Istrobotics

Robotour 2019, 15.9.2019

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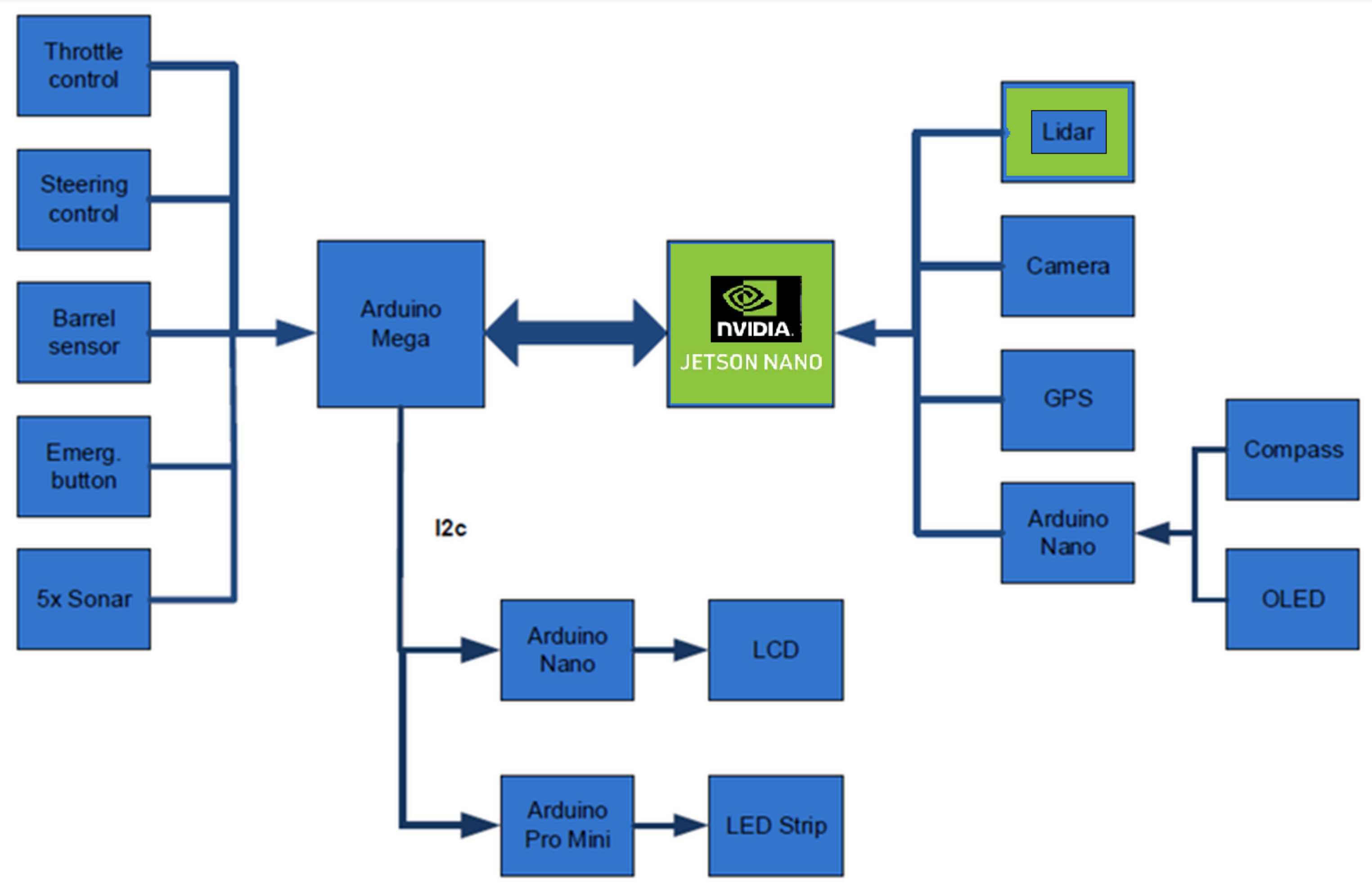
2016 2017 2018 2019

HARDWARE DESIGN



HARDWARE

- **Jetson Nano: 1.4GHz 4-core, 4GB RAM, 64GB SD**
  - Arduino Mega: 16MHz, 8KB RAM
  - 2x Arduino Nano: 16MHz, 2KB RAM
  - Arduino Pro Mini: 16MHz, 2KB RAM
- **2D Lidar: Sick TiM571, 15Hz, 0.3° res. ($2400)**
- 2D Lidar: RoboPeak RPLIDAR 360, 7Hz, 1° res. ($400)
- **Camera #1: Odroid oCam 5MP (640x480, 170 FOV)**
- Camera #2: Odroid USB Cam (640x480, 65 FOV)
- Mouse type GPS/Glonass: Holux M-215+
- Compass: Bosch BNO055
- 5x Sonar: HC - SR04
- LCD & OLED displays, 8x LED

