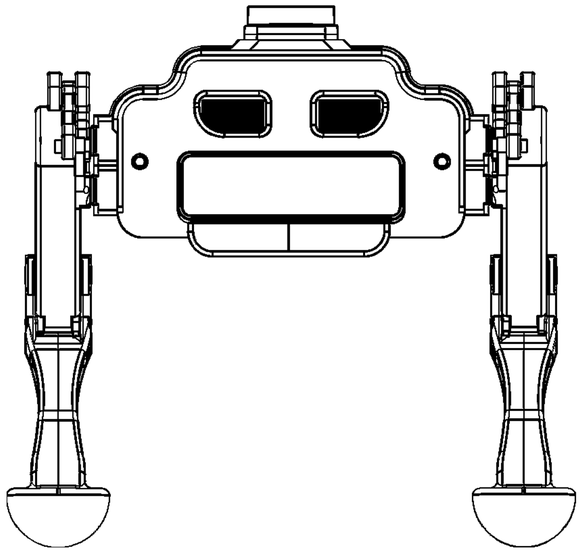
IBM **TechXchange**

Engineering a Cost-Effective Quadruped

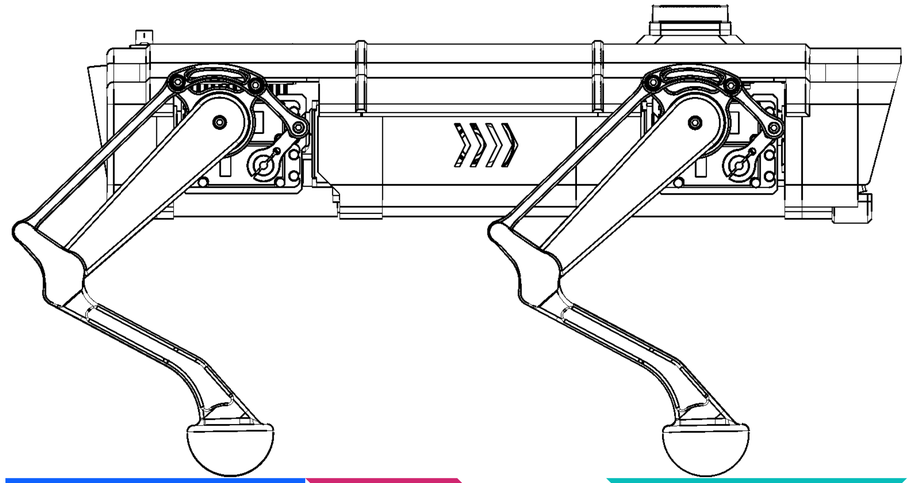
Paving new paths in automated disaster response

Session 3834
AI-Powered Student Projects
Gian-Luca Fenocchi
Student, Imperial College London



October 21-24, 2024
Mandalay Bay Convention Center
Las Vegas, Nevada

What We'll Cover Today



01 The Challenge
02 Introducing **REX**
03 Design
04 WatsonX
05 SkillsBuild

The Challenge of Disaster Response

Natural disasters create unpredictable, dangerous environments

Existing robotic systems are costly and inaccessible for many organizations

Current robots face challenges in decision making and maintaining effective communication

2021 Haiti Earthquake

[Photo: Ricardo Arduengo / Reuters]

> Resulted in an estimated economic loss of $1.6B.

The impacts of natural disasters underscore the urgent need for advanced, cost-effective disaster response technologies.

The Challenge of Disaster Response

PackBot – Endeavor Robotics

Deployed during 9/11 and Fukushima, is reliable but needs a human operator

Spot – Boston Dynamics

Agile with advanced sensors but costs around $74,500

Vision 60 – Ghost Robotics

Rugged and autonomous, but at $150,000, it’s too expensive

Introducing REX: Affordable Autonomous Robot

RESCUE & EXPLORATION

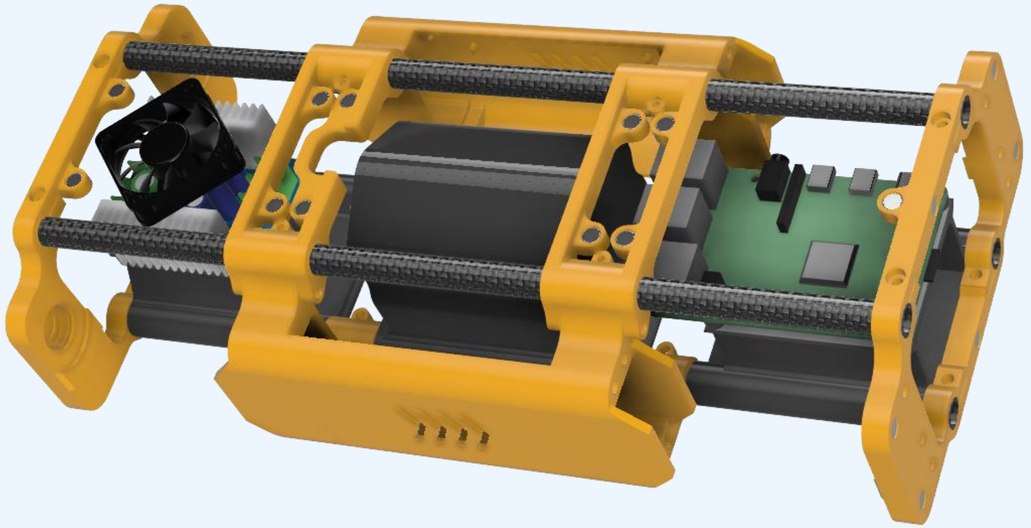
Cost-effective – accessible to smaller organizations ~$1,000

Commercial off the shelf parts

Embedded WatsonX Assistant

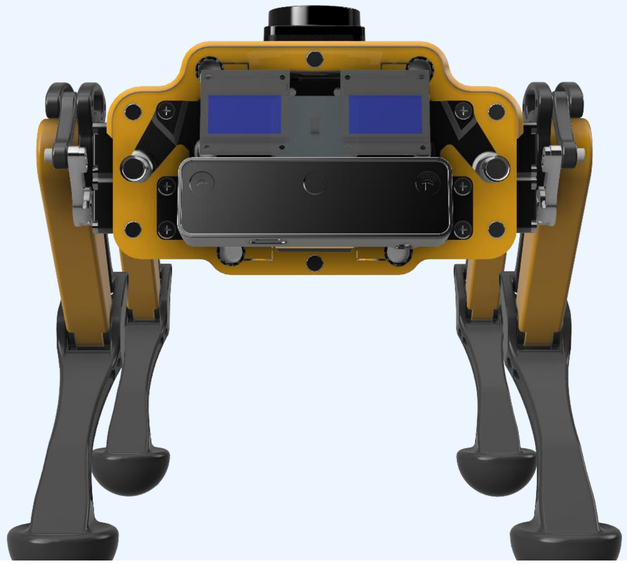
Open source platform for extended support

