SpotON

Team Members

Ian Wu

LoRaWan server stack

PCB enclosure CAD design

CNN training

Data collection

Kyle Wong

CNN design/training

Data collection

Data augmentation

Web app development

Haoming Chen

Image processing

Peripheral communication

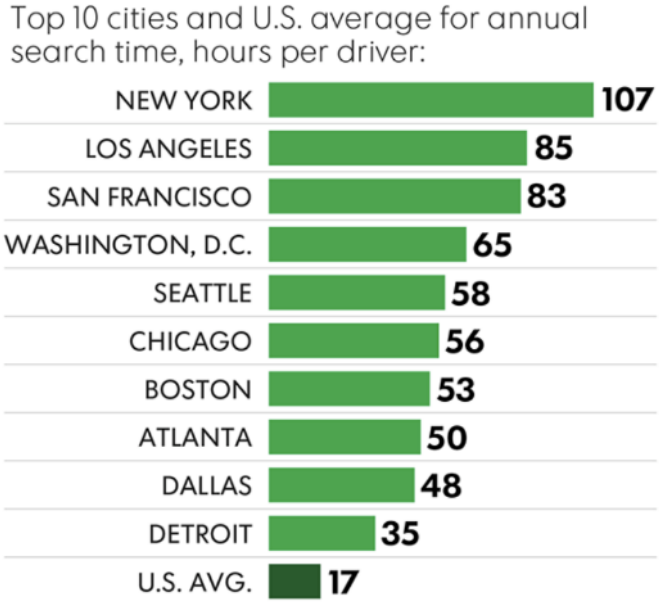
Power management

Jiachen Zhang

Web app development

Parking Problem

- Finding parking spots is a serious issue
- Annually, drivers in the US spend in parking lots:
  - 17 hours
  - $345 on time, gas, and emissions.
  - $97 from overpaying
- Major problem in **urban areas**



https://www.usatoday.com/story/money/2017/07/12/parking-pain-causes-financial-and-personal-strain/467637001/

Can we design a smart parking system that allows drivers to check real-time occupancy?

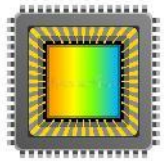
While ensuring user privacy?

Impact

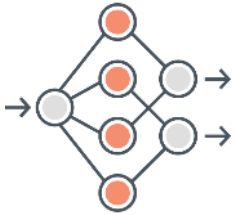
- Save money, time, environment
- Reduce search traffic
- Parking management market globally worths **$5.76 Billion**

Proposed Solution

Underground parking lot



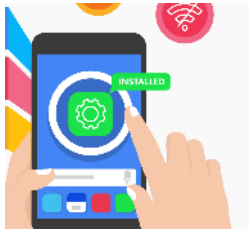
Camera captures image of parking spots



CNN model

Transmit result of CNN data through LoRa

Database stores parking space status

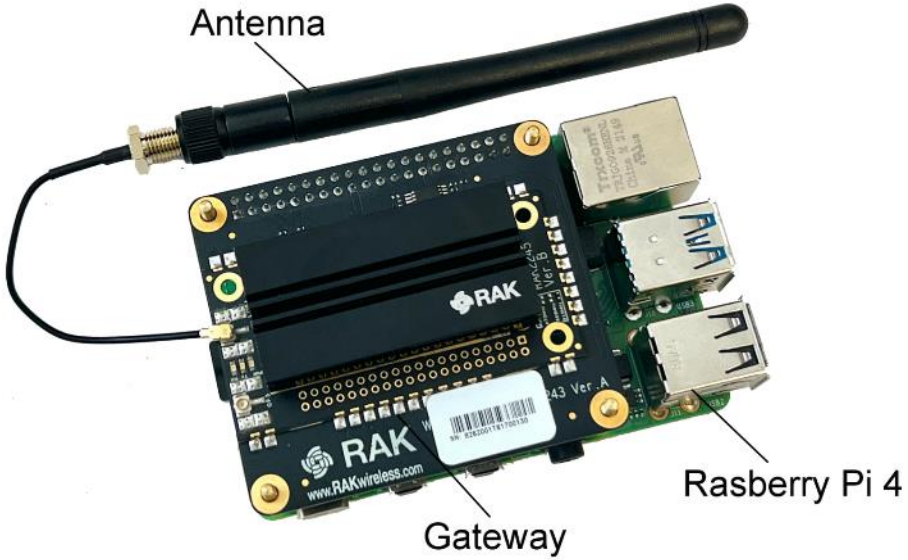


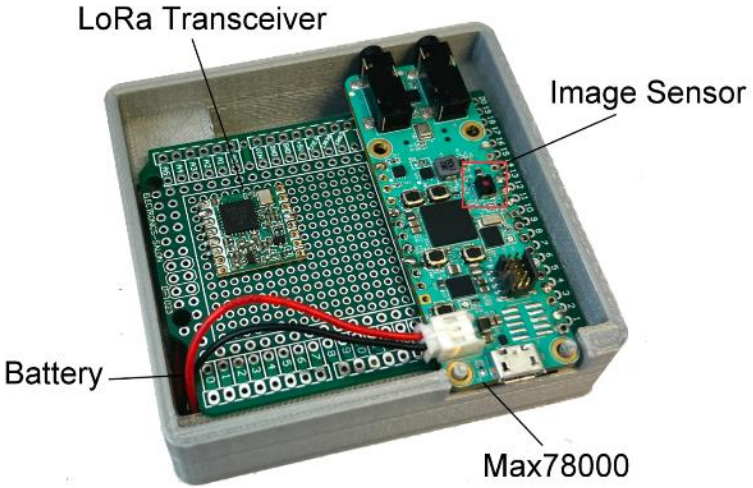
Render parking lot information on web app

