Institute of Production Engineering and Photonic Technologies
Univ.Prof. DI Dr.techn. habil. Friedrich Bleicher

3DMC 3D METROLOGY CONFERENCE

Aachen | 2022

Tactile Surface Roughness Measurement System for In-Situ Measurement in Machine Tools

November 2022

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TU WIEN IFT

Institute of Production Engineering and Photonic Technologies

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IFT - Organization and Research Groups

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Education
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Manufacturing Technology	Machine Tools	Control Technology and Integrated Systems	Production Metrology and Adaptronic Systems
Univ.Prof. F. **Bleicher** (with support of Prof. Frank **Pfefferkorn**)	Univ.Prof. F. **Bleicher** (with support of Prof. Tony **Schmitz**)	Univ.Prof. F. **Bleicher**	Univ.Prof. F. **Bleicher**
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Machining technology	**Design and optimization of machine tools**	**Digital production**	**Laboratory for Production Metrology**
Grinding and subtractive processes	**Control and automation technology**	**Energy efficiency**	Clemens **Sulz**, MSc
Forming and surface technology		**Virtualization of process and machines**	**Adaptronic systems and integrated metrology**
Dr. Stefan **Gössinger**		DI Gernot **Pöchgraber**	
Additive Manufacturing		**Process innovation**	

IFT - Laboratory for Manufacturing Technology

TEC-Lab

Franz-Grill-Straße 4, Obj. 221
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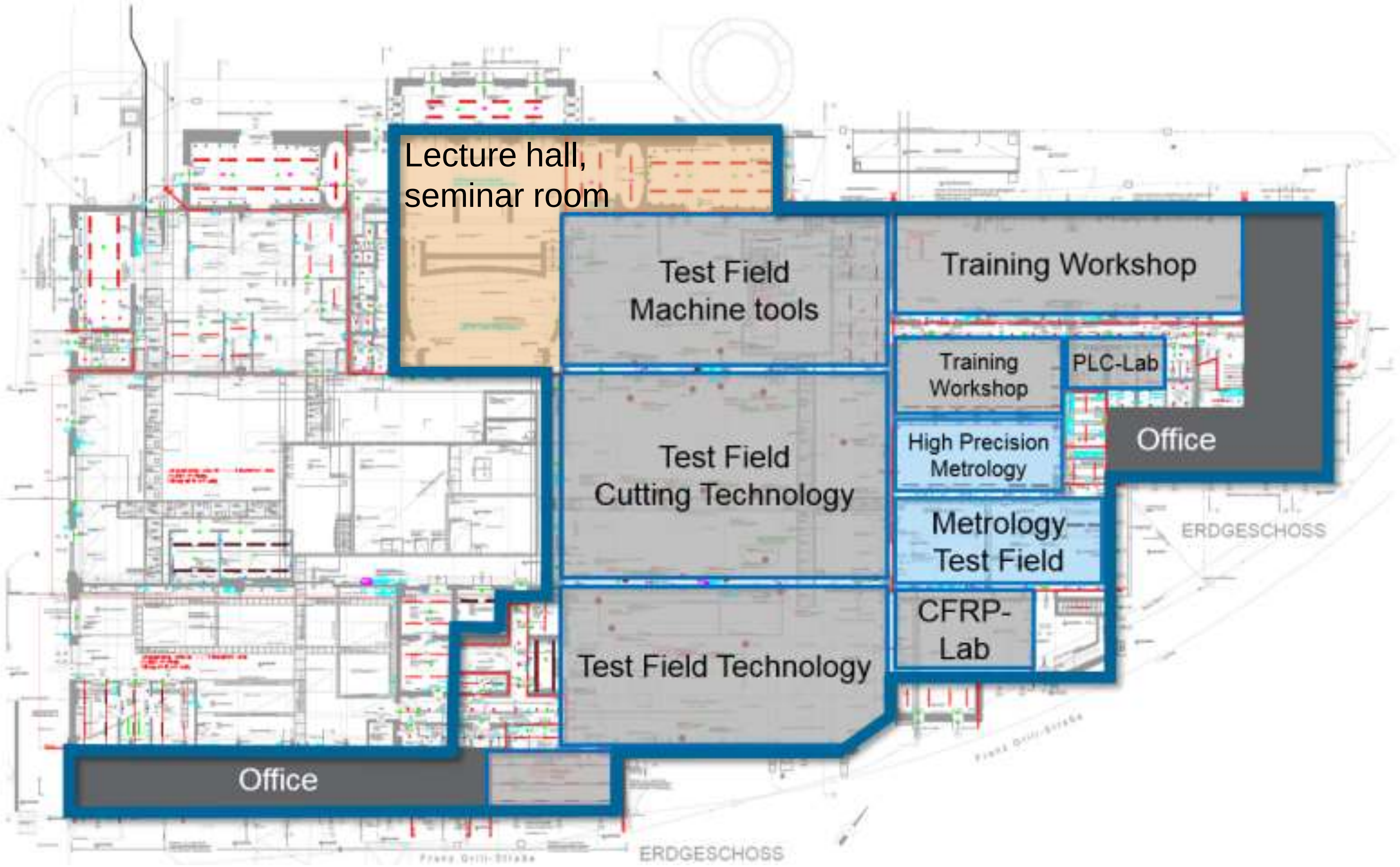