Modularity & Repairability



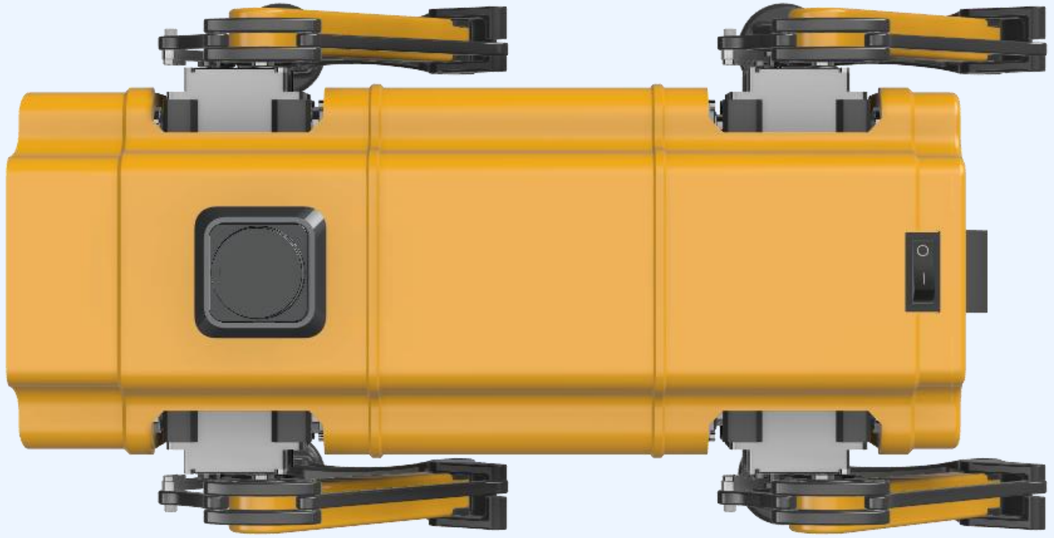
REX's modular design allows for quick part replacements using off-the-shelf components

Ensures minimal downtime during operations

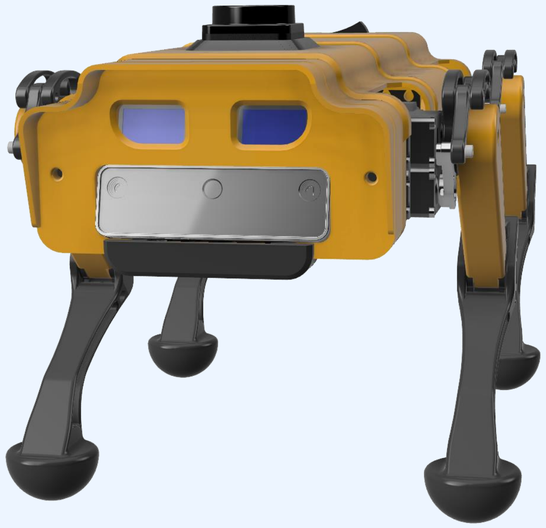


With 3D-printed components and simple assembly, REX can be repaired directly in the field

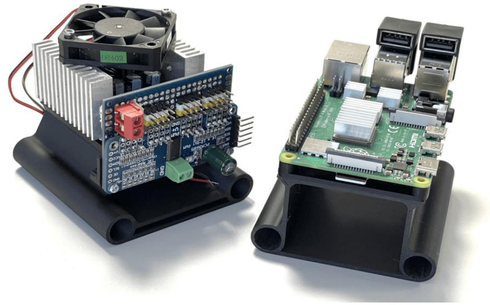
Reduces the need for specialized tools or facilities



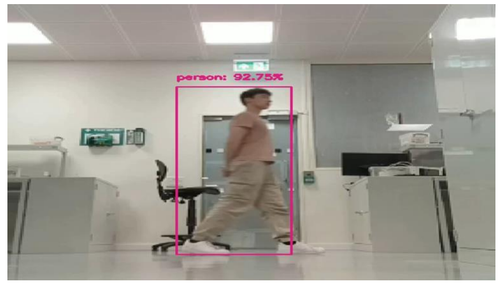
High-Level Design Overview



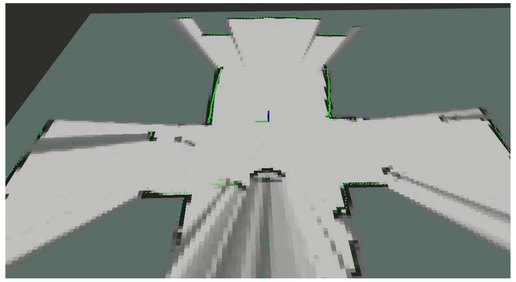
Powered by a Raspberry Pi 4B, serving as the on-board computer for processing and control



Depth camera enables real-time person identification and localization

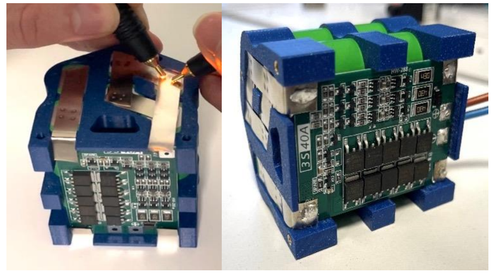


LiDAR scanner provides precise environmental mapping & obstacle detection through SLAM

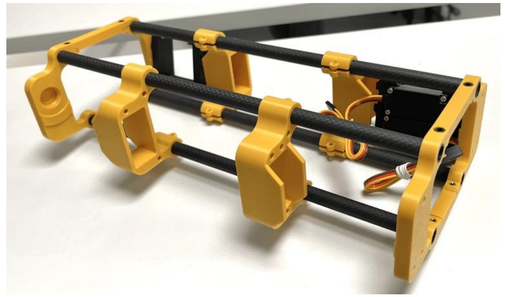


WatsonX Assistant integrates with stereo speakers & a dual mic array for communication

