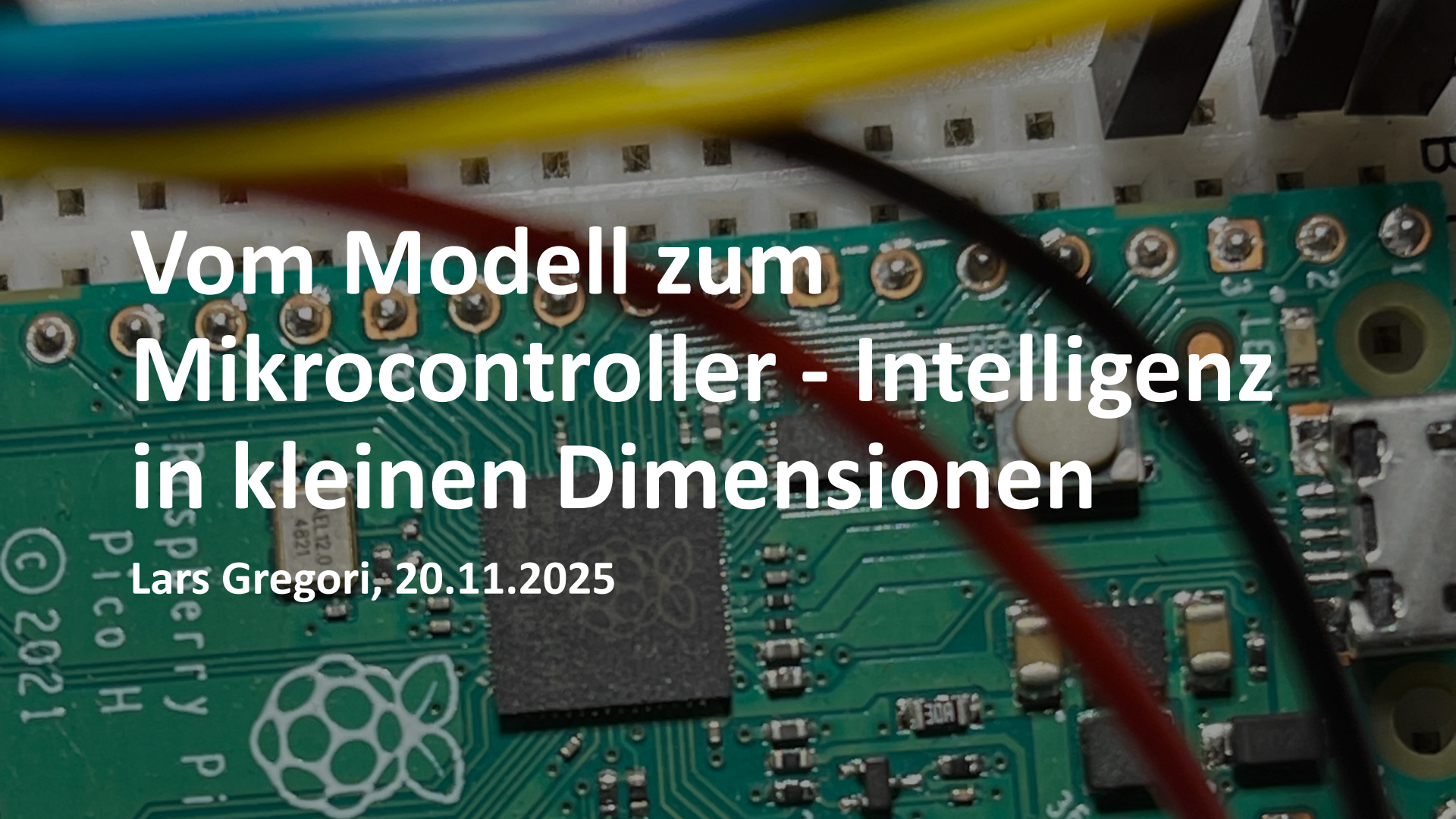


A close-up photograph of a Raspberry Pi Pico H microcontroller board. The green PCB is populated with various components, including a large black microcontroller chip in the center, several gold-colored surface-mount components, and a white ribbon cable connected to the top edge. The Raspberry Pi logo and 'Pico H' text are visible on the board. Overlaid on the image is the title 'Vom Modell zum Mikrocontroller - Intelligenz in kleinen Dimensionen' in large white text, and the author 'Lars Gregori, 20.11.2025' in smaller white text below it.