Final Product

Gateway Server

Monitor

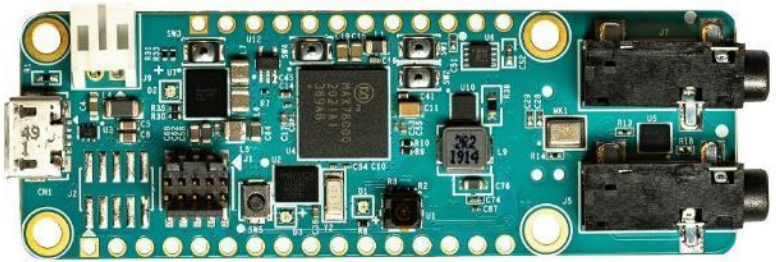




MCU

MAX78000

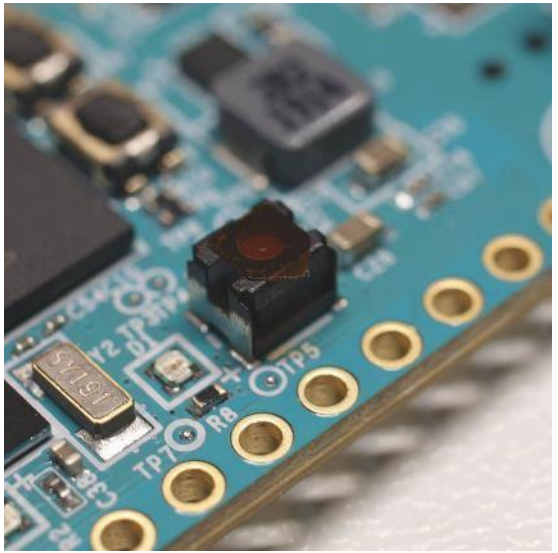
- Small, low power, microcontroller board built for neural network applications
- Arm Cortex-M4 Processor
- 512KB Flash Memory, 128KB SRAM, 16KB Cache
- Convolutional neural network accelerator
  - Programmable Network Channel Layer with up to 1024 Channels
  - 442k 8-Bit Weight Capacity



Peripherals

Image Sensor - OVM7692

- CMOS VGA camera
- Optical size 1/13’’
- Active Pixel Array: 640H x 480V
- Automatic/manual control of automatic exposure control (AEC), automatic gain control (AGC), automatic 50/60 Hz luminance detection and automatic black level calibration (ABLC)

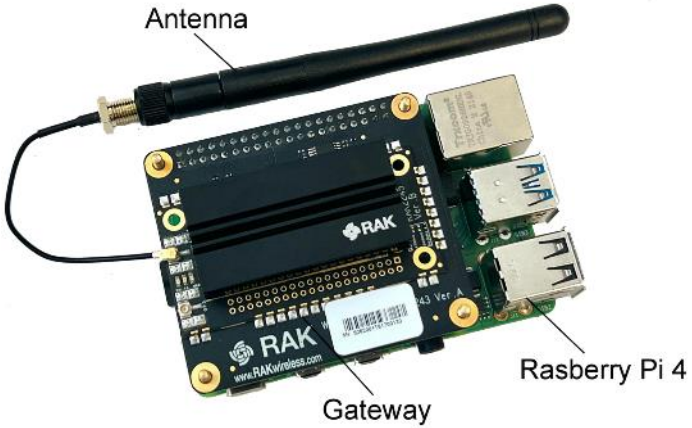


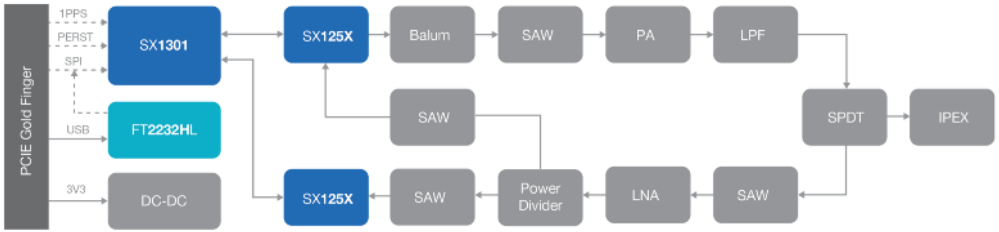
LoRa Transceiver- RFM95W

- Full duplex two way communication
- Bandwidth
  - 7.8 - 500kHz
- Size
  - 16mm x 16mm
- SPI interface
- Optional Antenna

