XNAV

Realtime robotic control on xcore.ai

ELECOMP Capstone Design Project 2025-2026

Sponsoring Company:

XMOS Ltd.
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Company Overview:

XMOS is a fabless semiconductor company, headquartered in Bristol in the UK.

Our mission is to change the way systems are deployed on silicon – disrupting system-on-chip economics and time to market by enabling embedded software engineers to create custom SoC solutions simply by loading software onto our uniquely flexible and accessible hardware platforms.

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Project Motivation:

A mobile robot is the perfect platform to demonstrate some of the key benefits of xcore.ai processors: precise IO control, high performance processing cores, and software defined communication interfaces.

Robotics demands tight synchronization between sensors and actuators. xcore.ai's hardware-level deterministic timing and multi-threaded I/O enable reliable, low-latency handling of encoders, motor drivers, ultrasonic sensors, and more without relying on external peripherals or interrupt-heavy MCU code.

The parallel architecture and real-time scheduling of xcore.ai allow it to run closed-loop motor control, sensor fusion algorithms (e.g., IMU + odometry), and obstacle avoidance logic concurrently, on a single chip. This demonstrates how the processor can handle complex, time-sensitive workloads typically spread across multiple components.

The ability to configure UART, SPI, I2C, USB, and Ethernet interfaces in software enables rapid prototyping and integration with a wide range of robotic sensors and host systems. This flexibility is especially valuable in robotics, where system requirements and configurations can evolve quickly.

In addition to showcasing these hardware strengths, the project creates a compelling, hands-on reference design that can be used to engage customers, support application notes, or seed future development kits. It also serves as a testbed for reusable I/O and control IP, helping reduce time-to-market for real-world robotic solutions built on XMOS technology.

Anticipated Best Outcome:

- Implement the following external interfaces on xcore:
    - Wheel/track control
    - At least one continuous sensor (IMU, camera, ranger, etc.)
    - At least one intermittent sensor (e.g. collision detector)
    - Communication interface
- Implement a control loop that drives the robot along a set path using its onboard sensors, the robot should also safely stop if it detects and obstruction.
- Logging or higher-level feedback over UART, USB, or wireless — potentially integrating with ROS2 if paired with XROS.
- Bonus: pair 2 or more continuous sensors with a sensor fusion algorithm (i.e. combine ranging data from radios with odometry data from wheel encoders to compute a position)

Project Details:

This project aims to design and implement a real-time control system for a mobile robot using the XMOS xcore.ai processor. The robot will autonomously navigate an indoor environment using multi-modal sensor data, such as IMU, encoders, and distance sensors (e.g., ultrasonic or LIDAR), with control loops and sensor fusion handled entirely on the xcore.ai.

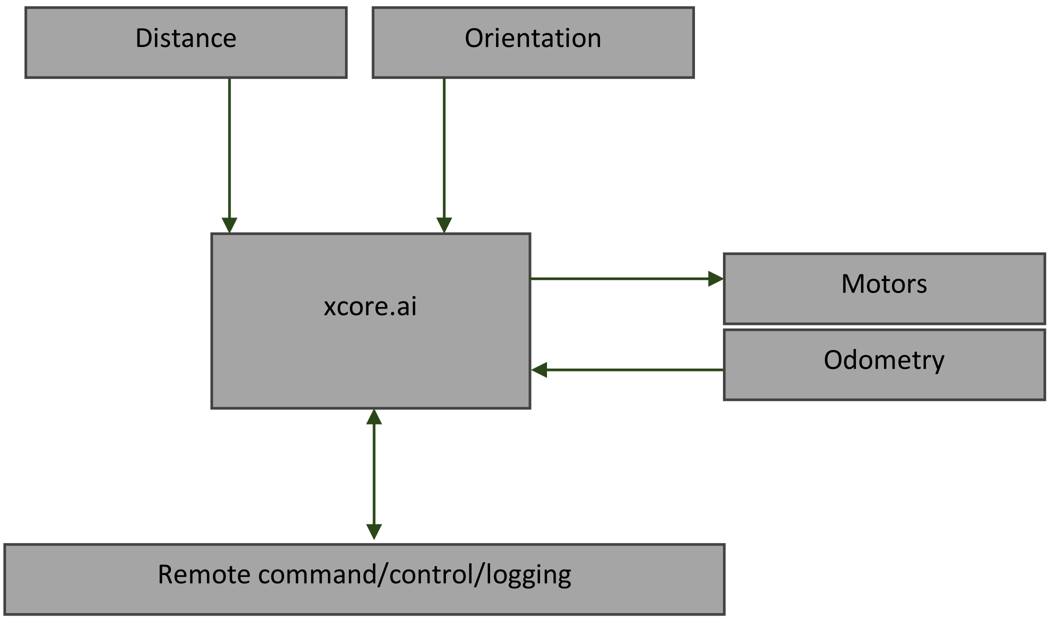
The unique parallel processing architecture and deterministic I/O of xcore.ai make it ideal for simultaneously:

- Capturing and fusing sensor inputs
- Performing control loop computations (e.g., PID)
- Generating motor PWM outputs
- Logging data or communicating status over most commonly available protocols

The robot will be built on a differential drive platform (or something equivalent, the team will have a say in what commercially available platform they select) and will include obstacle avoidance and trajectory tracking. The system is designed to function standalone but can optionally be extended to integrate with ROS2 systems through the outputs of XROS.

While the project requires only an XMOS development board and a commercial robot platform, there may be some PCB design required in order to interface the two.

Block Diagram:



Hardware/Electrical Tasks:

- Design system-level schematics
- Manage hardware interface considerations such as
    - IO voltage / current characteristics
    - Data rates
    - Port/pin map
    - Size/weight/power/cost considerations
- Build any supporting infrastructure for components such as:
    - Power supplies
    - Voltage conversions / single ended to LVDS conversions
    - Wiring, housing, any mechanical design
- Time permitting, design PCB to integrate the final design (and remove any unused peripherals from the original development kit)

Firmware/Software/Computer Tasks:

- Implement all required interfaces (use existing libraries whenever possible), it is recommended to use a real time operating system (FreeRTOS currently supported)
- Architect a control loop (should take periodic inputs as well as intermittent inputs and output actuation commands in real time)
- Implement any sensor processing / fusion
- Design tests
- Write documentation
- Organize all code / tests / docs into a coherent repository on Github

Composition of Team:

1 Electrical Engineer & 2 Computer Engineers

Skills Required:

Electrical Engineering Skills Required:

- Strong basic Physics / Math background
- Ability to read datasheets and evaluate components
- PCB design experience is a plus
- Any of the computer engineering skills below would also be a plus

Computer Engineering Skills Required:

- Strong c/c++ programming
- Experience with embedded systems (Microcontrollers/FPGAs)
- Good troubleshooting skills
- Signal processing / control systems knowledge is a plus
- Experience with version control systems, preferably Git
- Good written communication skills

Anticipated Best Outcome's Impact on Company's Business, and Economic Impact

The anticipated best outcome of this project is the demonstration of a compelling, real-world application of the XMOS xcore.ai processor in a robotics context, showcasing its unique capabilities in deterministic real-time control, parallel processing, and low-latency I/O. By validating the xcore.ai platform in a domain that demands both performance and reliability, this project supports XMOS's strategic goal of expanding into high-growth markets such as robotics, industrial automation, and intelligent edge systems.

Economically, the project has the potential to yield reusable software components, hardware designs, or integration patterns that can accelerate future product development or form the basis of customer reference designs. A successful outcome enhances the marketability of XMOS technology by providing demonstrable proof-of-concept systems, reducing customer adoption friction, and highlighting differentiators against conventional MCUs or SoCs. Over time, this could contribute to increased design wins and licensing opportunities, particularly in emerging application areas where deterministic compute is critical.

Broader Implications of the Best Outcome on the Company's Industry:

The anticipated best outcome of this project would highlight the practical advantages of software-defined architecture like xcore.ai in robotics and sensing applications where deterministic behavior, low latency, and I/O flexibility are essential. It would demonstrate that complex, time-sensitive control systems can be implemented without resorting to power-hungry FPGAs or multi-chip solutions, thereby reducing system cost, board space, and integration complexity.

In sectors like industrial robotics and drones, there is a growing demand for systems that combine precise real-time control with increasing levels of autonomy and sensor integration. Traditional architectures often struggle to balance these needs without adding cost, complexity, or power consumption. This project aligns with the broader industry movement toward consolidating different workloads onto fewer, more capable platforms that can meet tight timing requirements while remaining adaptable. Demonstrating these capabilities in a practical, working system reinforces the feasibility of this approach and may help shape future design decisions in high-growth, performance-sensitive applications.