Vom Modell zum Mikrocontroller - Intelligenz in kleinen Dimensionen

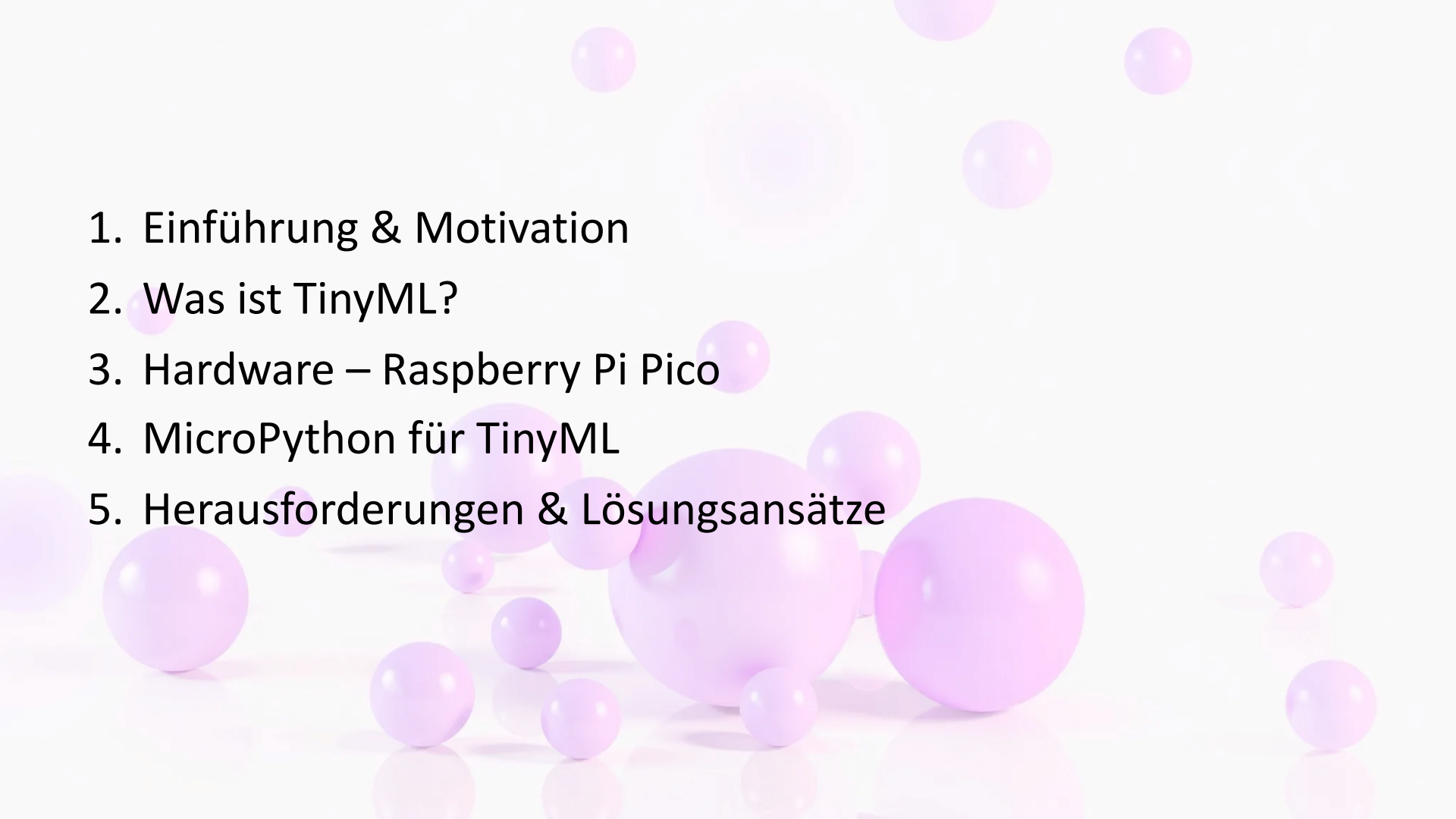
Lars Gregori, 20.11.2025

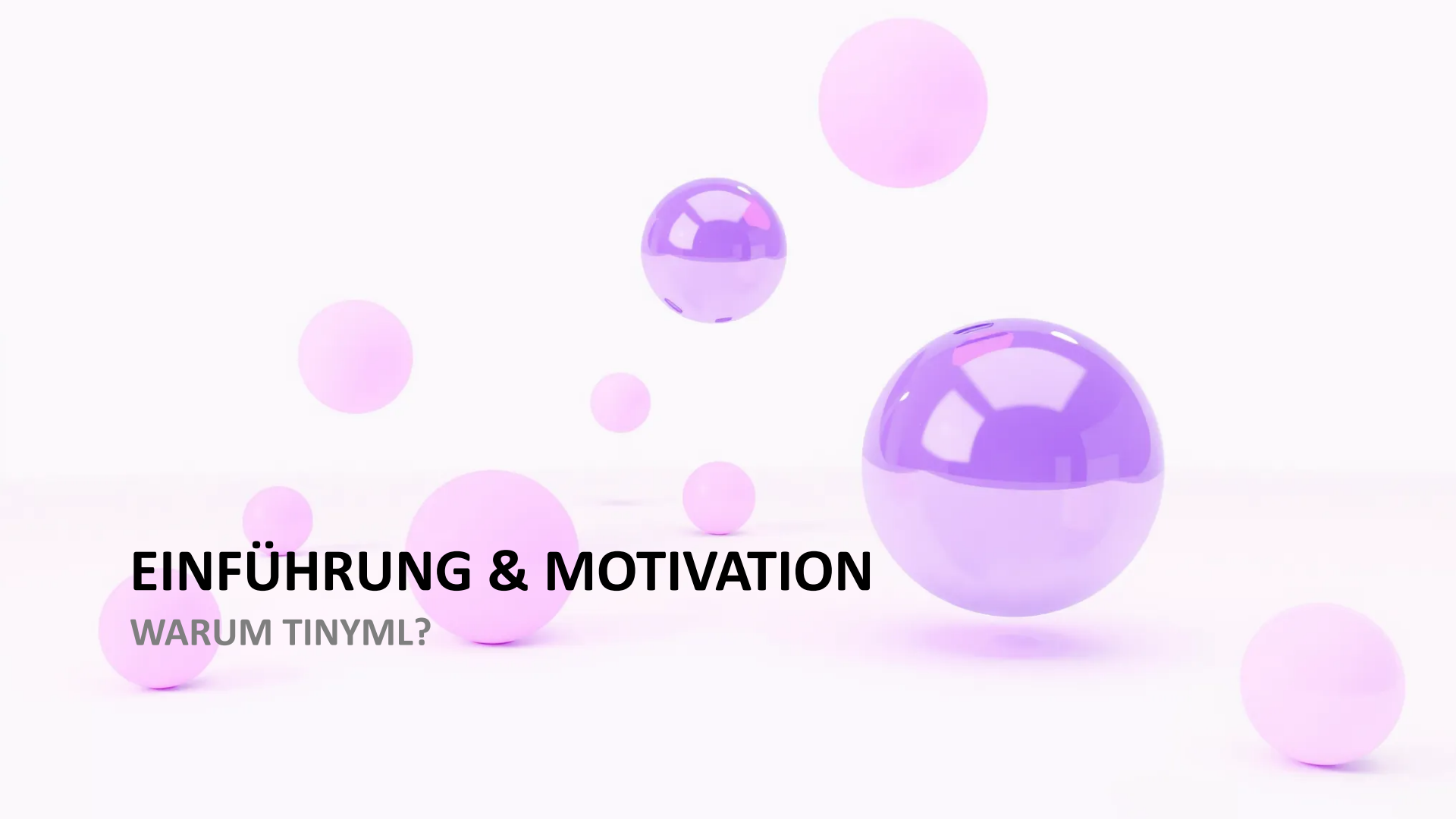
TinyML mit TensorFlow und Python für Microcontroller

The background illustration features a hand holding a magnifying glass over a microcontroller chip on a circuit board. Above the chip is a blue brain-like shape composed of circuit patterns. Surrounding the central elements are various icons: a pie chart, a bar chart, a Wi-Fi symbol, and a document with a checklist. The entire scene is set against a light gray background with abstract blue and white shapes.