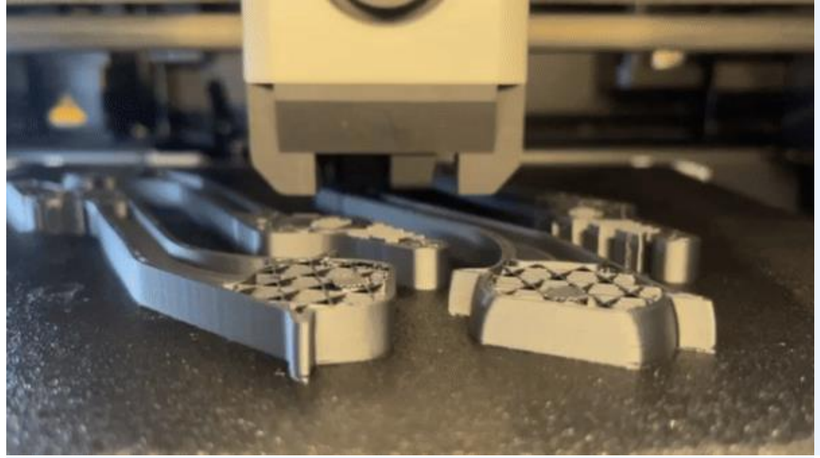
Lithium-Ion battery pack ensures long operational time, with USB-C quick charging



Chassis made from carbon-fiber & durable thermoplastics

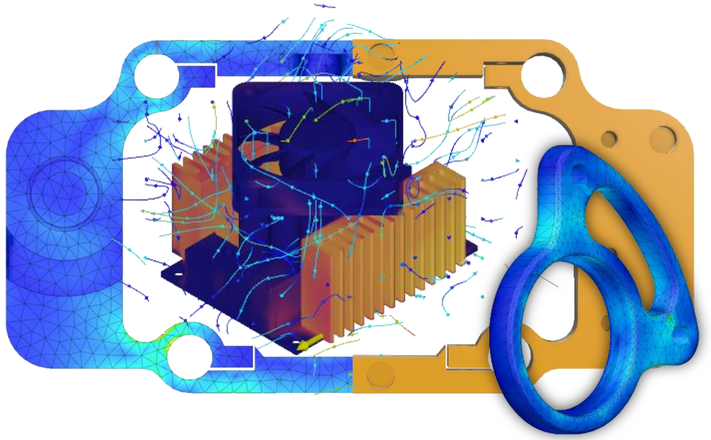


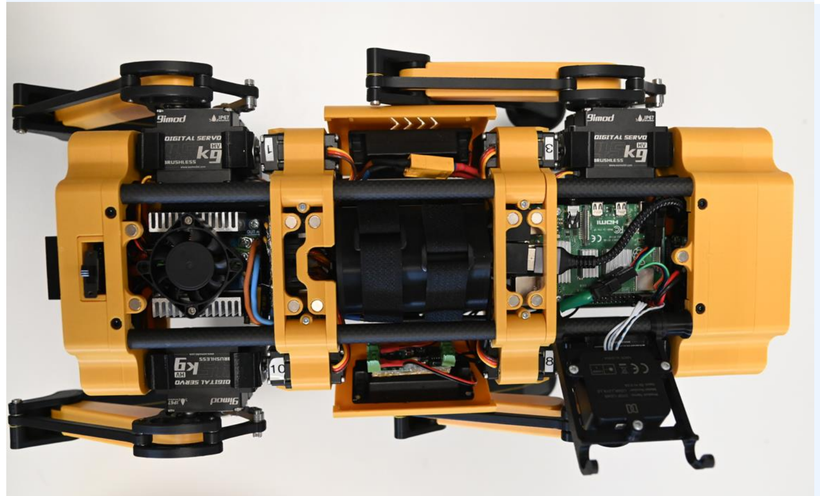
Design and Assembly



3D-printed chassis and components enable rapid prototyping and easy modifications

Designed using CAD & FEA to optimize for strength, weight, and durability



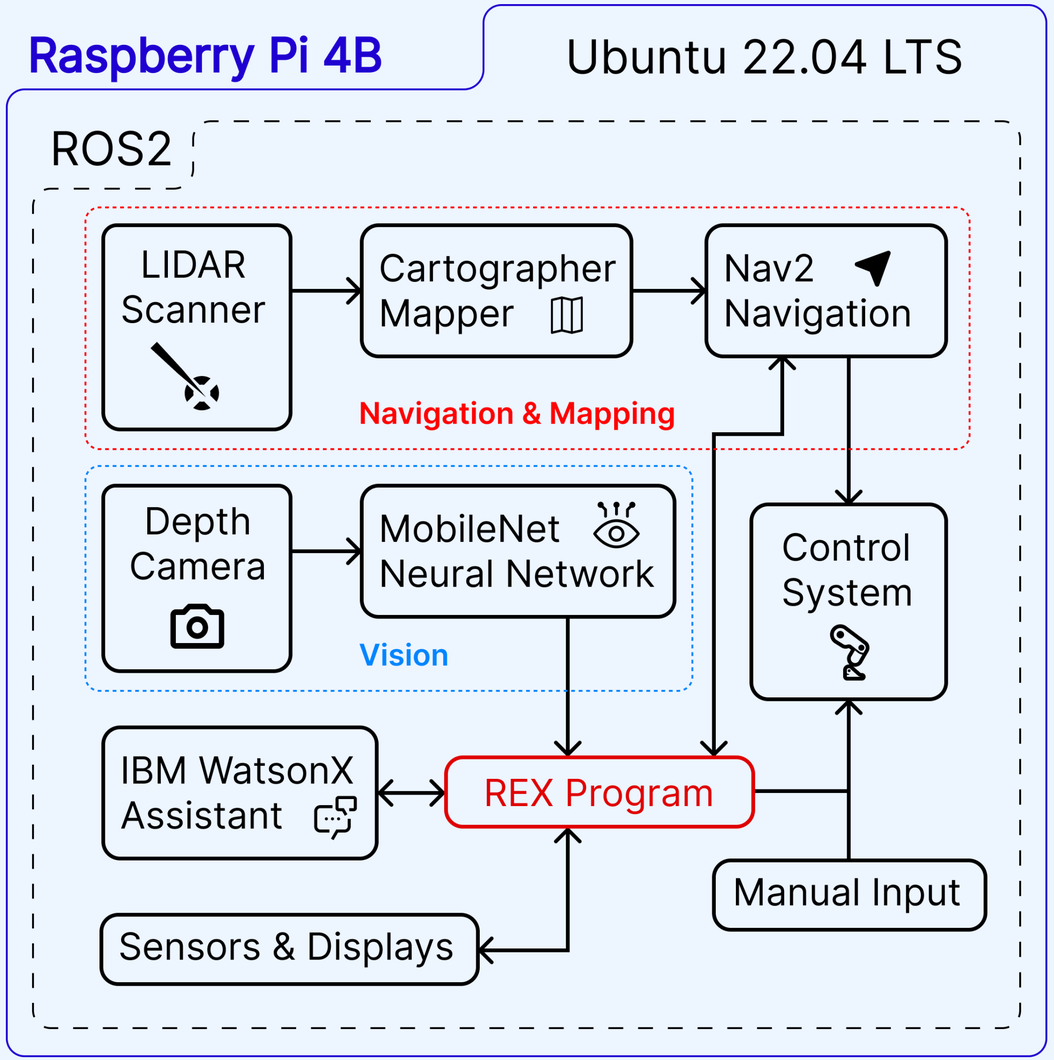


Modular assembly allows for easy customization, repairs, and upgrades in the field