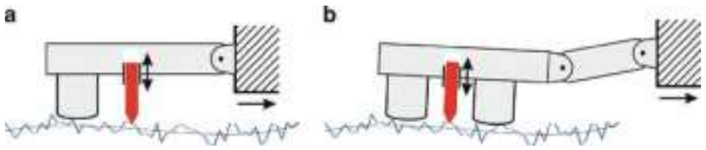
4 275 m² (46 000 ft²) building space, 70 workplaces for scientific staff, 3 conference rooms, lecture hall, training workshop for student education, cleanroom (ISO 6)

Roughness measurement technologies

- Optical systems (3D surface measurement)
  - Laser auto focus method
  - Confocal microscope
  - White light interferometer

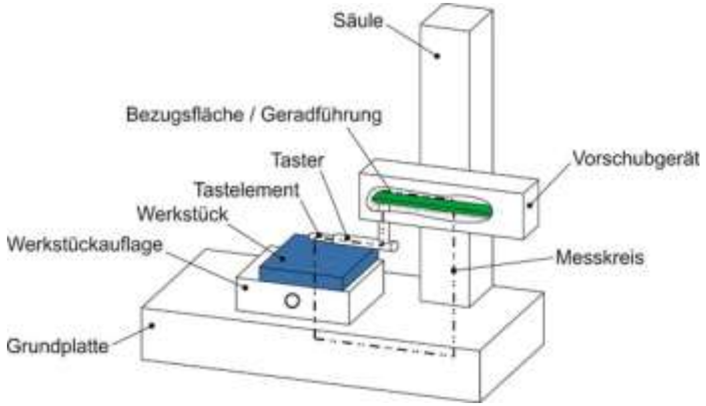
- Tactile systems
  - Skidded profilometer
    - Uses the workpiece surface as a reference
    - Insensitive to vibrations
    - Small device (mobile measurement)

  - Skidless profilometer
    - Refers to a reference surface in the device
    - standard-compliant reference system
    - Highest precision



Source: (Keferstein et al., 2018)

Source: Mahr.com



Source: (Keferstein et al., 2018)

Source: Mahr.com

Problem statement

- Continuous monitoring and display of surface finishes is usually only possible outside the machine tool, resulting in loss of quality and time or processing has to be interrupted for manual roughness measurement
- Tool wear difficult to predict, tool life not optimal
- Trend towards more and more automation and integration of measurement technology in the production line or directly in the machine