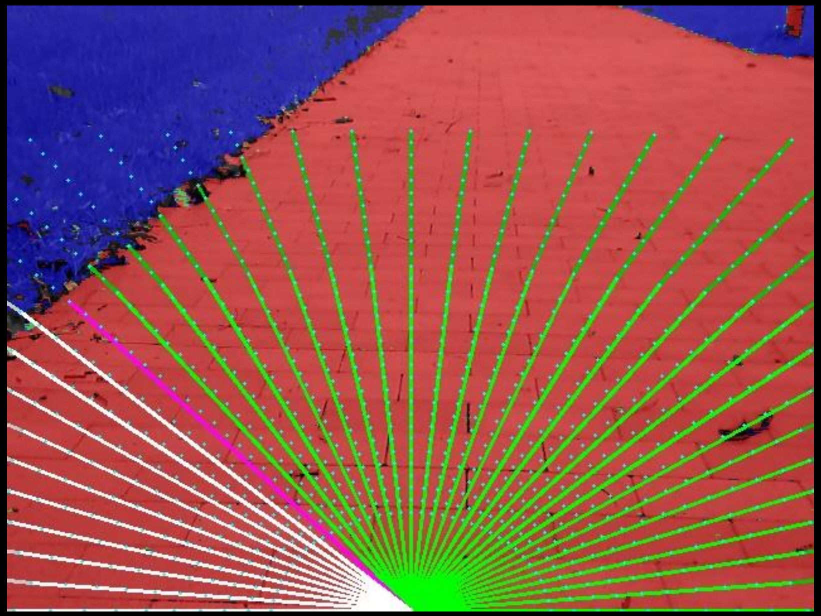
Jetson Nano vs Odroid-XU4

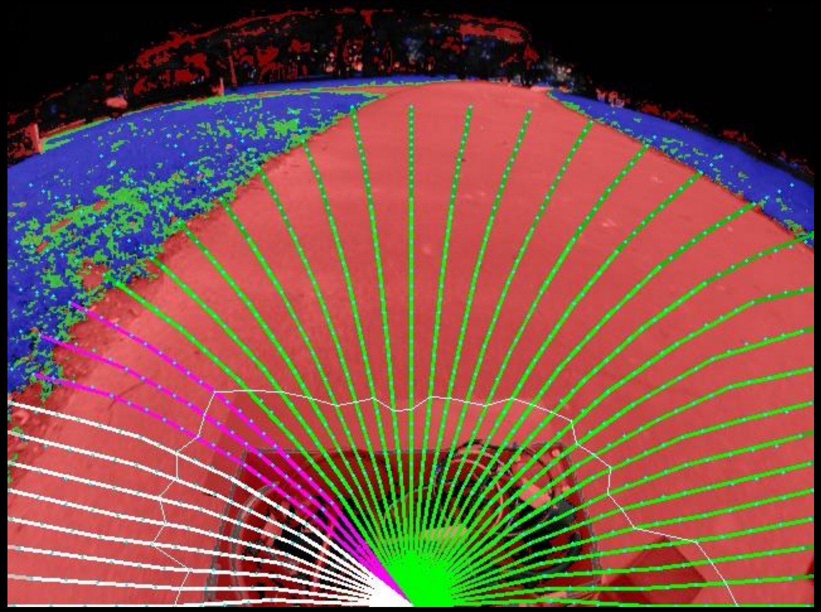
	Raspberry Pi3	Odroid-XU4	Jetson Nano
CPU	ARM Cortex-A53	Samsung Exynos5422 Cortex	ARM Cortex-A57
Clock	1.2 GHz	2 GHz	1,43 Ghz
Cores	4x	8x	4x
RAM	1GB LPDDR2	2GB LPDDR3	4GB LPDDR4
Flash	microSD	eMMC5.0 HS400	microSDXC Class 10 UHS-I
Ethernet	10/100 Mbit	1 Gigabit	1 Gigabit
USB	4× USB 2.0	2x USB 3.0 1x USB 2.0	4x USB 3.0

	R-Pi3	O-XU4	J-Nano
Image processing	167,3 ms	39,4 ms	27,3 ms
JPG/PNG writing	55 ms	17,7 ms	8,1 ms
Processing lag	2 sec	100 ms	0 ms (ramdisk)

FISHEYE IMAGE PROCESSING

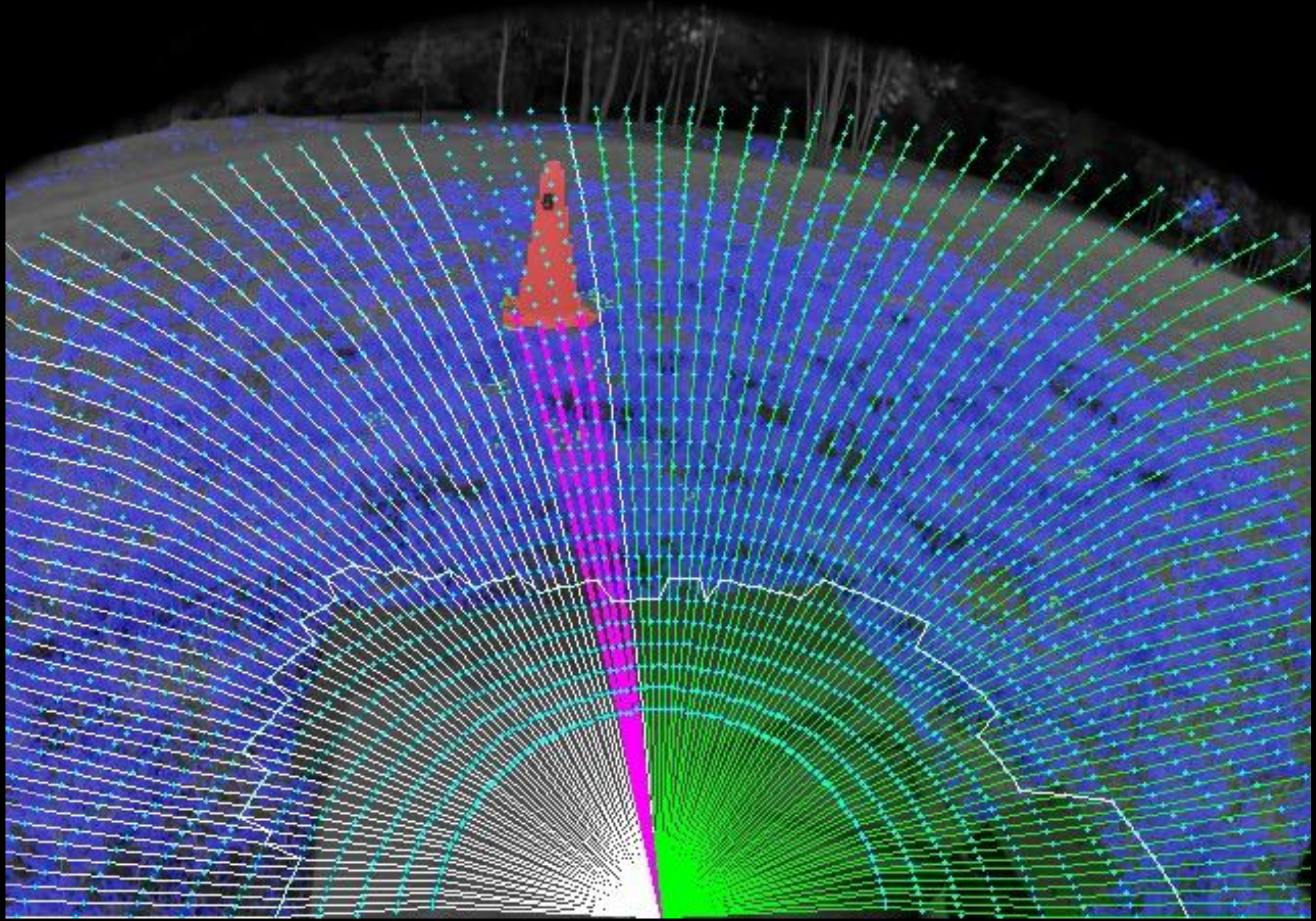
- **image transformation**
  - correction of mapping between XY points and local map coordinates – curved lines
  - OpenCV undistort() was not used (because of slow performance)
- **front side of the robot on every image**
  - was fixed by SW masking
  - presents an issue for training a neural network
- **sky was “masked” using a black tape**
  - for avoiding white ballancing camera issues