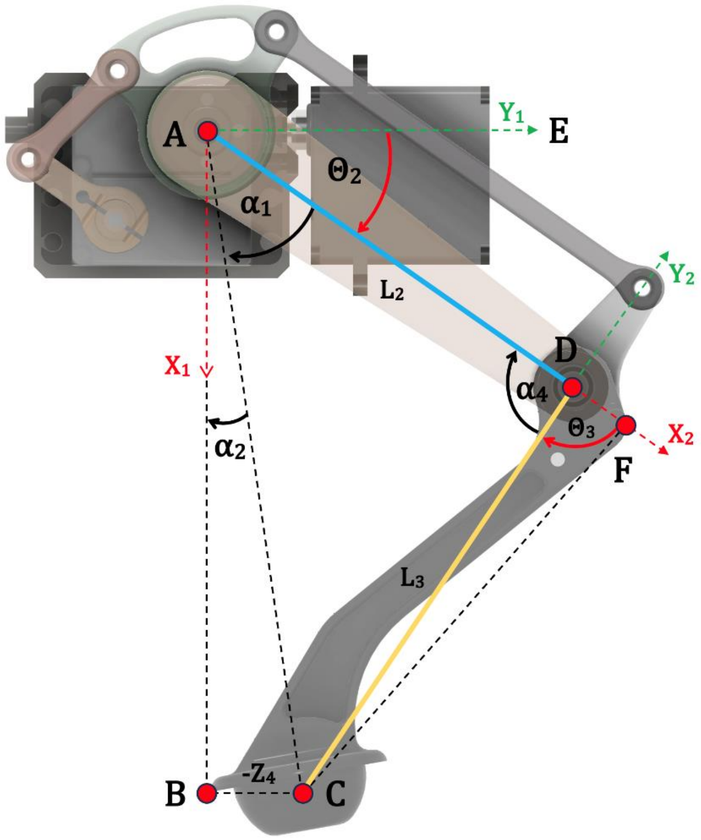
Software Overview

Uses LiDAR and depth sensors to build a real-time map of the environment, enabling precise movement and obstacle avoidance

The core REX program coordinates all systems - navigation, mapping, and vision - into a seamless operation, enabling autonomy in disaster zones



Inverse Kinematics



Motion control requires determining each joint's rotation for a desired foot position through inverse kinematics

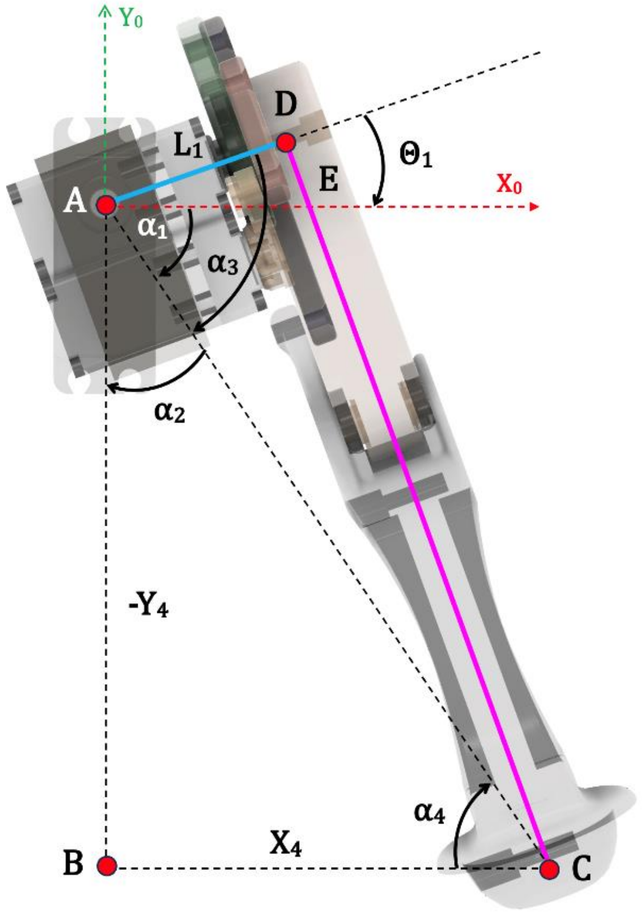
Ensures accurate leg movements for tasks such as walking and obstacle avoidance

Foot coordinates in X, Y, Z, are translated into a rotation angle for each motor.

$$\theta_1 = \arctan\left(\frac{\sqrt{{x_4}^2 + {y_4}^2 - {L_1}^2}}{L_1}\right) - \arctan\left(\frac{-y_4}{x^4}\right)$$

$$\theta_2 = 90° - \arctan\left(\frac{L_3 \sin(\theta_3)}{(L_2 + L_3 cos(\theta_3))}\right) - \arctan\left(\frac{-Z_4}{\sqrt{{x_4}^2 + {y_4}^2 - {L_1}^2}}\right)$$