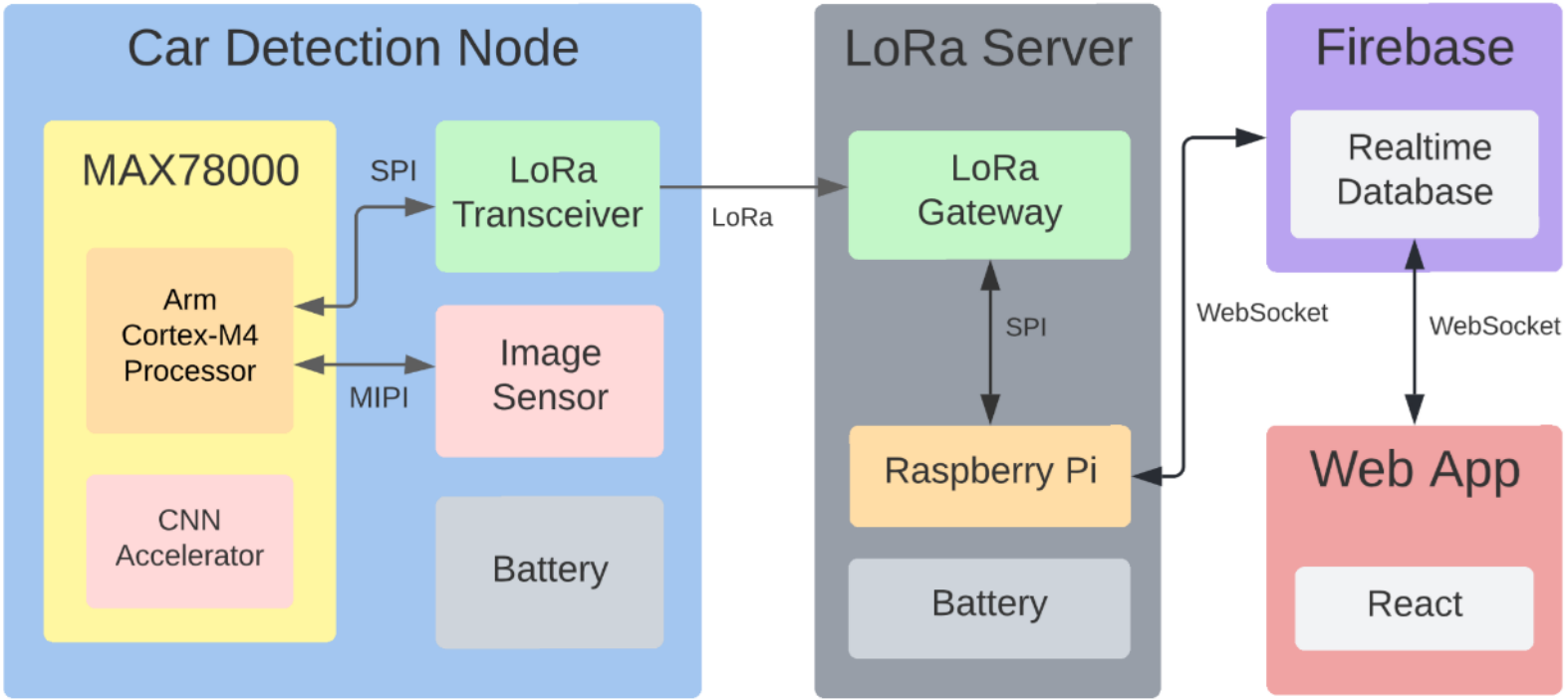
Gateway - RPI & RAK2247

- Raspberry Pi 4
  - Hosting LoRaWan Network Stack
- RAK2247 WisLink LPWAN Concentrator
  - 1 SX1301 & 2 SX1255
  - Receives data packet from LoRa transceiver
  - SPI Communication





Block Diagram


Car Detection Node
MAX78000
Arm
Cortex-M4
Processor
CNN
Accelerator
SPI
MIPI
LoRa
Transceiver
Image
Sensor
Battery
LoRa
LoRa Server
LoRa
Gateway
SPI
Raspberry Pi
Battery
WebSocket
Firebase
Realtime
Database
WebSocket
Web App
React

