Project Description Sheet

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Reutlingen

Initial Description

Project Title

Smart Proximity Radar for Obstacle Monitoring

Acronym

SPROM

Short Description

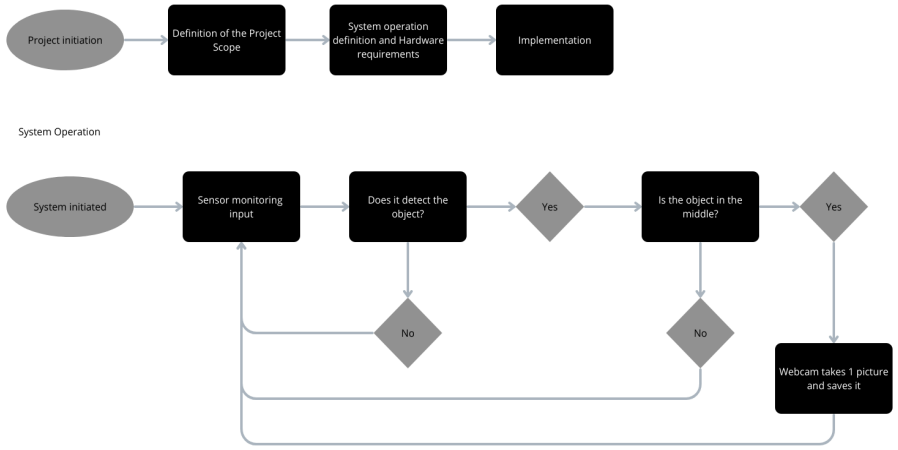
SPROM is a compact radar system built around a Raspberry Pi sensor that detects approaching objects, captures images at specific moments, and displays them on a local screen. Designed for educational and prototyping purposes, it provides an accessible and affordable alternative to complex object recognition systems..

Project Vision

Background and Motivation

In precision agriculture, it is important to monitor the collection of sugarcane from the fields. During this process, a truck harvests the sugarcane through a pipe and, upon arriving at the processing facility, a probe collects samples and deposits them into a bucket. Currently, trained machine learning models are used to detect the bucket's approach for sample collection. However, maintaining these models is complex and highly specific to each installation. By implementing a system that detects the bucket's approach without relying on heavy model training, we can generalize the process, reduce maintenance efforts, and make the operation more fluid, accurate, and efficient.

System Overview



Goal

Intended Purpose (Zweckbestimmung)

The SPROM (Smart Proximity Radar for Obstacle Monitoring) system is designed to detect the approach of objects in agricultural contexts, particularly in environments where physical sampling or interaction with moving components is required. Its primary purpose is to serve as a reliable, low-maintenance, and affordable alternative to complex object detection systems, especially in use cases such as sugarcane sample collection in precision agriculture. SPROM aims to increase operational efficiency and precision while reducing dependency on computationally intensive and installation-specific machine learning models.

Intended Use (bestimmungsgemäßer Gebrauch)

SPROM is intended to be installed in fixed positions near zones where object detection is critical, such as near sampling stations or industrial input points. The system consists of a radar sensor connected to a Raspberry Pi, which remains in standby mode until it detects an approaching object. Upon detection, the system captures an image of the event and displays it locally on a screen or via a web interface. Typical use includes configuring the device through a simple setup interface, positioning the sensor for optimal coverage of the target area, and using the visual feedback to monitor the process in real time. It is particularly suited for prototyping, research, and educational applications where ease of use and adaptability are key.

Features and Performance

Functional Requirements (Features)

1. **Object Proximity Detection:** Detects approaching objects using a radar sensor with configurable detection range.

2. **Image Capture on Trigger:** Automatically captures an image when an object is detected within a predefined distance.

3. **Local and Remote Visualization:** Displays captured images and detection status on a local screen and optionally via a web interface.

4. **Event Logging:** Records detection events and timestamps for monitoring and analysis.

5. **System Initialization and Standby Modes:** Operates in predefined stages, including initialization, monitoring, and trigger response.