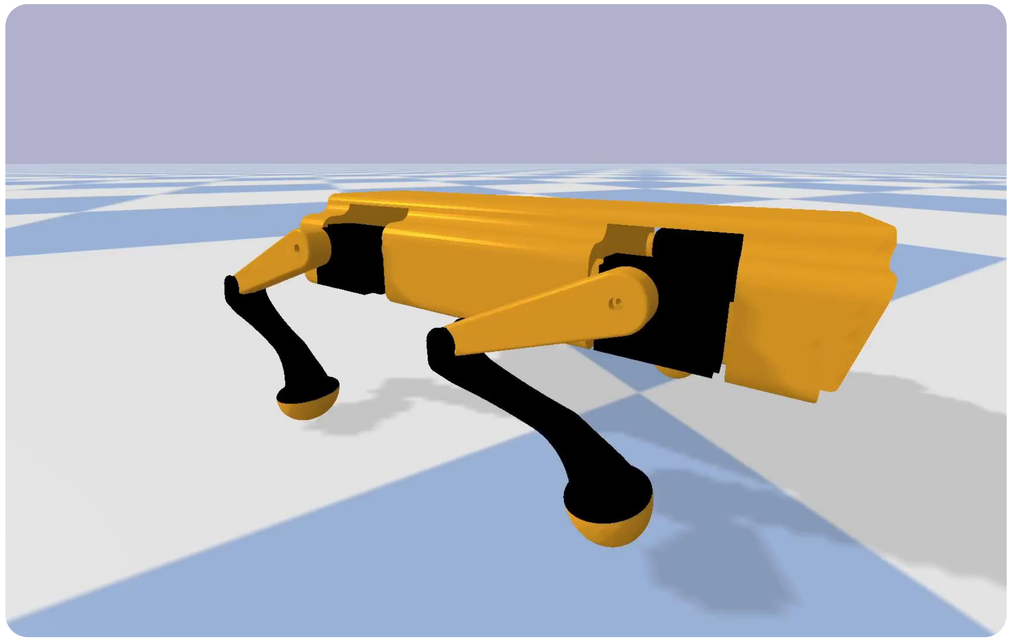
$$\theta_3 = 180° - \arccos\left(\frac{({L_2}^2 + {L_3}^2 - {x_4}^2 - {y_4}^2 - {L_1}^2 - {Z_4}^2)}{(2L_2L_3)}\right)$$

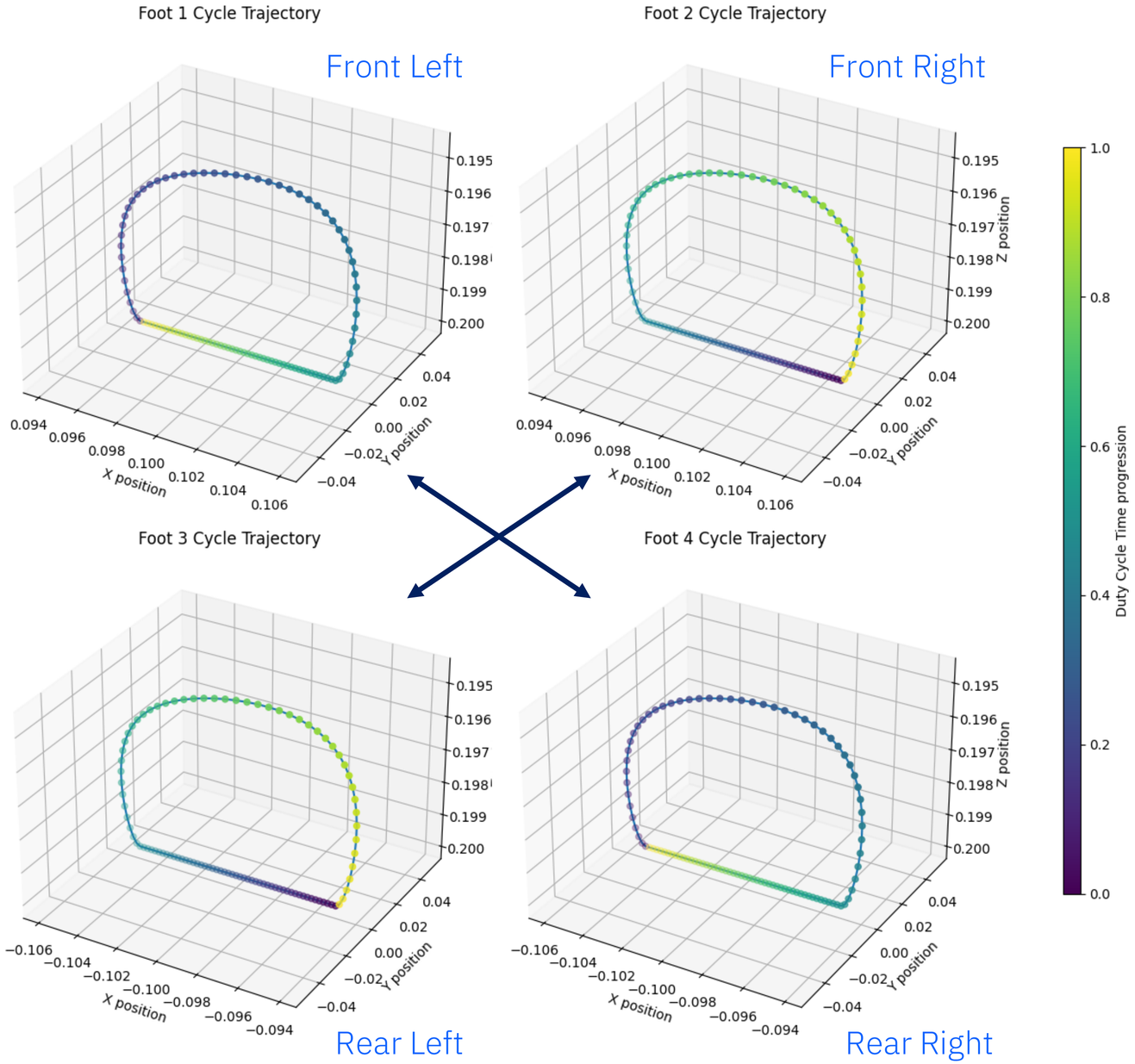


Control Simulation

The graphs show foot trajectory and position with time - Trajectories of all four feet form a gait cycle

Each plot represents the movement of one foot in 3D space, with colour indicating the progression of the duty cycle