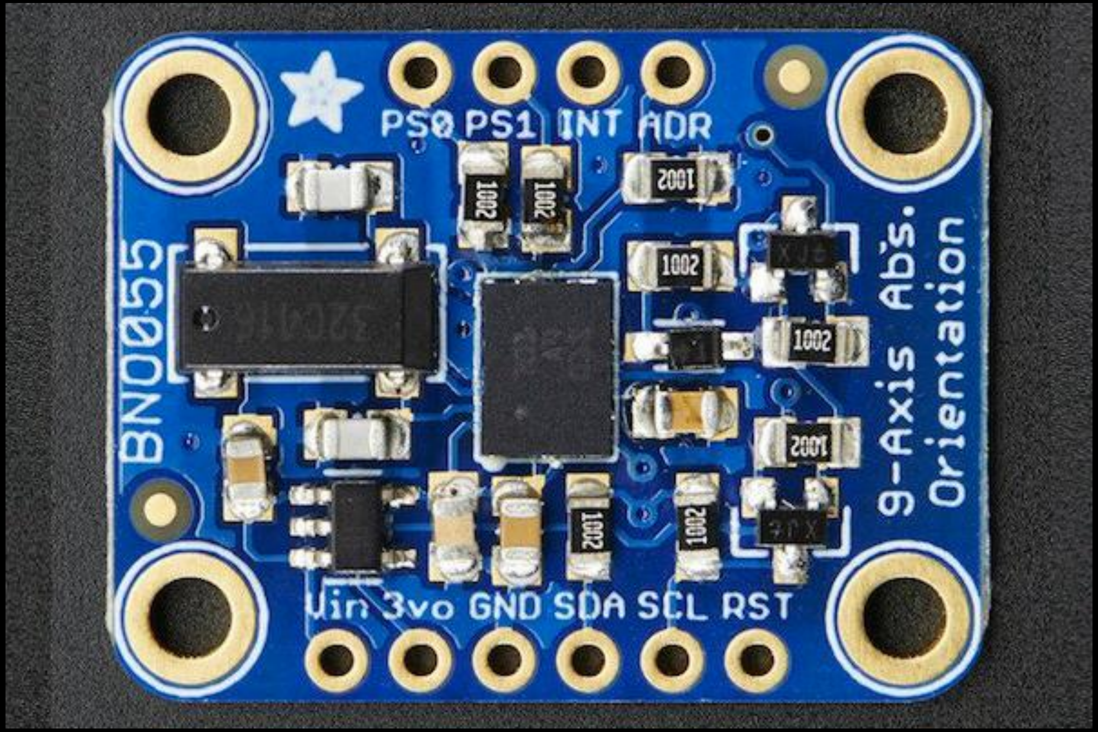


VISION - ROBOORIENTEERING

- Vision algorithm was modified to detect orange cones

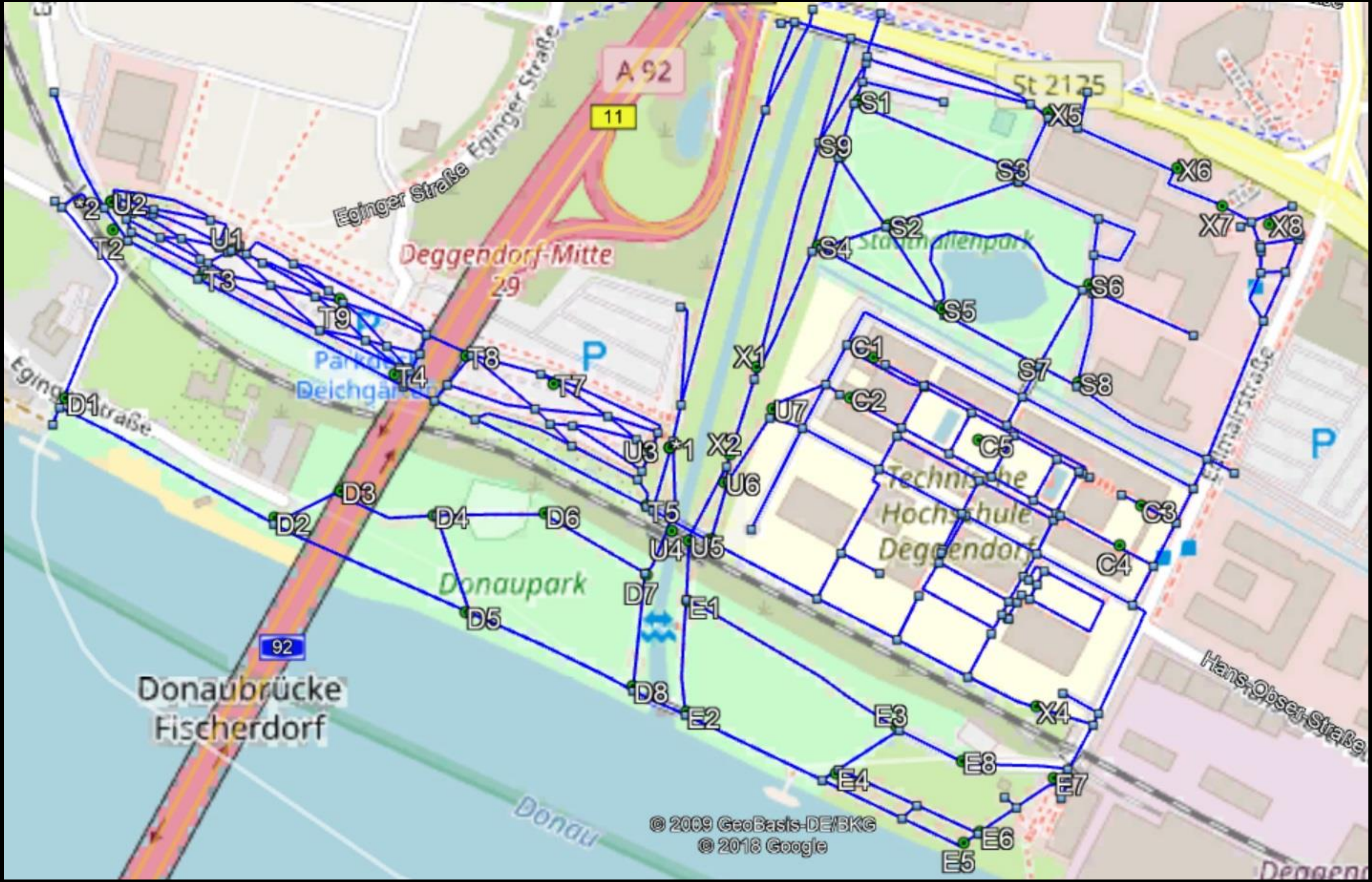


COMPASS ISSUES



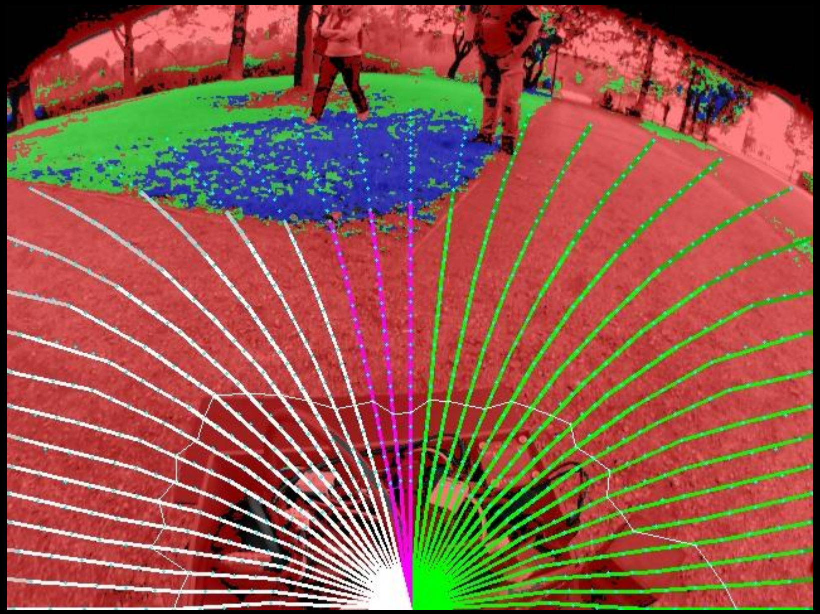
- Compass vs GPS calibration:
  - interval of 7 seconds - robot is moving straight
  - gps and compass azimuths to be fixed
  - could be performed every 30 seconds – 3 minutes
- Issues:
  - after Round #1 very inaccurate results – delta values between 45° and 90 °
  - robot is sometimes slightly left turning
  - local changes during the day (bridge)
- for testing in Bratislava and also for competition we used fixed value 60 °