Car Detection

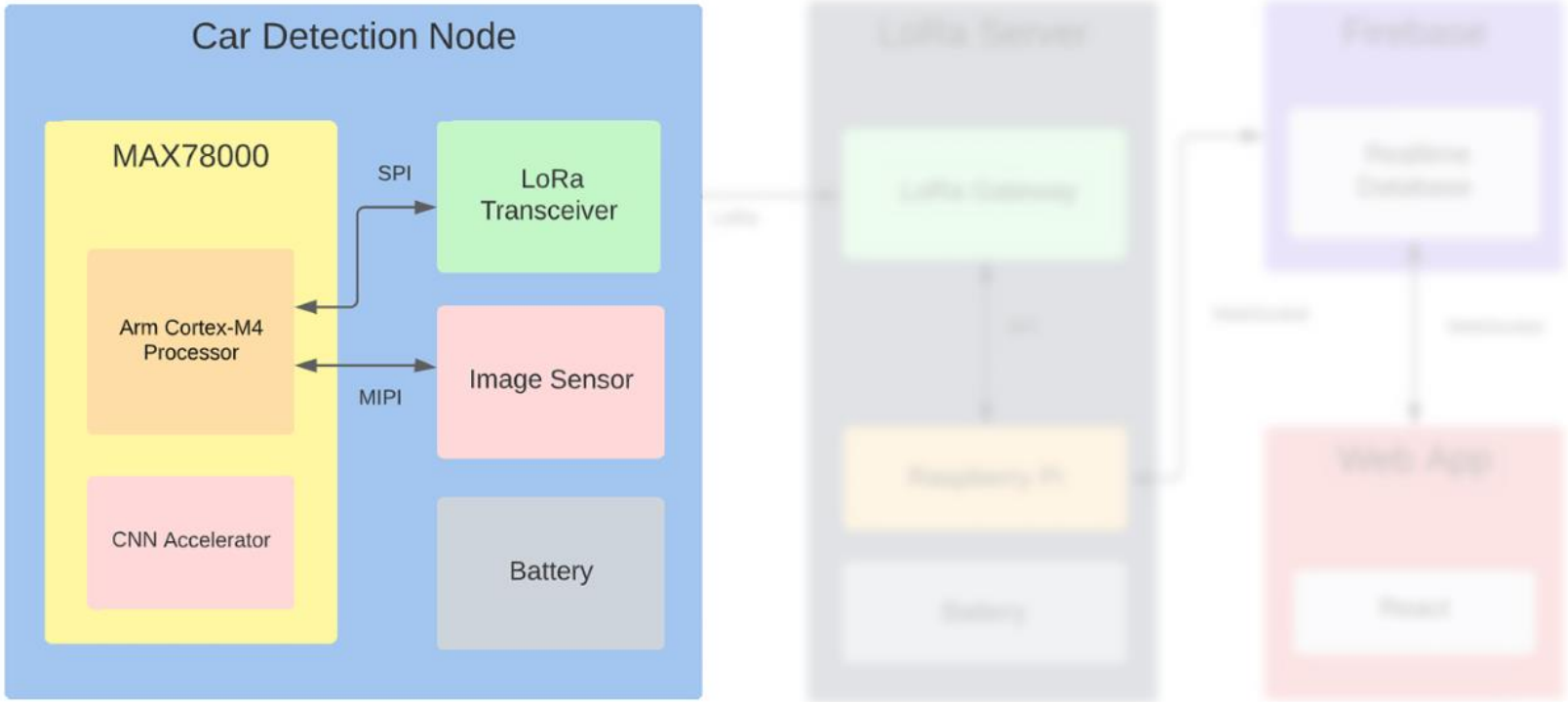


Image Processing

- Resolutions
  - 128x128 with rgb888
  - 240x160 with rgb565

- Segmentation
  - Capture a 240px x 160px image
  - Segment the image at its middle into four 64px x 64px image blocks (each block represents each spot)

sample image:

Detection Process

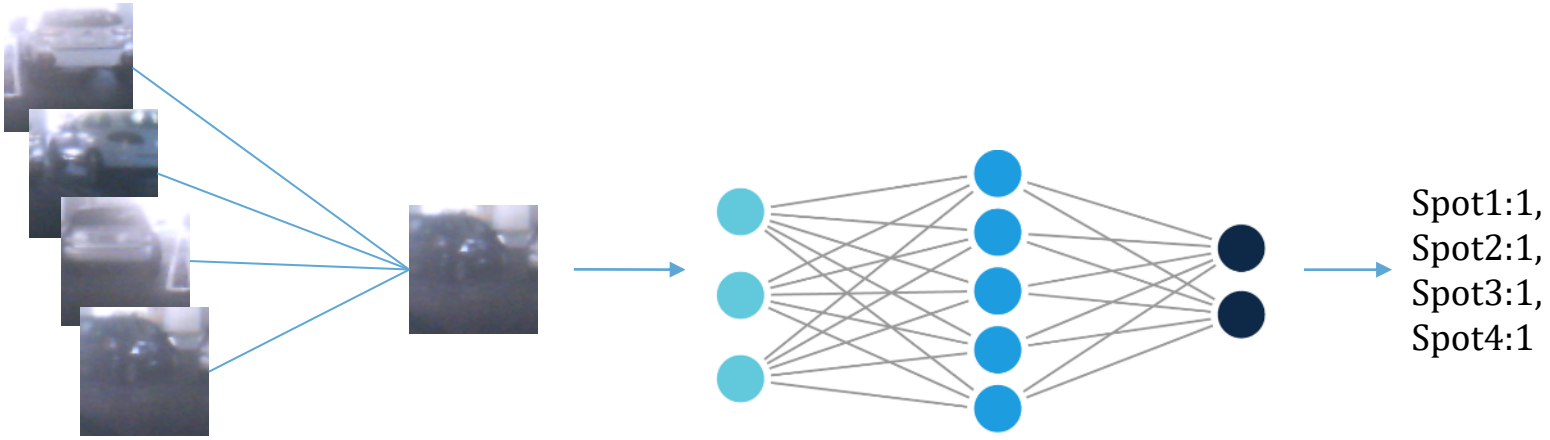


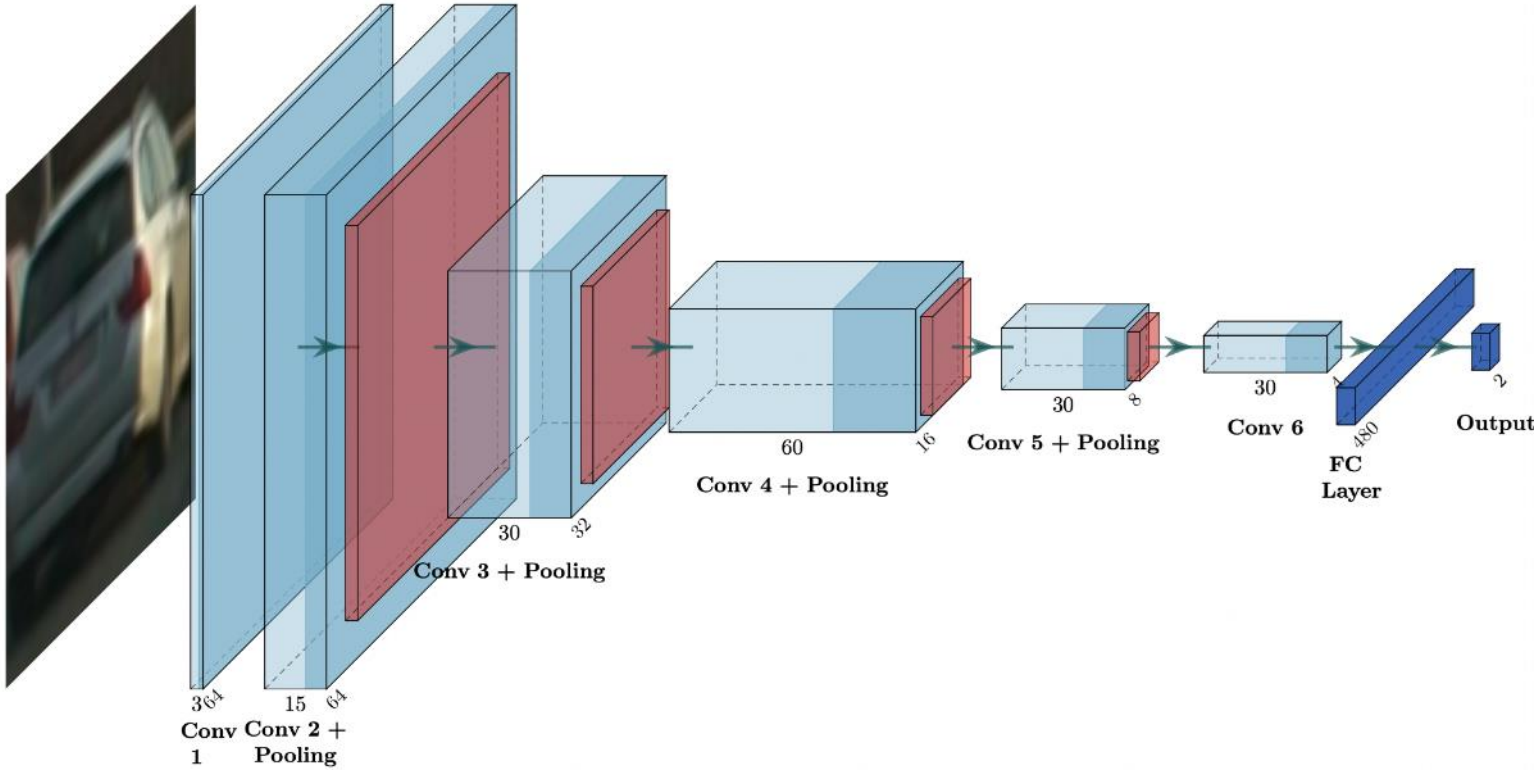
Image blocks
4 64x64 images

Input image
1x64x64 image

CNN model
Convolution,
pooling,
Flattening
Fully connected layer

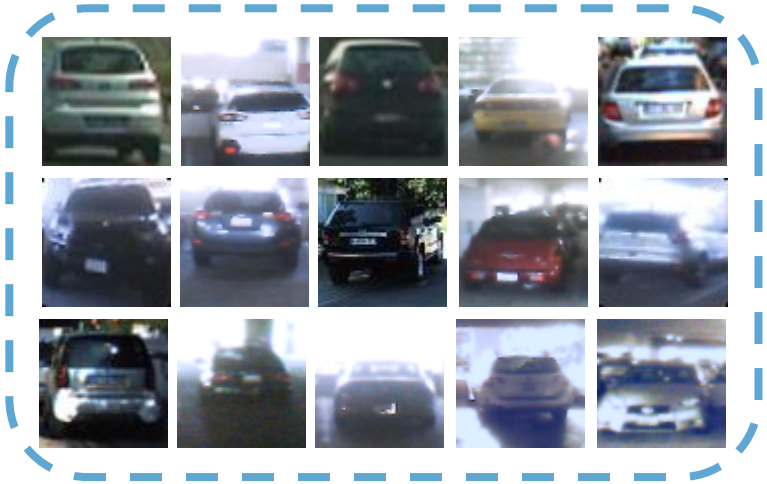
Output
4 bits

CNN Model Architecture



Training Dataset

- Vehicle Detection Image Set (Baris Dincer, Kaggle)
  - 17,760 images
- Custom dataset (Parking Lot 10, UCSB)
  - ~ 4000 images