The background features a collection of purple spheres of various sizes. Most are matte, but one large sphere on the right is highly glossy, reflecting light and showing highlights. The spheres are scattered across a light purple gradient background, with some casting soft shadows on the surface below.

AGENDA

- 
1. Einführung & Motivation
 2. Was ist TinyML?
 3. Hardware – Raspberry Pi Pico
 4. MicroPython für TinyML
 5. Herausforderungen & Lösungsansätze

The background of the slide features several 3D-rendered spheres in various shades of purple and magenta. Some spheres are highly reflective, showing highlights and shadows, while others are more matte. They are scattered across the frame, with some appearing to sit on a light-colored surface that casts soft shadows. The overall aesthetic is clean and modern.

EINFÜHRUNG & MOTIVATION

WARUM TINYML?

Die IoT-Revolution

- **41,1 Mrd. vernetzte Geräte bis 2030** (Source: IoT Analytics)
- **Bedarf an autonomen, intelligenten Lösungen**
- **Aber: Ressourcenbeschränkungen!**



Warum TinyML?

Vorteile	Beschreibung
Datenschutz	Daten verlassen das Gerät nicht.
Latenz	Millisekunden statt Sekunden.
Kosten	Keine Cloud-Gebühren, günstige Hardware.
Verfügbarkeit	Funktioniert offline.
Energieeffizienz	Batteriebetrieb für Monate/Jahre.

The background of the slide features several translucent purple spheres of varying sizes scattered across a light purple gradient. Some spheres are highly reflective, showing highlights and shadows, while others are more matte. They are positioned at different depths, creating a sense of three-dimensional space.

WAS IST TINYML?

DEFINITION UND ANWENDUNGSBEREICHE

TinyML Definition

- **Tiny Machine Learning**
- KI-Modelle auf Mikrocontrollern
 - **Speicherbedarf:** $< 1 \text{ MB}$
 - **Energieverbrauch:** $< 1 \text{ mW}$