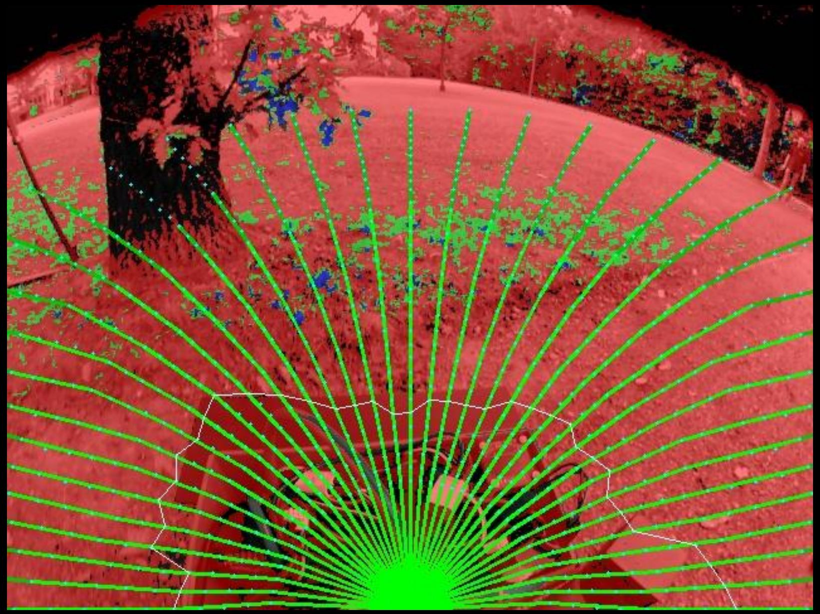
NAVIGATION MAP



PROBLEMS - ROUND #1

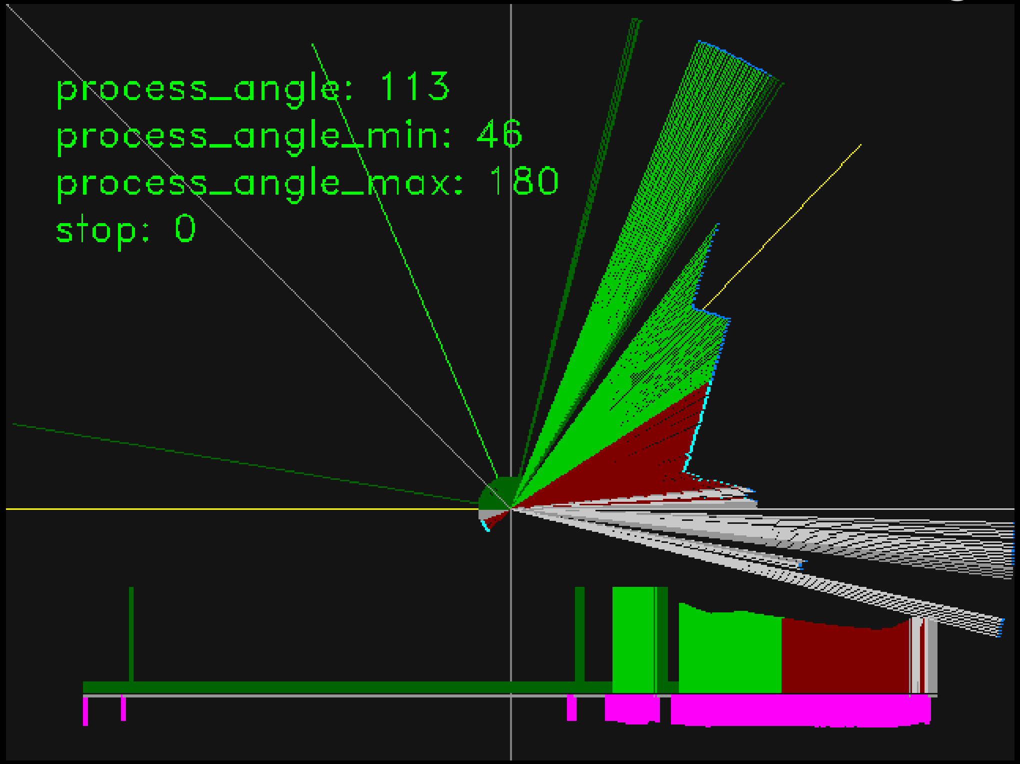
- **ROUND1** (failed before loading), 170FOV camera:
  - we realized that we forgot all our batteries in Bratislava
  - Pablo was soldering connectors for borrowed batteries – not enough time for testing
  - missed turn on the first crossing (still in semiautonomous area – we didn't know about it)
  - vision did not detect grass correctly during a U-turn