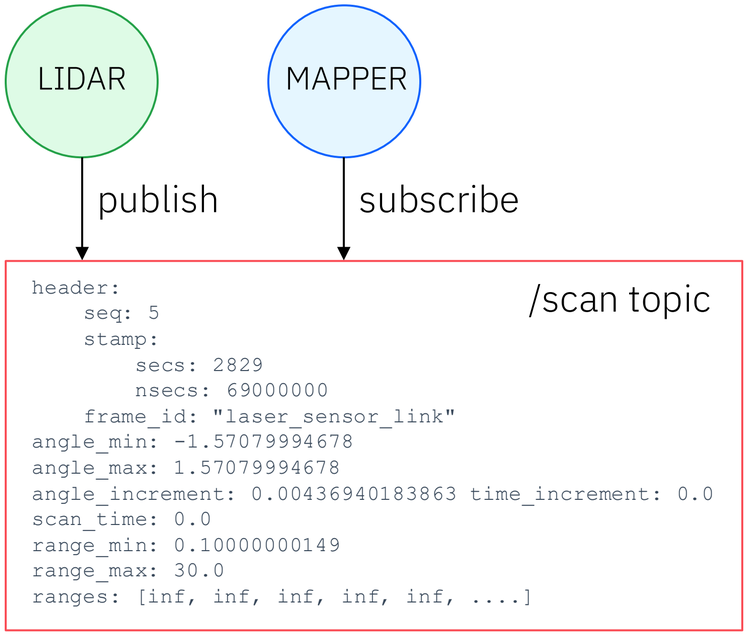


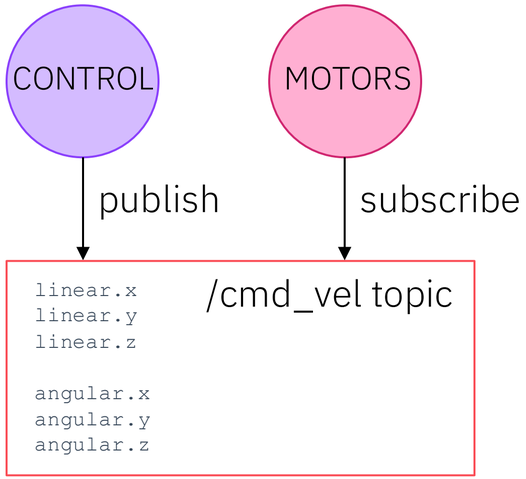
Robot Operating System

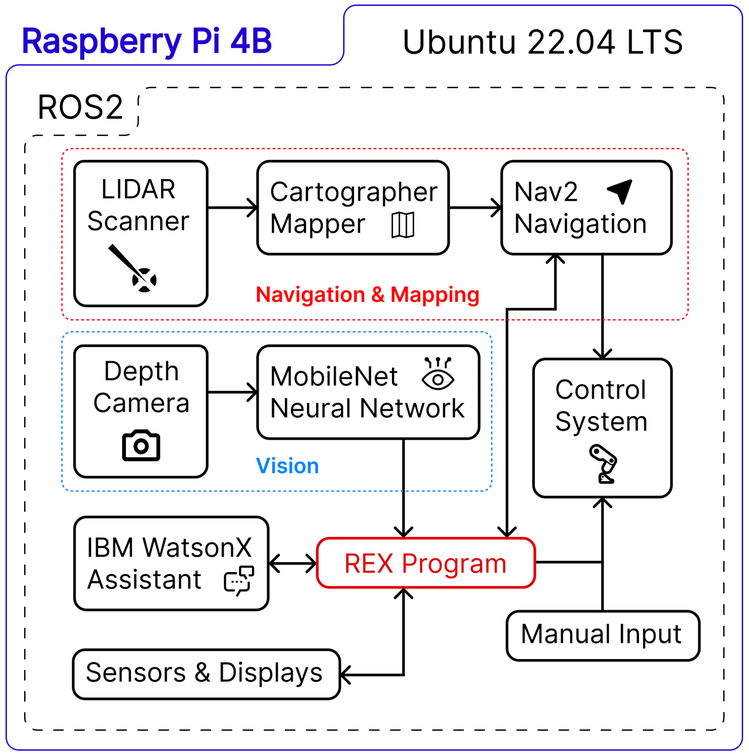
A set of tools and libraries for robot software development.

Uses a publish/subscribe messaging model for inter-node communication.

Supports multiple languages, primarily C++ and Python.





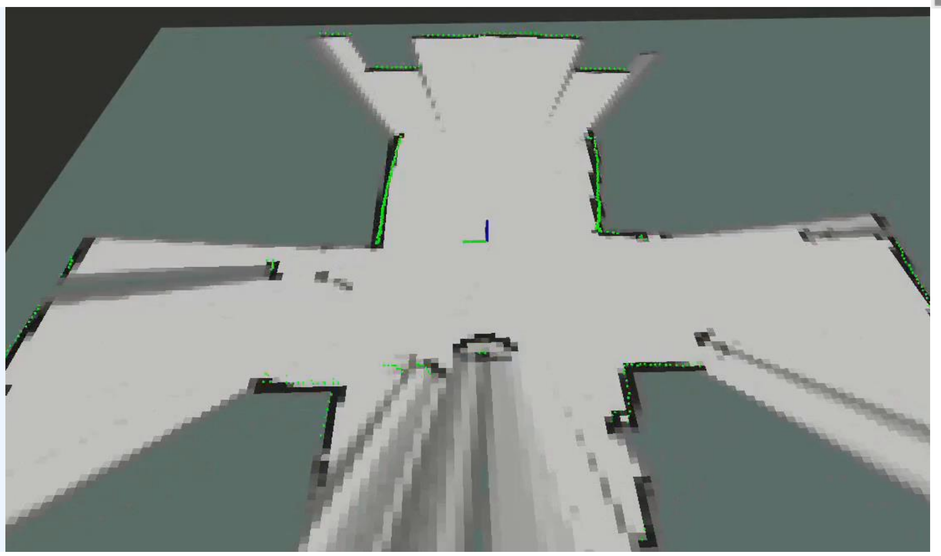


Mapping Software

Google Cartographer Package

Cartographer processes incoming sensor data to generate real-time maps

Simultaneous Localisation and Mapping (SLAM) for generating real-time 2D maps



Wavefront Frontier Exploration

Explores and maps unknown areas by navigating towards the boundaries between known and unknown regions (frontiers)

Frontiers are selected for exploration based on criteria:
Closeness: To minimize travel distance
Cluster Size: To explore significant unknown areas efficiently