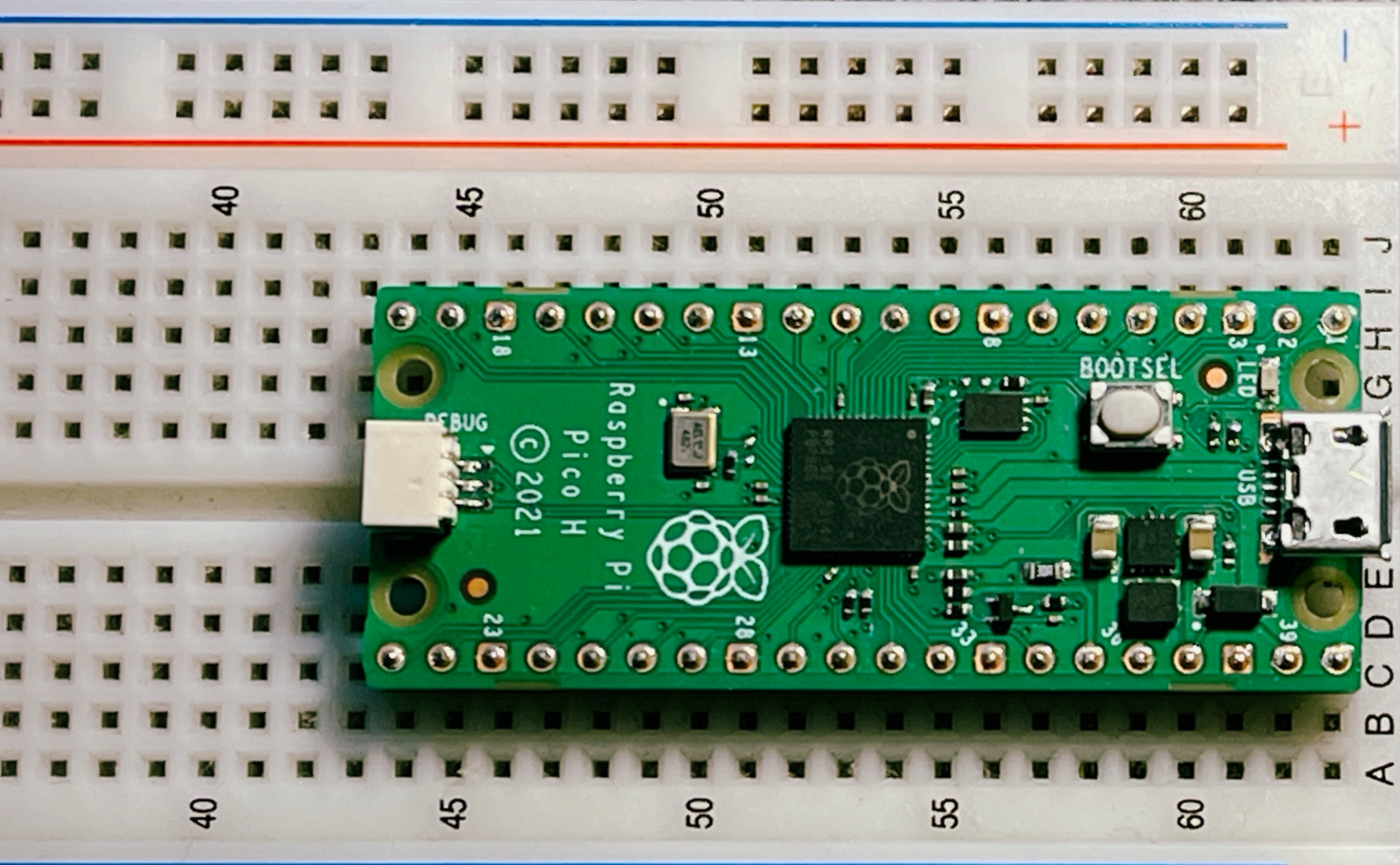
Anwendungsgebiete

- **Wearables:** Fitnesstracker, Gesundheitsmonitoring
- **Voice Assistants:** Wake-Word-Erkennung
- **Predictive Maintenance:** Industrie 4.0
- **Smart Cities:** Verkehrsoptimierung, Umweltüberwachung
- **Autonome Systeme:** Drohnen, Roboter

The background of the slide features several translucent purple spheres of varying sizes scattered across a light purple gradient. Some spheres are highly reflective, showing highlights and shadows, while others are more matte. They are positioned at different depths, creating a sense of three-dimensional space.

HARDWARE: RASPBERRY PI PICO

BEISPIELPLATTFORM



Warum Raspberry Pi Pico?

- **Kostengünstig** (~5€), weit verbreitet, aktive Community
- **Technische Spezifikationen:**
 - Dual-core ARM Cortex M0+ (133 MHz)
 - 264 KB SRAM, 2 MB Flash
 - 26 GPIO Pins
- **MicroPython-Support** out-of-the-box

Limitierungen von MCUs

- **Begrenzter Speicher** (KB statt GB)
- **Eingeschränkte Rechenleistung**
- **Update-Herausforderungen**

The background of the slide features several translucent purple spheres of varying sizes scattered across a light purple gradient. Some spheres are highly reflective, showing highlights and shadows, while others are more matte. They are positioned at different depths, creating a sense of three-dimensional space.

MICROPYTHON FÜR TINYML

PRAKTISCHE UMSETZUNG

Vorteile von MicroPython

- Einfache Syntax, ideal für Prototyping
- Cross-Platform-Kompatibilität
- Interaktive REPL für Live-Testing



TensorFlow Lite Micro Integration

- Modelle im **.tflite**-Format
- **Quantisierte Modelle** für Speichereffizienz



Entwicklungs-Workflow

1. Datensammlung
2. Training (Jupyter Notebook)
3. Modelloptimierung
4. TFLite-Konvertierung
5. MicroPython-Integration
6. Hardware-Test
7. Deployment