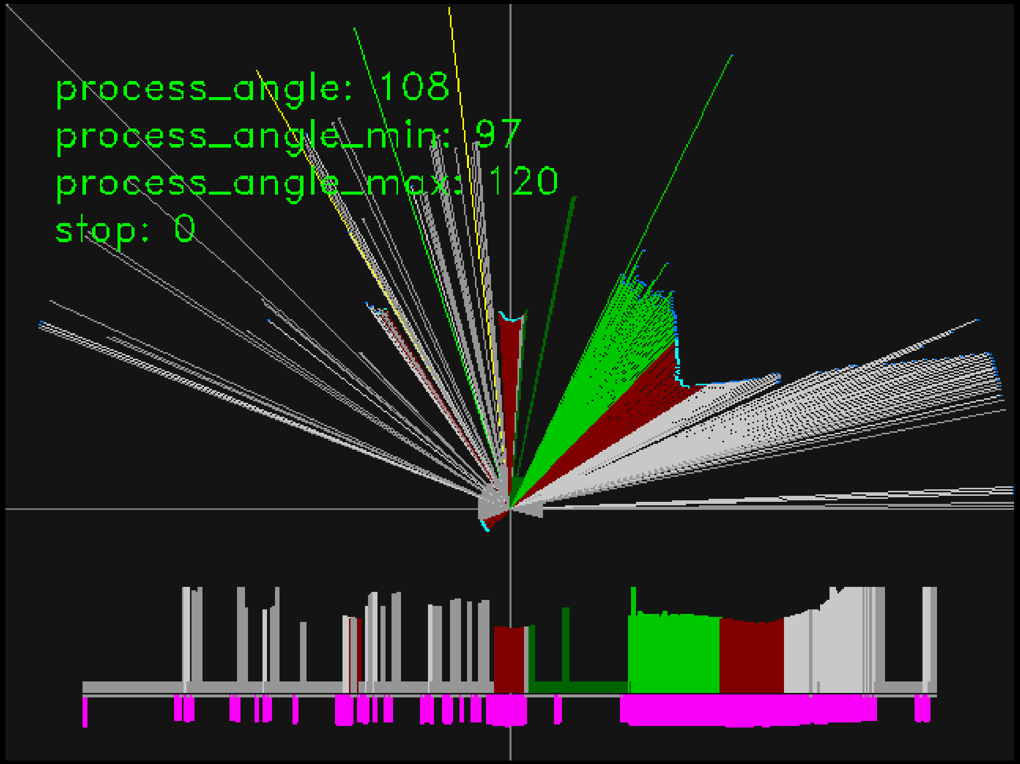




PROBLEMS - ROUND #2

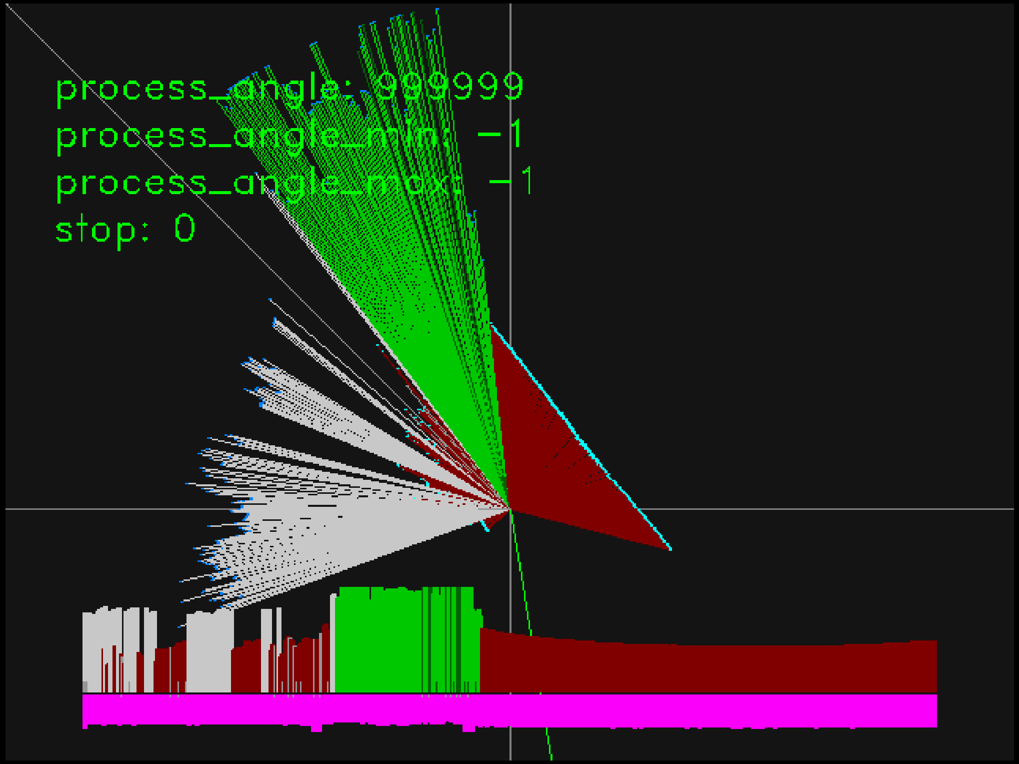
- **ROUND2** (failed before loading) , 170FOV camera:
  - camera stopped working (USB3 issue)
  - robot started to turn too late on a T-crossing