WatsonX Assistant

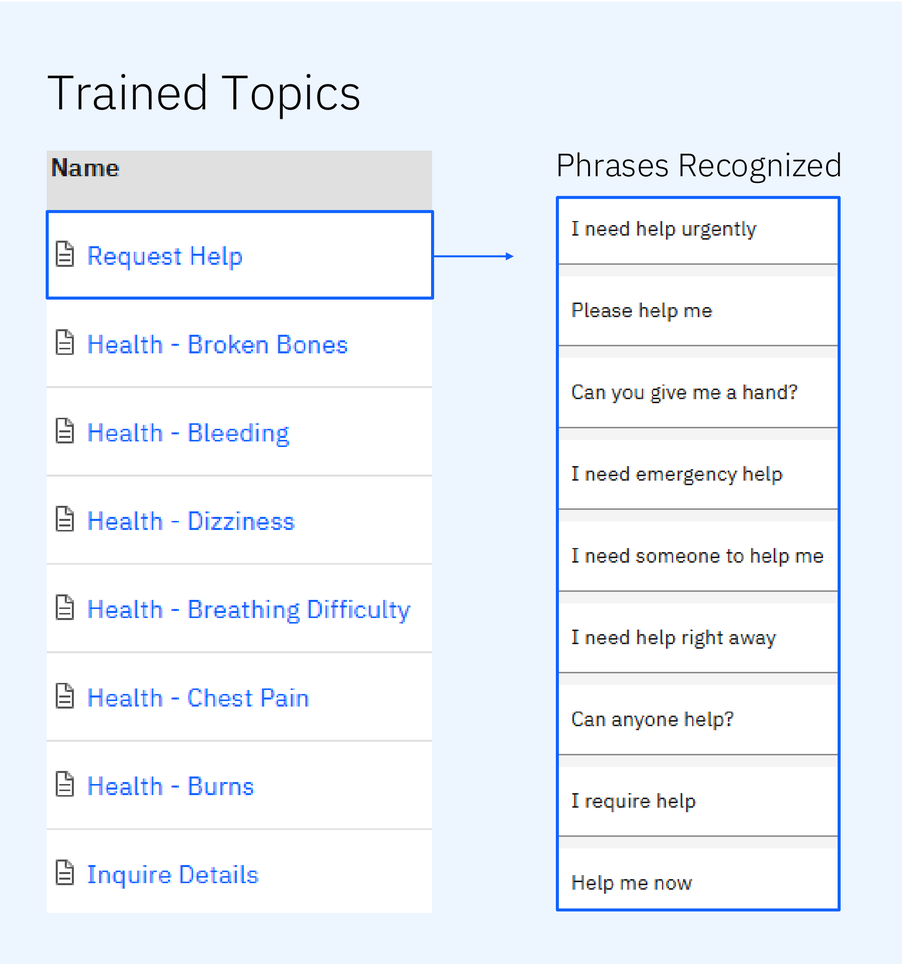
Provides advanced natural language processing (NLP) and speech recognition capabilities

Allows the REX to ask if individuals need assistance and respond accordingly

Data is sent to cloud storage using a secure API, where remote operators can access data through a web-based dashboard

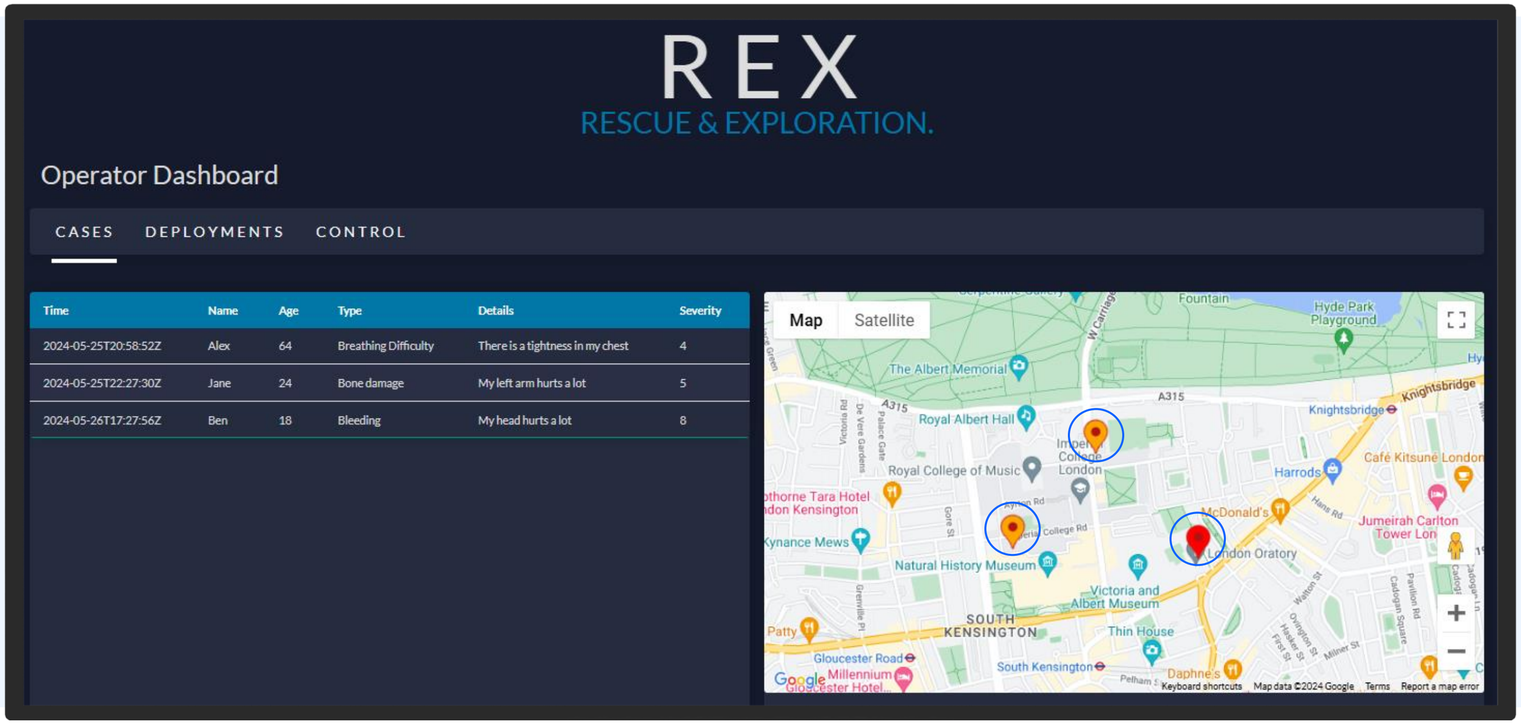
Example

Wake-word: “Hey, REX” or “Help Me”
REX asks the individual if they require assistance
Responses are converted into speech, and played through REX’s speakers



Operator Dashboard

A dashboard provides a platform for remote monitoring and control of the autonomous quadruped robot