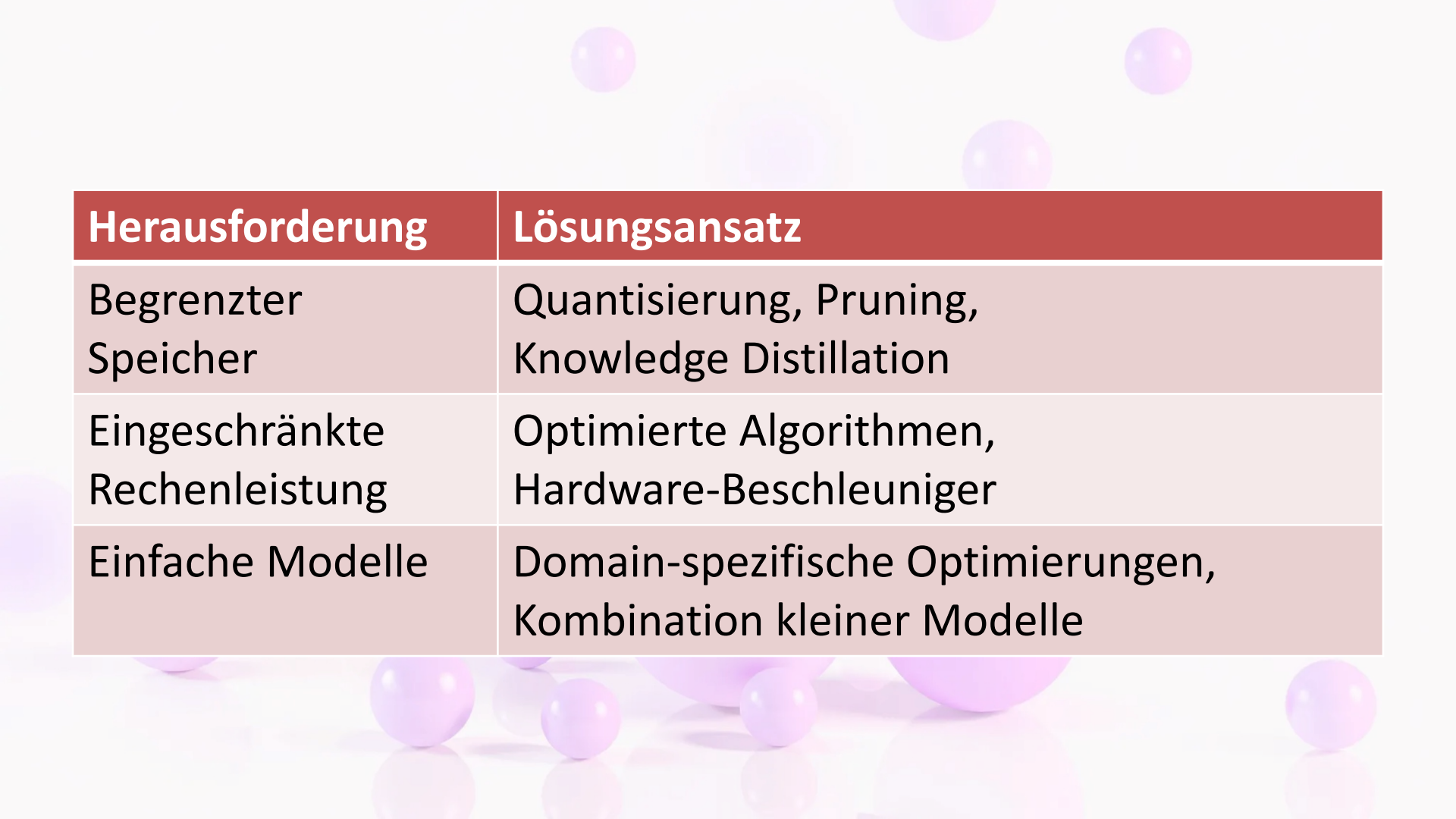


The background of the image is white and is populated with numerous purple spheres of varying diameters. These spheres are scattered across the frame, with some appearing as small dots and others as large, prominent circles. The spheres have a glossy, three-dimensional appearance, with highlights and shadows that suggest a light source from the upper left. The word "DEMO" is centered in the image, rendered in a bold, purple, sans-serif typeface. The overall composition is clean and modern, with a strong color contrast between the purple and white.