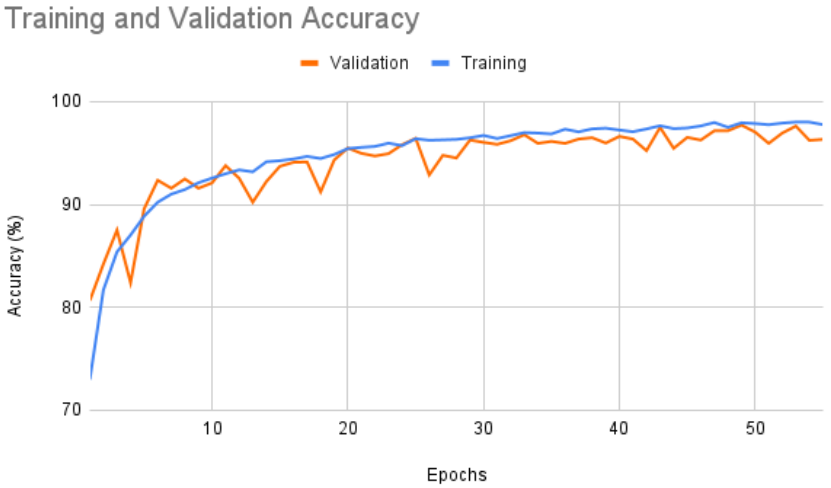


Data Augmentation

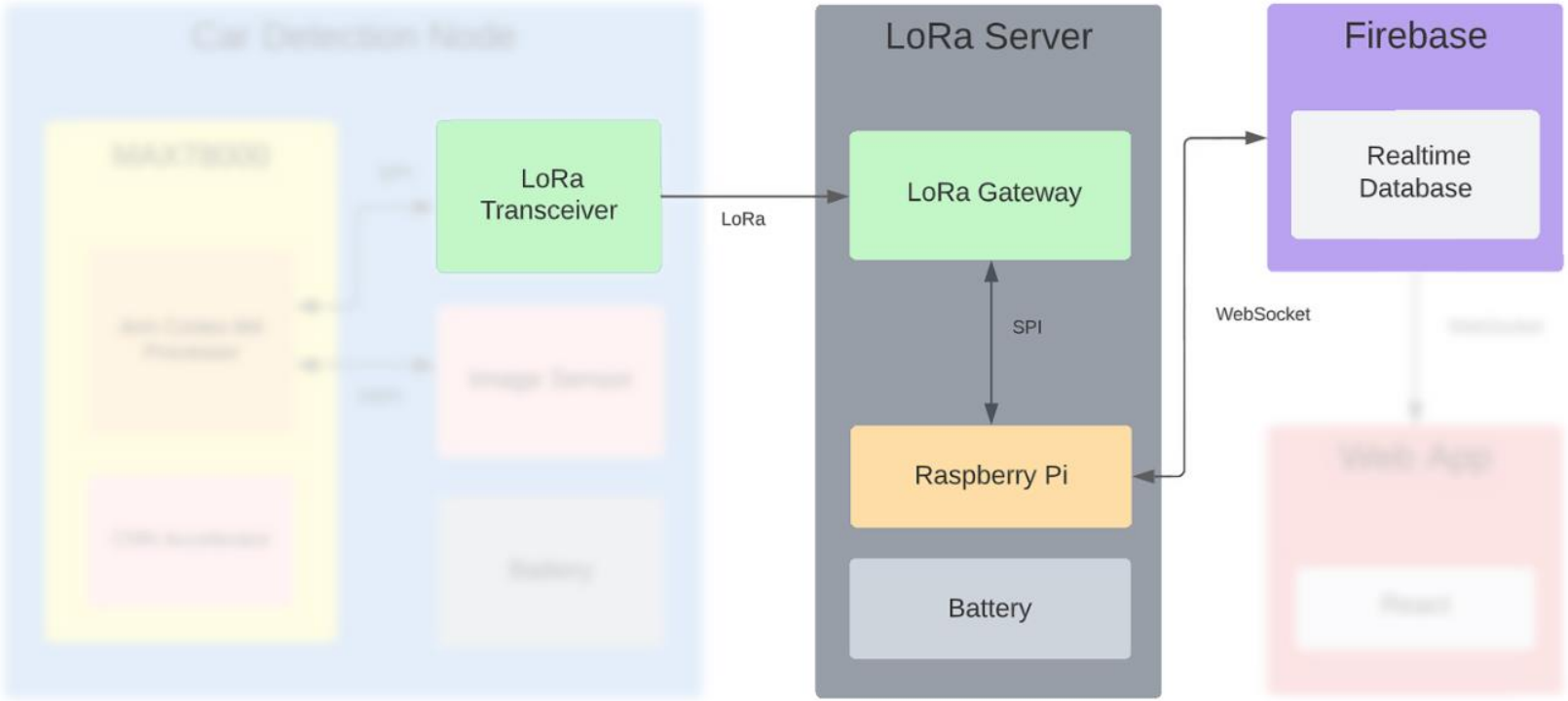
- Transformations: rotation, perspective skew, horizontal flip, brightness adjustment
- Resulting training dataset: 27,876 images

CNN Model

- 54,059 8-bit weights
- Trained for 55 epochs
- 96.9% accuracy achieved on validation dataset
- 88.1% accuracy achieved during field test
- 4.25 ms inference time

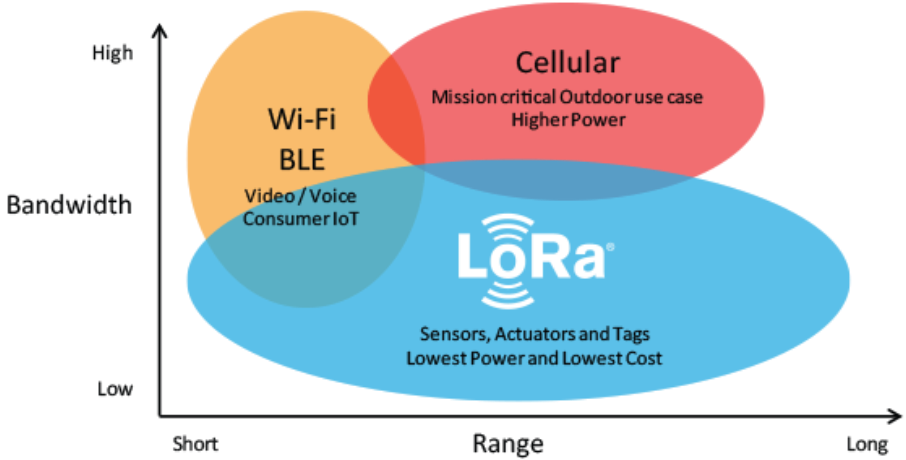


Wireless Communication



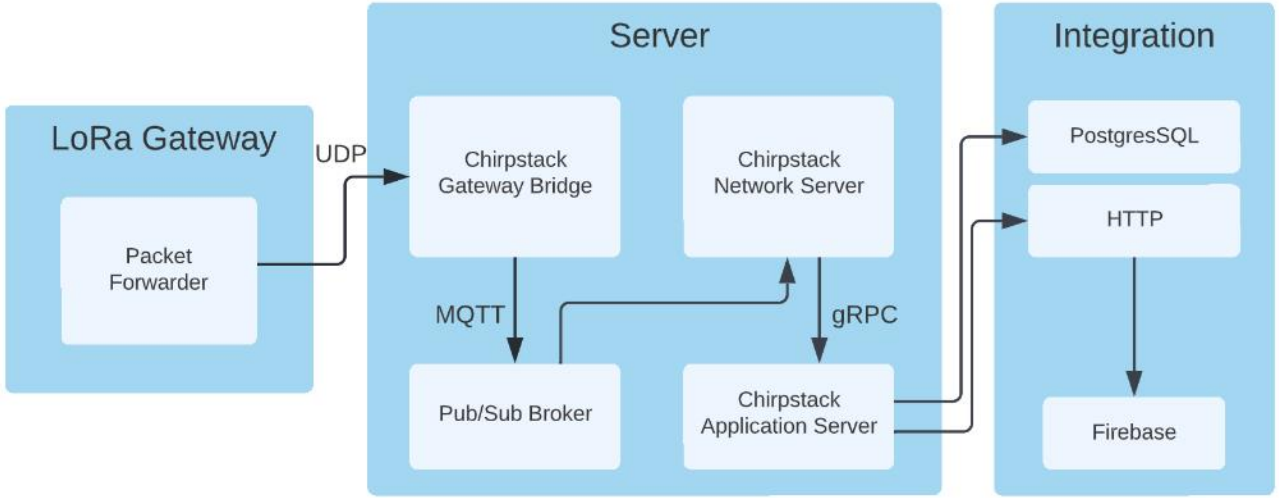
LoRa & LoRaWAN Overview

- LoRa (Physical Layer)
  - Low-power
  - Long-range
  - Maximum data transfer rate: 27 kbps
  - Maximum range: 3 miles
- LoRaWAN
  - Communication protocol based on LoRa
- Why LoRa?
  - Flexible in deployment
  - Low cost
  - Easy for scalability



