools, and technologies for all life cycle phases (*design, production, operation, MRO, recycling*)

- Innovation fields
 - Product strategies
 - **Digital modelling and information management**
 - Process and manufacturing technologies
 - Life cycle monitoring

Innovation cluster Life Cycle Engineering (LCE)

Innovation field Digital Modeling and Information Management



- Information management
- Reverse engineering
- Customization, configuration management and tracing of product composition
- Process and project management for a life cycle-oriented system
- Product visualization by VR and AR



Thank you for your attention!