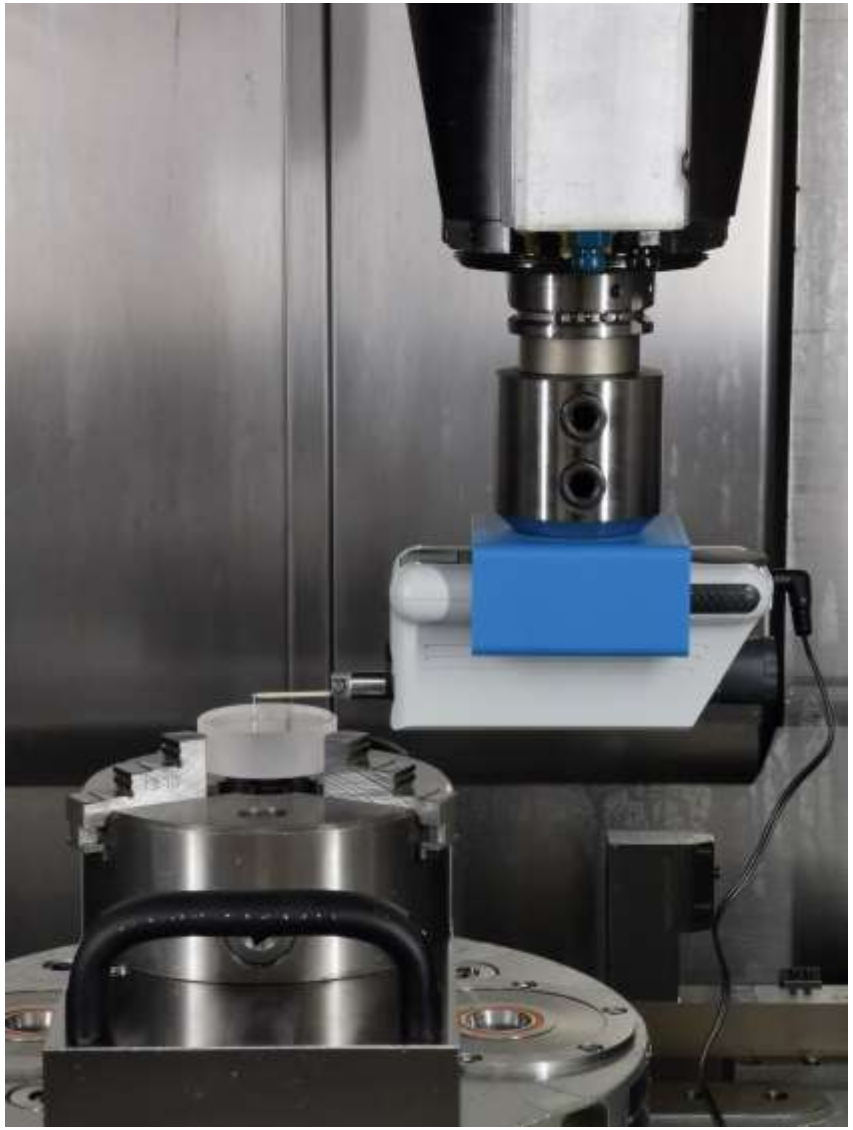
Project goal:
Development of a fully integrated surface roughness measurement device for machine tools