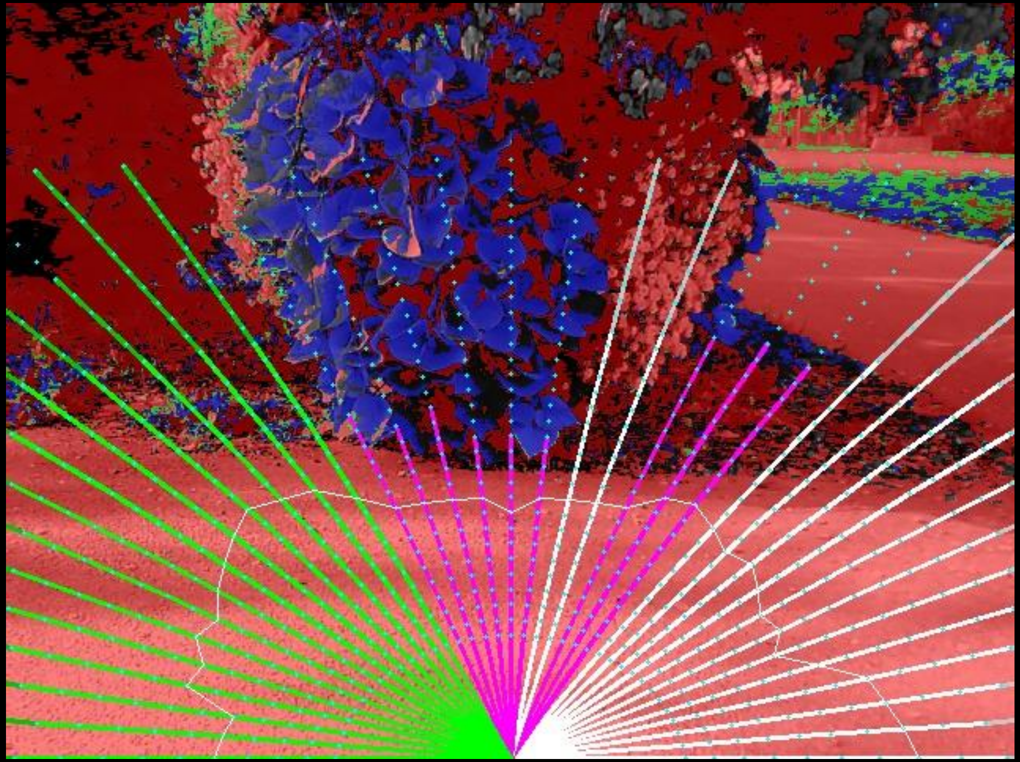
PROBLEMS - ROUND #3

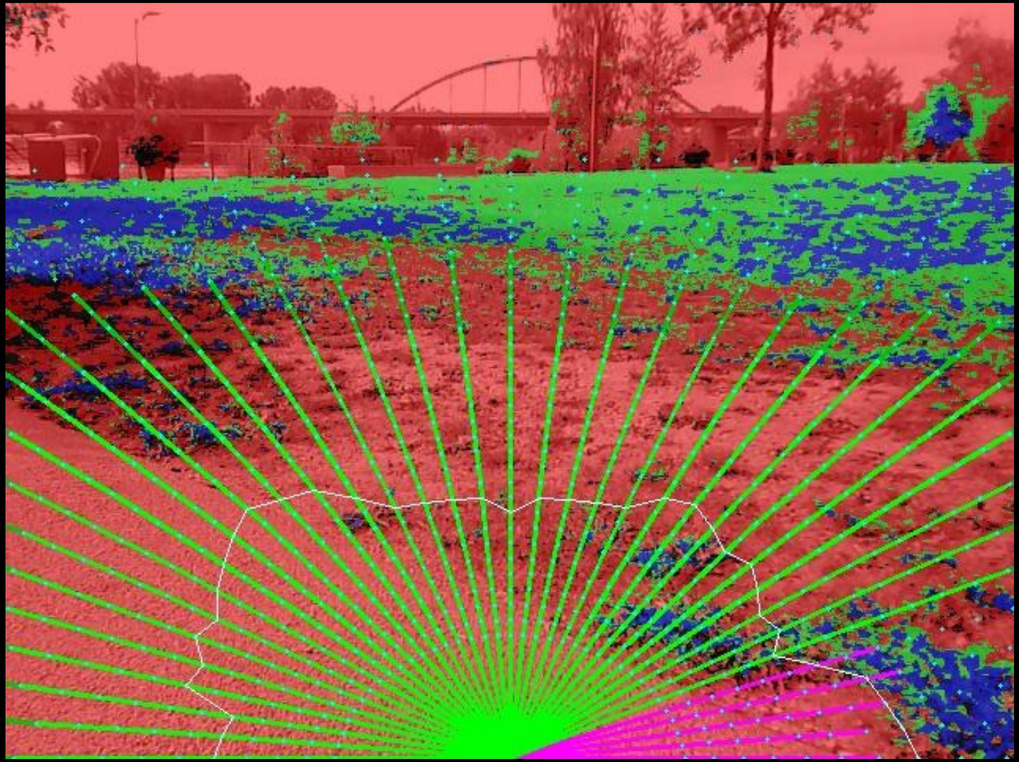
- **ROUND3** (failed before loading), old camera:
    - wide road – robot came into U-shape corner (trap)



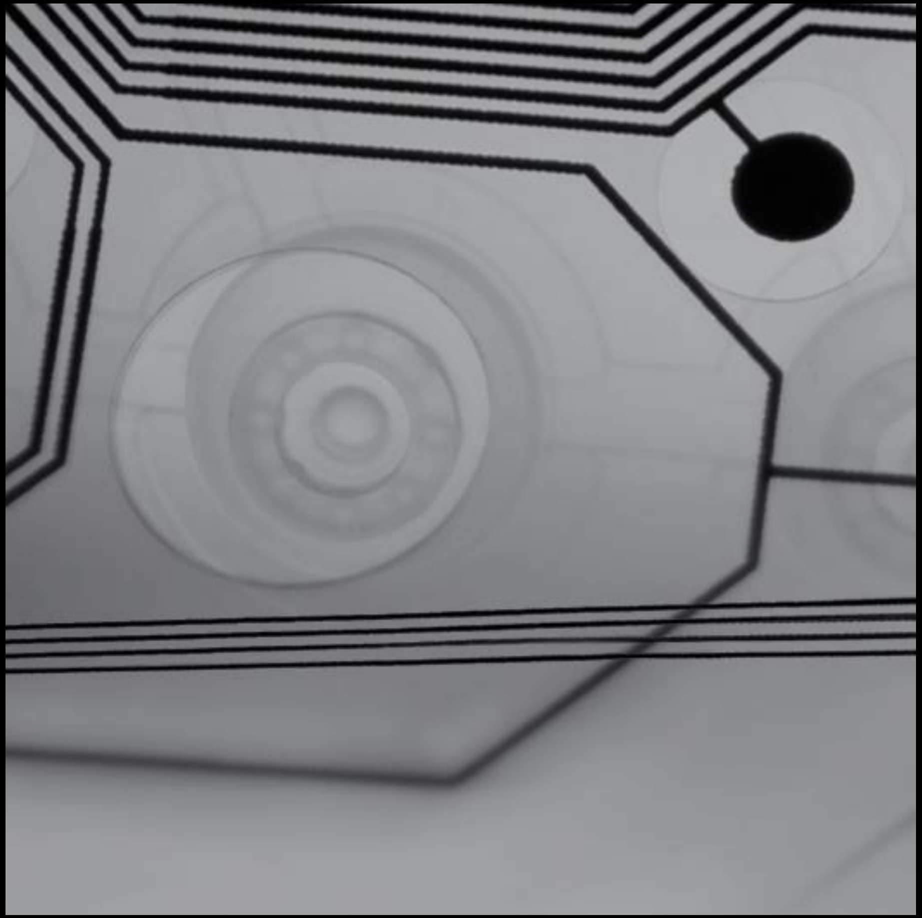
PROBLEMS - ROUND #4

- **ROUND4** (failed before loading) , old camera:
  - missed turn on a 4-way crossing – deciding locally
  - vision did not detect grass correctly during a U-turn