LoRaWAN Network Server Stack

- Provides web-interface for device management and API for integration
- Network server is hosted on Raspberry Pi
  - Receive and process LoRaWan packets



FireBase

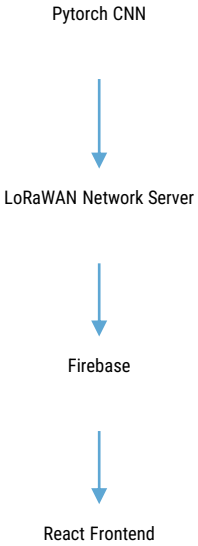
- Spot status storage
  - Occupied?

PostgreSQL

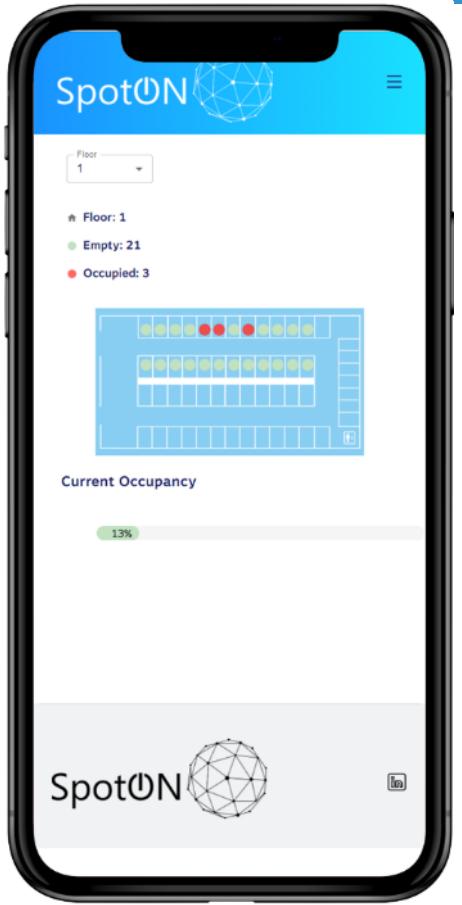
- LoRaWan Network Server storage
  - Device management
  - Device event
  - User info