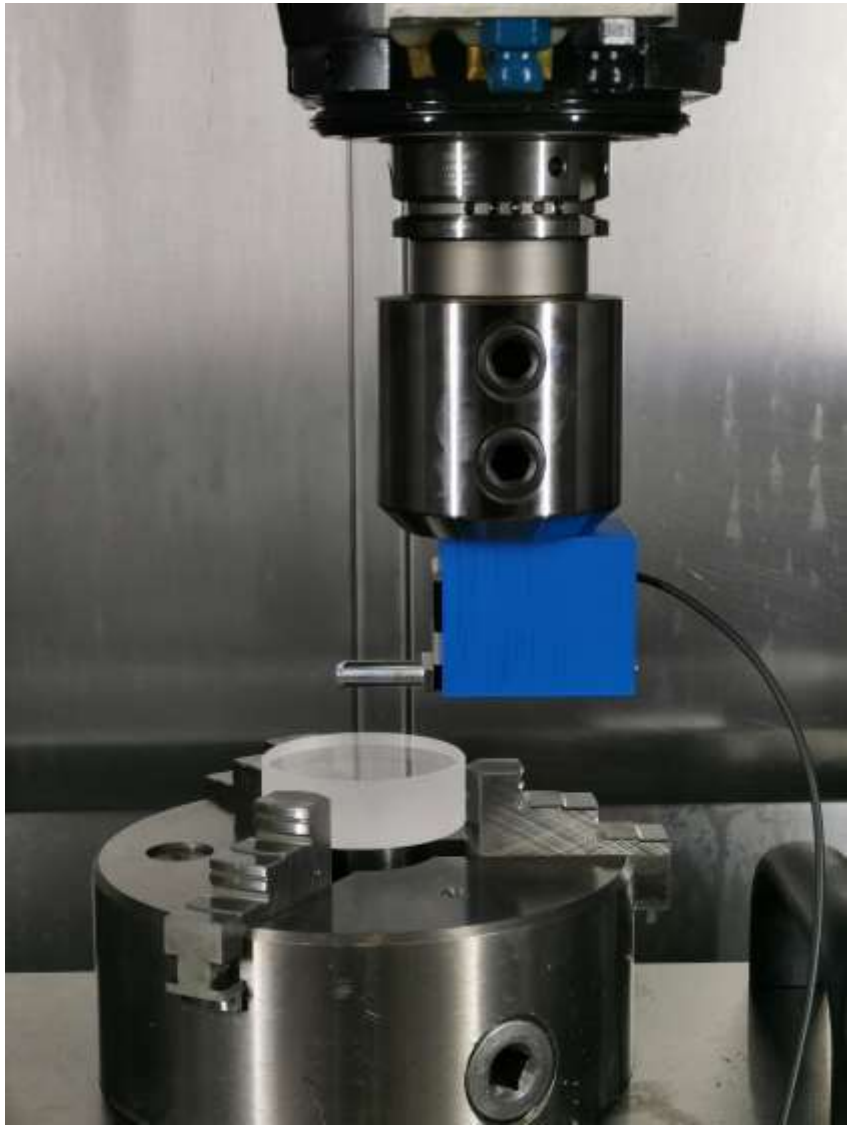
State of the art

- Until now one system for integrated tactile measurement in machine tools on the market
  - Limited accessibility of measuring points
  - Uses feed of the machine tool → Too inaccurate for plausible reference
  - No standard-compliance measurement possible
  - Can only measure Rz > 2µm

- Development goals / requirements:
  - Free touch probe system in machine tool
  - Integrated reference surface (enables standard-compliant measurement)
  - Use machine tool for positioning the measuring device
  - Driven by internal feed unit
  - Robust against dirt and vibrations
  - Wireless communication
  - Interchangeable via tool magazine

First tests using commerically available free probing systems

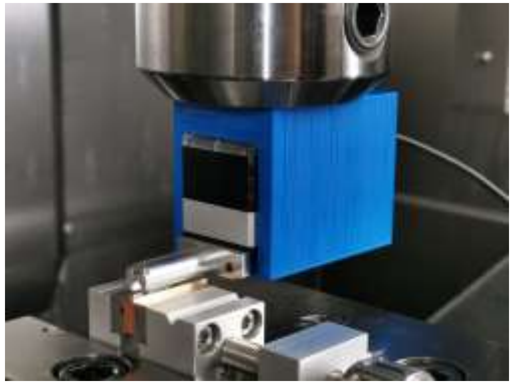




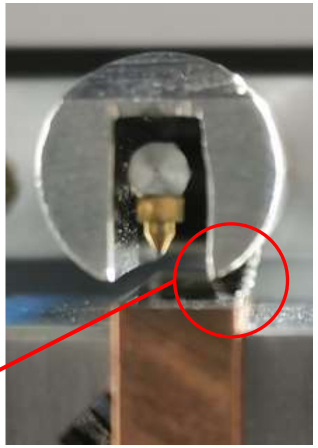
First findings

- Mechnical contact of the device to the measured object is absolutely necessary
- Test measurement results on planar glass (figures differ): **Rz= 0,038µm**

