**Catalog Description:**
This course provides hands-on training in intelligent robotic systems with an emphasis on human-centric, safety-aware robot operation in modern manufacturing environments. Students will work with a 7-DoF industrial robotic manipulator to understand robot kinematics, coordinate frames, rotation representations, and redundancy. The course covers robot programming, sensor integration, safety mechanisms, and human–robot collaboration (HRC), progressing from foundational hardware configuration to advanced XR-based teleoperation. Through structured laboratory modules and a final project, students will develop practical skills in perception-driven control, safety-critical interaction, and collaborative robotic task execution. Lab 1, Credit 2 (S).

| | |
|---|---|
| Date Range: | Jan 23, 2026 ~ May 11, 2026 |
| Meeting Locations: | Chem Lab-Nobel Lab (W2-224A)<br>FIR Lab (W2-521) |
| Times: | 9:00AM - 11:50AM Tuesday |
| Lecturer: | Dr. Yunbo Zhang (yunbozhang@hkust-gz.edu.cn) |
| Teaching Assistant: | Chenrui Chen<br>cchen512@connect.hkust-gz.edu.cn |
| Office Hour: | 2:00 PM~4:00 PM Friday at Rm 303, W2 |

**Text Book(s) and Supplemental Material(s): Lecture notes and other materials provided by lecturer**

**Course Goal(s):**
By the end of this course, you should:

- Explain and apply the concept of degree of freedom (DoF) and kinematic redundancy in 7-DoF robotic manipulators.
- Define and transform between robot coordinate frames, including base, tool, TCP, and task frames.
- Interpret and utilize rotation representations (e.g., axis–angle and rotation vectors) for motion planning and control.
- Safely initialize, configure, and operate industrial robots in shared human–robot workspaces.
- Program robotic motion using teach-in, graphical, and script-based methods.
- Integrate external sensors using digital and analog I/O for perception-driven behaviors.
- Design and implement human–robot collaboration (HRC) tasks that consider safety, efficiency, and human intent.
- Optimize robotic task execution while respecting safety constraints.
- Perform XR-enabled teleoperation, mapping human motion to robotic trajectories with awareness of safety and collaboration.
- **Students are responsible for downloading class materials, reading materials, and checking notices about class on a regular basis at Canvas:**

**Grading:**

| | |
|---|---|
| 2 Lab Report Reports for Lab 3 & 4: | 15 points |
| 1 Final Project Report: | 30 points |
| 1 demonstration for lab 6: | 5 points |
| **Total:** | **50 points** |

**Attendance:**
**Required.** All students are expected to attend and participate in class and lab sessions. Your grade will be affected by your participation, as 10% of your final grade is determined by your participation.

**Project Report & Homework Submission:**
It is expected that you will complete exam and homework independently, and submit on time.

- No make-up exams for unexcused absences. If you have job interviews or other valid excuses, you must make arrangements ahead of time to reschedule an exam.
- Late HW submissions will lose 10 pts per day up to the point when graded HW is returned or a solution key is posted. Submissions after answers are available will receive a maximum of 50% credit.

## Laboratory Modules

### LAB 1: ROBOT HARDWARE, DEGREE OF FREEDOM & SAFETY FOUNDATIONS

Objectives:

- Understand robot hardware architecture and kinematic structure.
- Learn degree of freedom and redundancy concepts.
- Establish safe operation practices.

Topics:

- 7-DoF manipulator structure and joint types
- Kinematic redundancy and workspace
- Controller hardware and safety boards
- Emergency stop and collaborative safety modes
- Safe startup, shutdown, and recovery procedures

### LAB 2: COORDINATE FRAMES, ROTATION & MOTION REPRESENTATION

Objectives:

- Understand spatial representation of robot motion.
- Apply frame transformations and orientation control.

Topics:

- Base, tool, TCP, and task frames
- Frame transformations in programming
- Axis–angle and rotation vector representation
- Pose notation p[x, y, z, ax, ay, az]
- Frame selection and accuracy considerations

### LAB 3: PROGRAMMING METHODS & SENSOR INTEGRATION

Objectives:

- Program robotic motion using multiple paradigms.
- Integrate sensor feedback into control logic.

Topics:

- Teach mode, walk-through, and script-based programming

- Inverse kinematics fundamentals
- Digital and analog sensors
- Event-based waiting and conditional branching
- Perception-driven robotic behaviors

LAB 4: SAFETY-AWARE DEVICE INTERACTION & HUMAN–ROBOT COLLABORATION
Objectives:

- Implement safe device interaction.
- Design collaborative robot behaviors.

Topics:

- Digital and analog I/O control
- Dynamic payload and center-of-gravity adjustment
- Human–robot collaboration (HRC) concepts
- Proactive vs. reactive collaboration
- Safety-aware cycle optimization

LAB 5: INTELLIGENT COLLABORATIVE TASKS & COMPLEX PATH PLANNING
Objectives:

- Integrate motion, logic, sensing, and collaboration.
- Execute complex, safety-aware tasks.

Topics:

- Logic-based decision making
- Odd/Even sorting task
- Precision logo tracing
- Failure detection and recovery
- Human-in-the-loop interaction

LAB 6: XR-BASED TELEOPERATION & ADVANCED HUMAN–ROBOT COLLABORATION
Objectives:

- Perform XR-enabled teleoperation.
- Map human motion to robotic trajectories.

Topics:

- XR digital twin visualization
- Redundant DoF control via IK
- Safety in XR teleoperation
- Collision and workspace awareness
- Collaborative task execution in XR

**The HKUST Academic Honor Code:**
Honesty and integrity are central to the academic work of HKUST. Students of the University must observe and uphold the highest standards of academic integrity and honesty in all the work they do throughout their program of study. As members of the University community, students have the responsibility to help maintain the academic reputation of HKUST in its academic endeavors. Sanctions will be imposed on students, if they are found to have violated the regulations governing academic integrity and honesty.