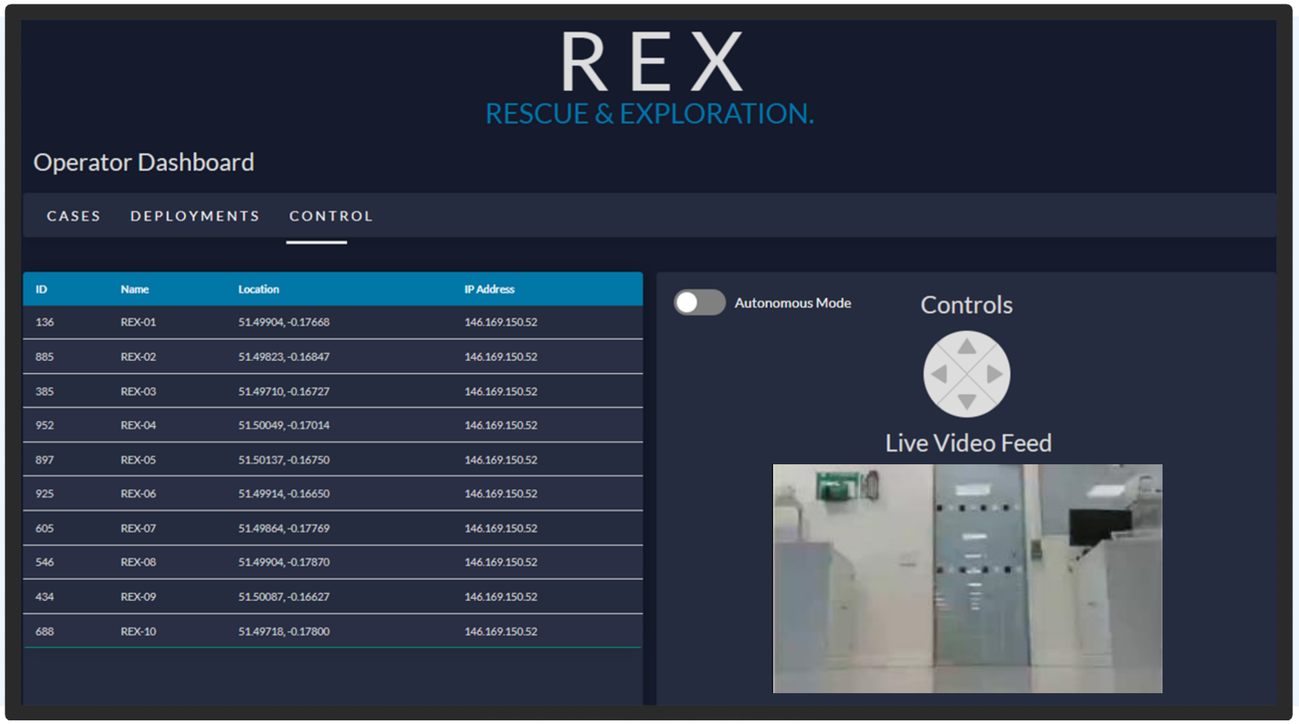


Displays Cases Supplied by WatsonX Assistant

Provides information that may be useful to first responders

Cases can be filtered by severity, with map pin colours reflecting this

Operator Dashboard



Remote Control of Deployments

Allows toggling between autonomous/manual mode

Allows direct movement control

Displays a live video feed of the robot.

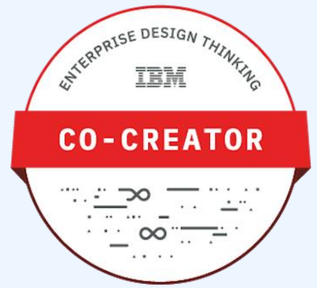
SkillsBuild

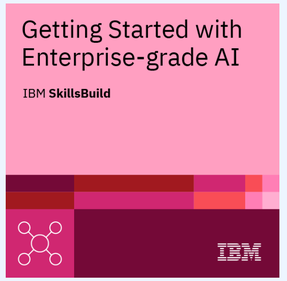
Provided essential training for developing an AI-powered chatbot and honing essential design skills

Useful Skills Learnt

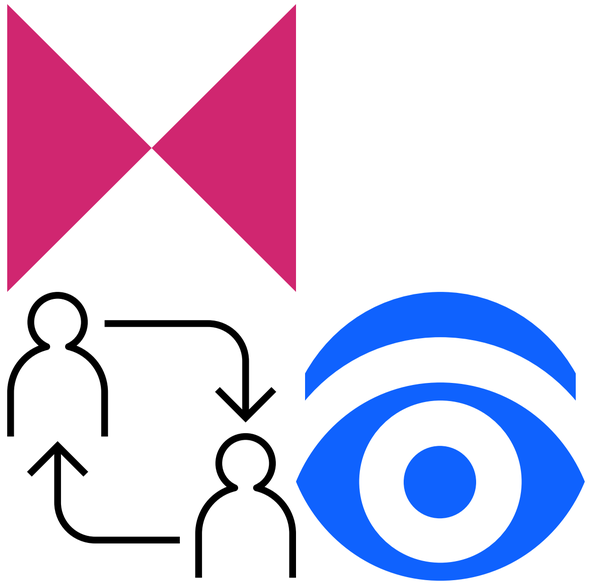
Watson Machine Learning Essentials enabled designing and deploying a customized chatbot with WatsonX

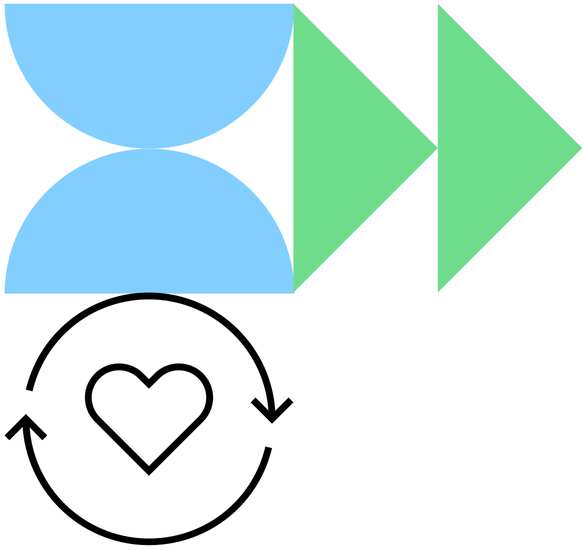
Applied IBM's Enterprise Design Thinking to create a user-centric, modular robot design, making REX easy to use, repair, and adaptable for disaster response scenarios





Thank You





Scan for the YouTube video presentation!

Gian-Luca Fenocchi
Imperial College London

linkedin.com/in/gfenocchi
gianluca@fenocchi.net

Software Engineer
@ KAIKAKU.AI