M	Lt	Ls	Lc	Vt	t	Messun	Verfahrac	Messach	Ra	Rz	Rzmax	Anmerkung
1	1,25 mm	2,5 µm	0,25 mm	0,1 mm/s		50	X+	Z	0,007	0,039	0,052	mit Abstützung
2	1,25 mm	2,5 µm	0,25 mm	0,1 mm/s		50	X+	Z	0,009	0,057	0,086	ohne Abstützung
3	1,25 mm	2,5 µm	0,25 mm	0,1 mm/s		50	X+	Z	0,007	0,042	0,062	Notaus aktiv --> keine Aggregate aktiv
4	1,25 mm	2,5 µm	0,25 mm	0,1 mm/s		50	X+	Z	0,022	0,086	0,114	auf Werkstück gelegt (ohne Niederspannung)
5	1,25 mm	2,5 µm	0,25 mm	0,1 mm/s		50	X+	Z	0,020	0,081	0,114	auf Werkstück gespannt
6	1,25 mm	2,5 µm	0,25 mm	0,1 mm/s		50	Y-	Z	0,009	0,060	0,085	mit Abstützung, Fräsprozess auf Hermle aktiv zu Begir
7	1,25 mm	2,5 µm	0,25 mm	0,1 mm/s		50	Y-	Z	0,010	0,063	0,086	ohne Abstützung
8	1,25 mm	2,5 µm	0,25 mm	0,1 mm/s		50	Y-	Z	0,008	0,046	0,064	mit Abstützung, Wiederholmessung ohne Fräsprozess
9	1,25 mm	2,5 µm	0,25 mm	0,1 mm/s		50	Y-	Z	0,008	0,050	0,062	Notaus aktiv --> keine Aggregate aktiv
10	1,25 mm	2,5 µm	0,25 mm	0,1 mm/s		50	Y-	Z	0,016	0,071	0,094	auf Werkstück gelegt (ohne Niederspannung)
11	1,25 mm	2,5 µm	0,25 mm	0,1 mm/s		50	Y-	Z	0,021	0,085	0,117	auf Werkstück gespannt
12	1,25 mm	2,5 µm	0,25 mm	0,1 mm/s		50			0,017	0,072	0,105	Boden vor Haas VF3
13	1,25 mm	2,5 µm	0,25 mm	0,1 mm/s		50	Z+	X	0,006	0,038	0,045	mit Abstützung
14	1,25 mm	2,5 µm	0,25 mm	0,1 mm/s		50	Z+	Y	0,007	0,035	0,421	mit Abstützung
15	1,25 mm	2,5 µm	0,25 mm	0,1 mm/s		50			0,033	0,127	0,182	Tisch nei Haas VF3



Use of skidless profilometers seems to be possible!