Non-Functional Requirements (Performance):

1. **Low Latency Detection**: The system must respond to object detection within 1 second.

2. **High Availability**: The system should operate continuously with minimal downtime in typical environmental conditions.

3. **Low Maintenance**: Designed to operate with minimal calibration or retraining, unlike traditional machine learning-based systems.

4. **Affordability**: Utilizes cost-effective hardware (Raspberry Pi and radar module) to maintain low production costs.

5. **Ease of Deployment**: System setup should take less than 30 minutes, including mounting, calibration, and configuration.

6. **Modularity**: The system architecture should allow for easy replacement or upgrading of components such as the radar sensor or display module.

Exclusion Criteria:

Despite correct installation and use, there are specific conditions under which the SPROM system may not fulfill its intended purpose. These exclusion criteria define the limitations of the system:

1. **Extreme Environmental Conditions**: The system is not designed for use in environments with excessive dust, moisture, heat, or electromagnetic interference, which may affect radar sensor accuracy and Raspberry Pi stability.

2. **High-Speed Object Movement**: Objects moving at speeds beyond the radar sensor's detection capabilities may not be accurately detected or photographed in time.

3. **Obstructed Detection Zone**: If the sensor's field of view is physically blocked or the object does not enter the designated detection zone, detection and image capture will not occur.

4. **Reflective or Non-Reflective Surfaces**: Some materials may interfere with radar signal reflection, such as highly absorbent, transparent, or irregularly shaped surfaces, reducing detection reliability.

5. **Power Supply Instability**: Inconsistent or insufficient power supply can cause system reboots or failure to operate, particularly during image processing or display.

6. **Incorrect Mounting or Alignment**: Improper installation angle or placement may cause the sensor to miss the object or misfire triggers.

7. **Software Modification**: Unauthorized or incorrect changes to the software or configuration may lead to malfunction or loss of core functionality.

Hardware Requirements

- Developer boards - Ultrasonic distance sensor, HC-SR04: https://www.reichelt.de/de/de/shop/produkt/entwicklerboards_-_ultraschall_abstandssensor_hc-sr04-161487?PROVID=2788&gad_source=1&gad_campaignid=18342381572&gbraid=0AAAADwnxtbz46rrjnN40hvERWyq_2hzB&gclid=Cj0KCQjw0LDBBhCnARIsAMpYlAp6daDj0ejkhjDFLdobA0Jq3A3kT5B71eE3lQdo14hVmM0RGVpMwQUaAsPUEALw_wcB#closemodal
- Raspberry Pi Zero 2W, 4x 1GHz, 512MB RAM, WiFi, BT: https://www.reichelt.de/de/de/shop/produkt/raspberry_pi_zero_2_w_4x_1_ghz_512_mb_ram_wlan_bt-313902
- Arducam 5MP OV5647 Miniature Camera Module with M6 Lens and Flexible Cable for Pi Zero, Pi 5 and Pi Compute Module: https://www.arducam.com/b006603-arducam-for-raspberry-pi-zero-camera-module-1-4-inch-5mp-ov5647-spy-camera-with-flex-cable-for-pi-zero-and-pi-compute-module.html
- Wires and breadboard for the circuits (ELEGOO Jumper Wire Cable Male Female 200 mm Set of 50 Together with a 170 Contacts Breadboard: https://www.amazon.de/Elegoo-Jumper-Female-Kontakte-Breadboard-mehrfarbig/dp/

B071RG9MFT?source=ps-sl-shoppingads-lpcontext&ref_=fplfs&psc=1&smid=AZF7WYXU5ZANW)

Demonstration Infrastructure

For the demonstration setup, a structure with a wooden board will be used to support the proximity sensor, the Raspberry Pi, and the ArduCam.
In front of this structure, the bucket will be placed on a small wheeled platform. Using a rope, I will pull the platform to simulate the movement of the rail that supports the bucket in a sugar cane mill.