Web App

Software Stack

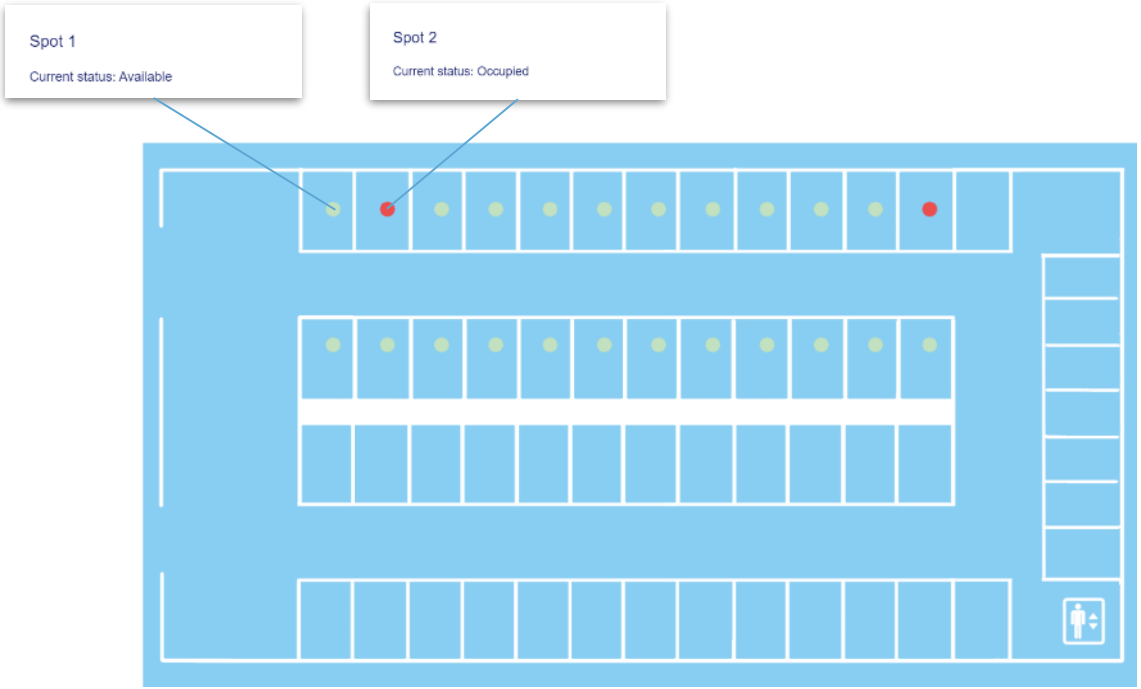


App Page

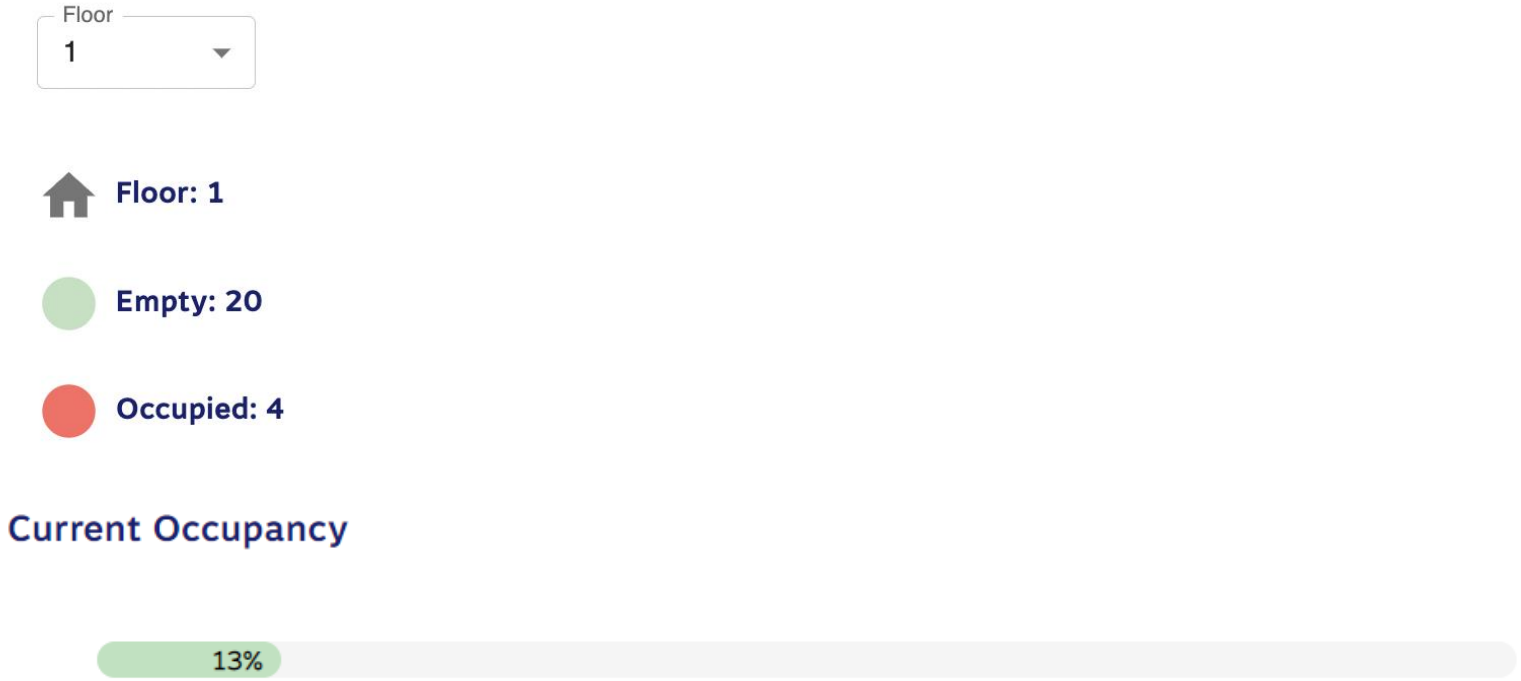


http://maxim-parking.netlify.app/

Map Indicator



Floor Selector & Status Indicator

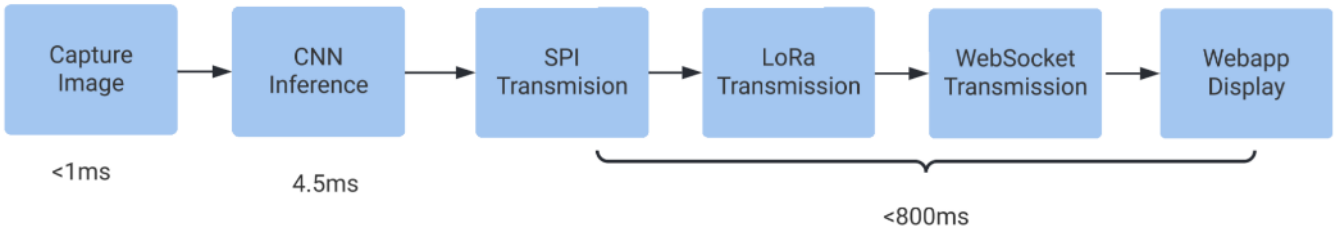


Demo

Field Test

Data Transfer Latency

- < 1s
- Issue
  - Packet loss
  - Range



Battery Life

- Operation power:
  - ~160mW at operation
  - < 0.002mW in low power mode at idle
- Power consumption:
  - 6.429mAh or 32.92mWh per hour
- **1 year**
  - Increasing idle time
  - 20000mAh battery

Cost Comparison

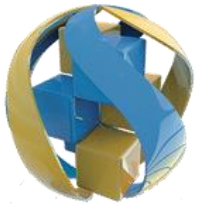
UCSB Lot10 Implementation

Requirement: 500 Spots / 5 Floors

	SpotOn Solution	Ground Sensor Solution
Detection Unit Cost	$90 $30 - MCU + Camera (MAX78000FTHR) $10 - LoRa Transceiver (RFM95W) $50 - 20000mAh Battery	$47 $6 - MCU (STM32L053R8) $6 - Magnetometer (LIS3MDLTR) $10 - LoRa Transceiver (RFM95W) $25 - 10000mAh Battery
Gateway	$200 - RAK2247 + RPI	$200 - RAK2247 + RPI
Units Required	125	500
System Cost	11,250	22,700
Additional Cost	Installation: Low Maintenance: Low	Installation: High Maintenance: High

Thanks To

- Analog Device
- UCSB
  - Dr. Yoga Isukapalli
  - Brycen Westgarth
  - Christopher Cheney
  - College of Engineering



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DEVICES

CACI

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Q&A