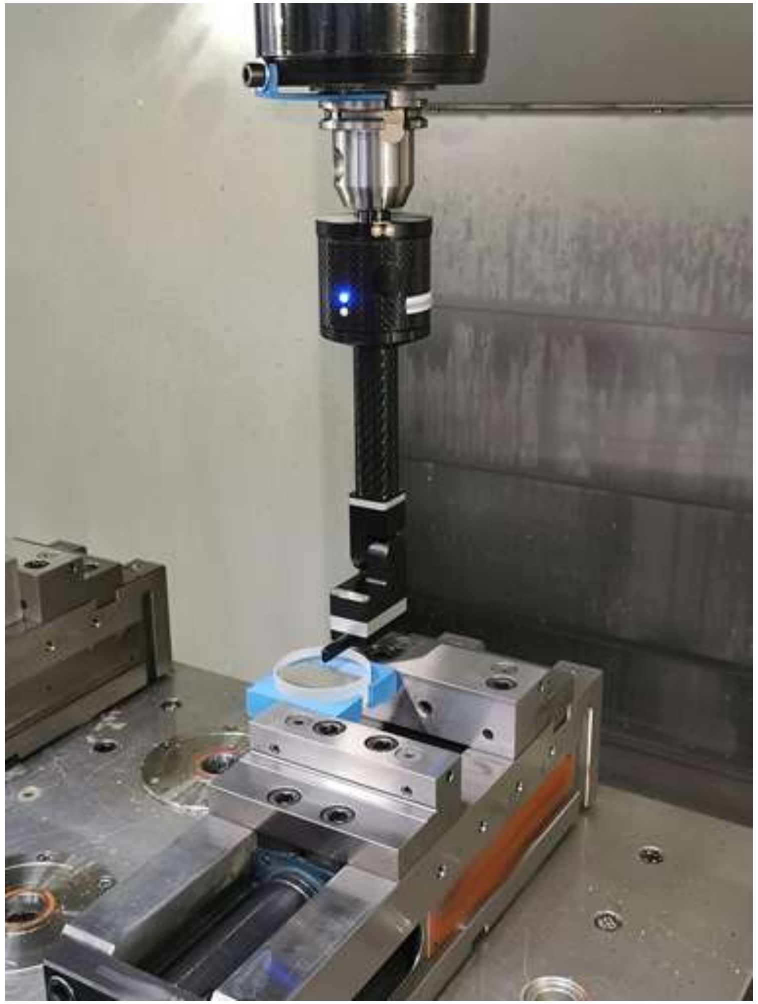


Mechanical contact to object surface is needed to get plausible data (to get robust against vibrations) Here e.g. through headless screw

Concept for integrated system

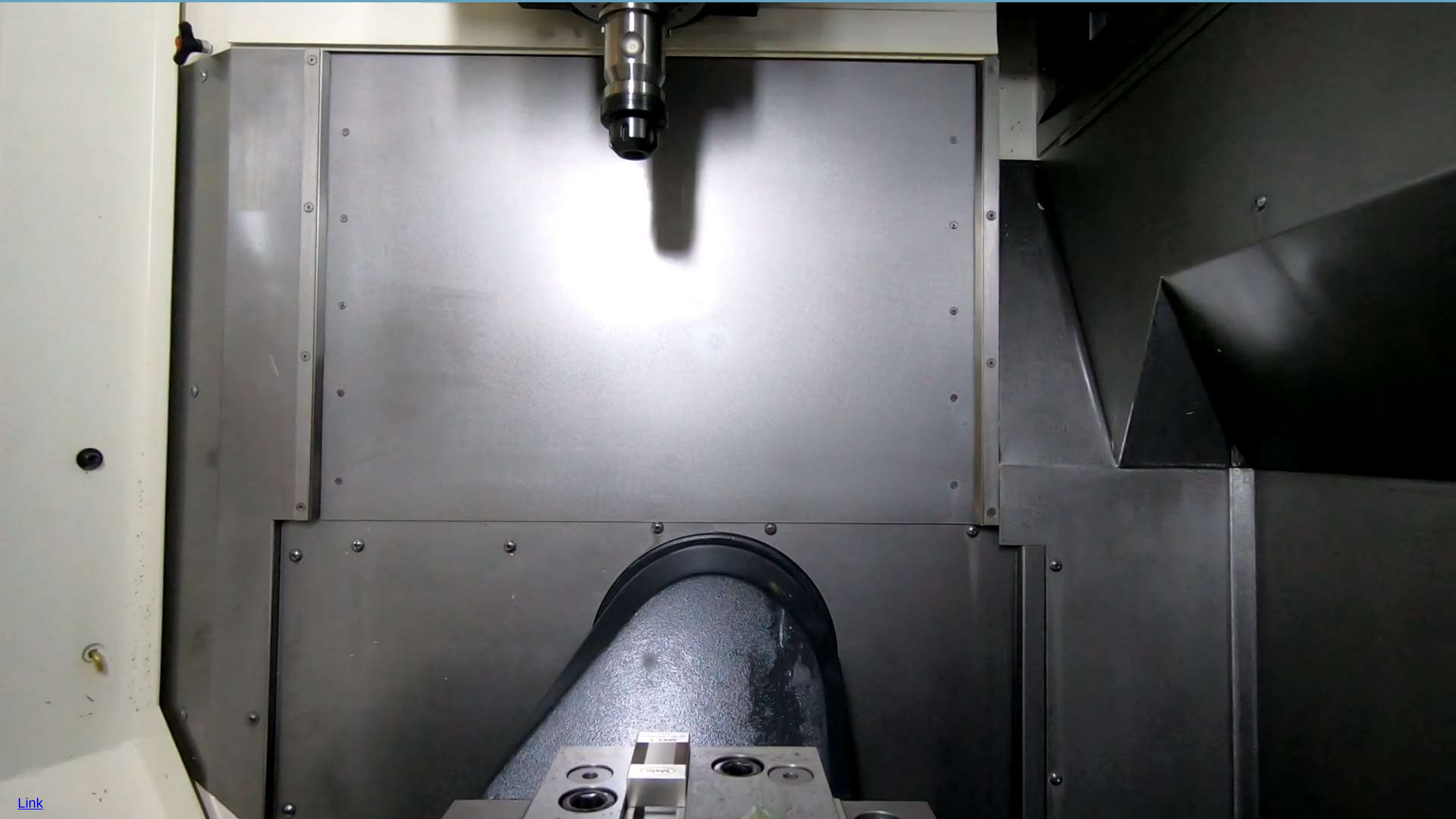
- Development of integrated solution, which can be exchanged by tool changer
- Integrated power supply (battery pack)
- Communication via Bluetooth (wake up from standby)
- Universal data exchange via OPC UA
- Integration of an additional rotary axis
  (for defined workpiece contact and more flexibility)
- Cleaning of workpiece must be considered