DEMO

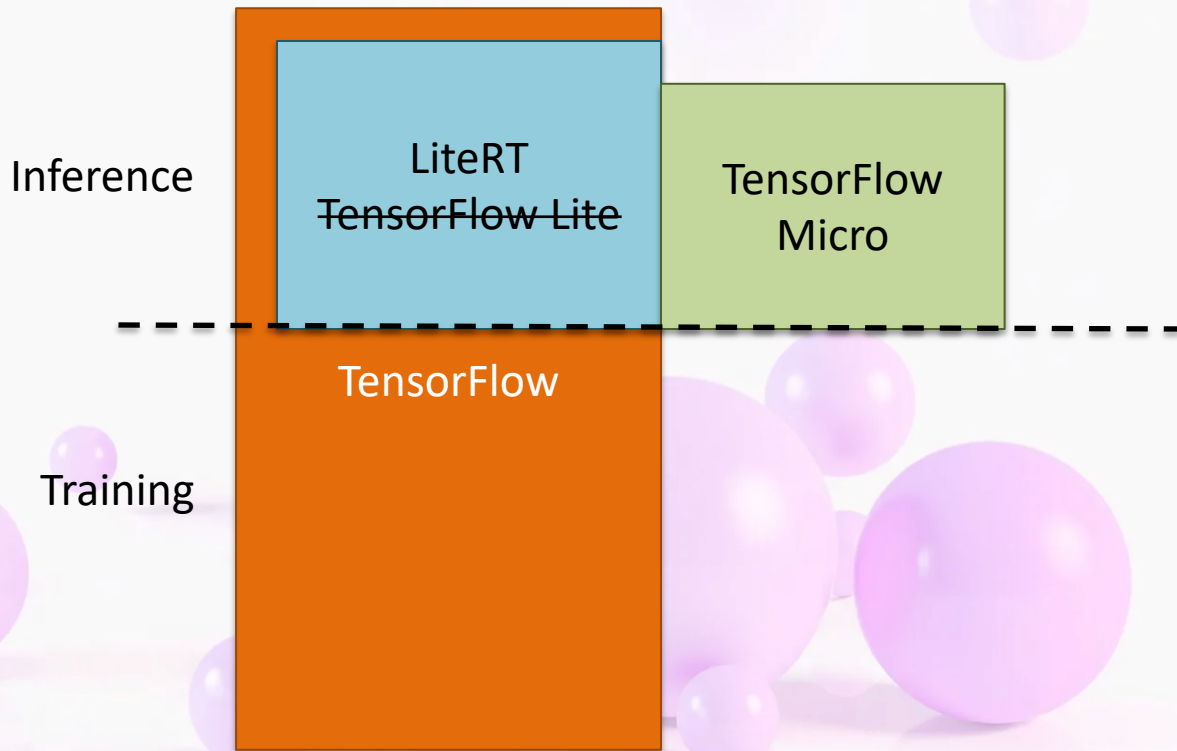
The background features several translucent purple spheres of varying sizes scattered across a light purple gradient. Two spheres, one in the upper center and one in the lower right, are highly reflective, showing highlights and shadows. The other spheres are more matte. The text is centered horizontally and partially overlaid by the spheres.

HERAUSFORDERUNGEN & LÖSUNGSANSÄTZE

The background of the slide is white and features several translucent purple spheres of varying sizes. Some spheres are positioned at the top, while others are at the bottom, creating a decorative border effect. The table is centered on the slide.

Herausforderung	Lösungsansatz
Begrenzter Speicher	Quantisierung, Pruning, Knowledge Distillation
Eingeschränkte Rechenleistung	Optimierte Algorithmen, Hardware-Beschleuniger
Einfache Modelle	Domain-spezifische Optimierungen, Kombination kleiner Modelle

TensorFlow Micro



The background features several translucent purple spheres of varying sizes scattered across a light purple gradient. A large, highly reflective sphere is positioned on the right side, showing clear highlights and shadows. Other smaller, more opaque spheres are distributed throughout the scene. The overall aesthetic is clean and modern.

ZUSAMMENFASSUNG & AUSBLICK

Zusammenfassung

- TinyML ermöglicht intelligente IoT-Geräte **ohne Cloud-Abhängigkeit.**
- Raspberry Pi Pico + MicroPython **ideale Entwicklungsplattform.**
- Herausforderungen sind lösbar durch **bewusste Design-Entscheidungen.**



FRAGEN & DISKUSSION

- **Offene Frage:** “In welchen Bereichen sehen Sie das größte Potenzial für TinyML?”
- **Kontakt:** about.larsgregori.de