First functional prototype in machine tool



Second prototype in machine tool

- More compact design
- Roughness measurement is possible without specialised metrologist
- Rugged aluminium housing
- Exchangeable with tool holder
- Higher battery capacity
- Wake-up via Bluetooth
- Communication with CNC via edge device (OPC UA)
- Complete Measuring cycle for roughness measurement:
  1. CNC calls roughness measurement
  2. Tool change to measurement tool
  3. Positioning of device on workpiece
  4. Send wake up and start command
  5. Wait until measurement is done
  6. Transmit measured profile and calculate desired values
  7. Transmit values to CNC controller via OPC UA
  8. Bring measuring devices back to tool changer
  9. React to measurement (OK/NOK/REWORK etc.)



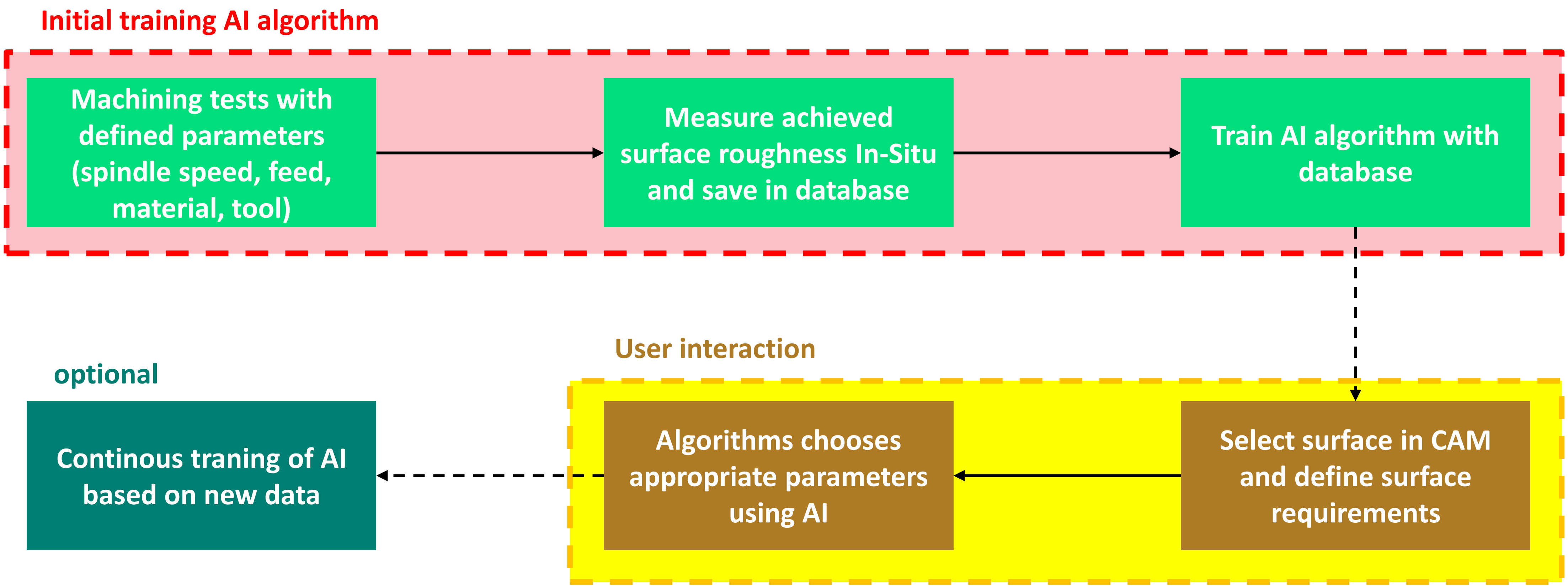
Link

Next steps

- Development of graphical user interface for configuration
- Integration in further CNC machines (different CNC controls)
- Integrate workpiece cleaning
- Construction of protecting housing for measuring tip
- Industrial endurance tests to identify weaknesses
- Full CAM integration to program measurements and include it in NC code through post-processor
- Parameter study with different processing parameters (save in database)

Vision: AI based selection of machining parameters

- Currently, machining parameters for machine tools are often based on user experience or machining tests
- Spindle speed and feed could often be increased, but due to uncertainty of the user they often remain



Contact

Thank you for your attention!

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USPs

- Continuous monitoring of surface qualities (Automated 100% documentation)
- Reproducible measurements without human influence
- no more loss of time due to clamping/unclamping of workpieces in order to measure externally
- High repeatability due to CNC-controlled positioning of the measuring device
- first marketable product for reproducible, standard-compliant in-line measurements
- Closed loop control for corrections during production process
- Prediction of tool wear based on produced surface (use until the end of the tool life)

- Future: AI algorithm defines processing parameters of machine tool (spindle speed, feed) based on required surface specification

Beispielhafte Amortisationsrechnung für integrierte Rauheitsmessung

ZIEL: Heranführung der Werkzeugnutzungsdauer an die erreichbare Standzeit

Vorteil der integrierten Rauheitserfassung: Messung der tatsächlichen Zielgröße der Oberflächengüte anstatt der Werkzeugbetrachtung → Werkzeug wird solange verwendet, solange es zufriedenstellend Oberflächen produziert

- Anschaffungskosten integriertes Rauheitsmesssystem: € 30.000,- (Annahme)

- Beispiel: Schaftfräser
- Kosten: ca. 75€ pro Stück
- Erhöhung der Schneidennutzung von 30 auf 45 Minuten durch integrierte Prozessmessung und Überwachung
- Annahme: Werkzeug ca. 15% der Bearbeitungszeit im Einsatz, 3x8h Schicht
  → Werkzeug 3,6h im Einsatz pro Tag
  → durch Einsparung 2,4 Fräser pro Tag eingespart
  → 2,4 * 75€ = 180€ pro Tag (3 Schichten) → 3.780€/Monat (21 Arbeitstage) → 45.000€ pro Jahr (250 Arbeitstage)

→ ROI beträgt 0,66 Jahre.

Investigation of basic vibrations