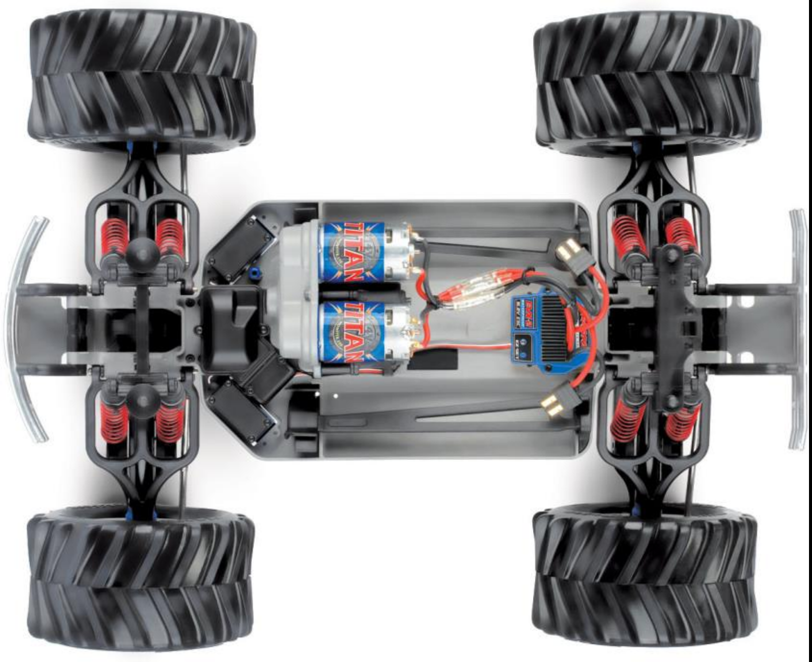


GENERAL SLIDES

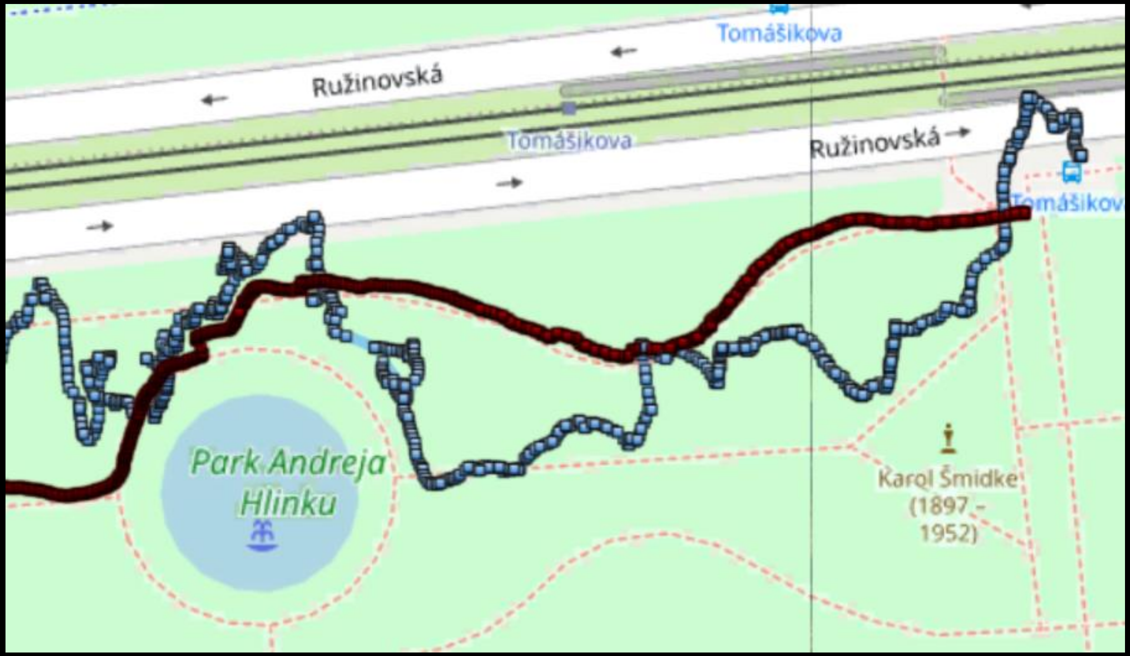


ROBOT CHASSIS

- RC model: Traxxas E-Maxx 4x4 monster truck
- Top Speed: 48 km/h
- Waterproof electronics, servos



GPS GROUND PLANE



- U-Blox GPS Antenna documentation
  - Patch antennas - flat surface is ideal
  - can show very high gain, if mounted **on large ground plane (70x70mm)**
- USB 3.0 impact on GPS
  - Intel paper: USB 3.0* Radio Frequency Interference Impact on 2.4 GHz Wireless Devices
- We used simple shield for GPS
- Results: **great improvement (3m accuracy)**

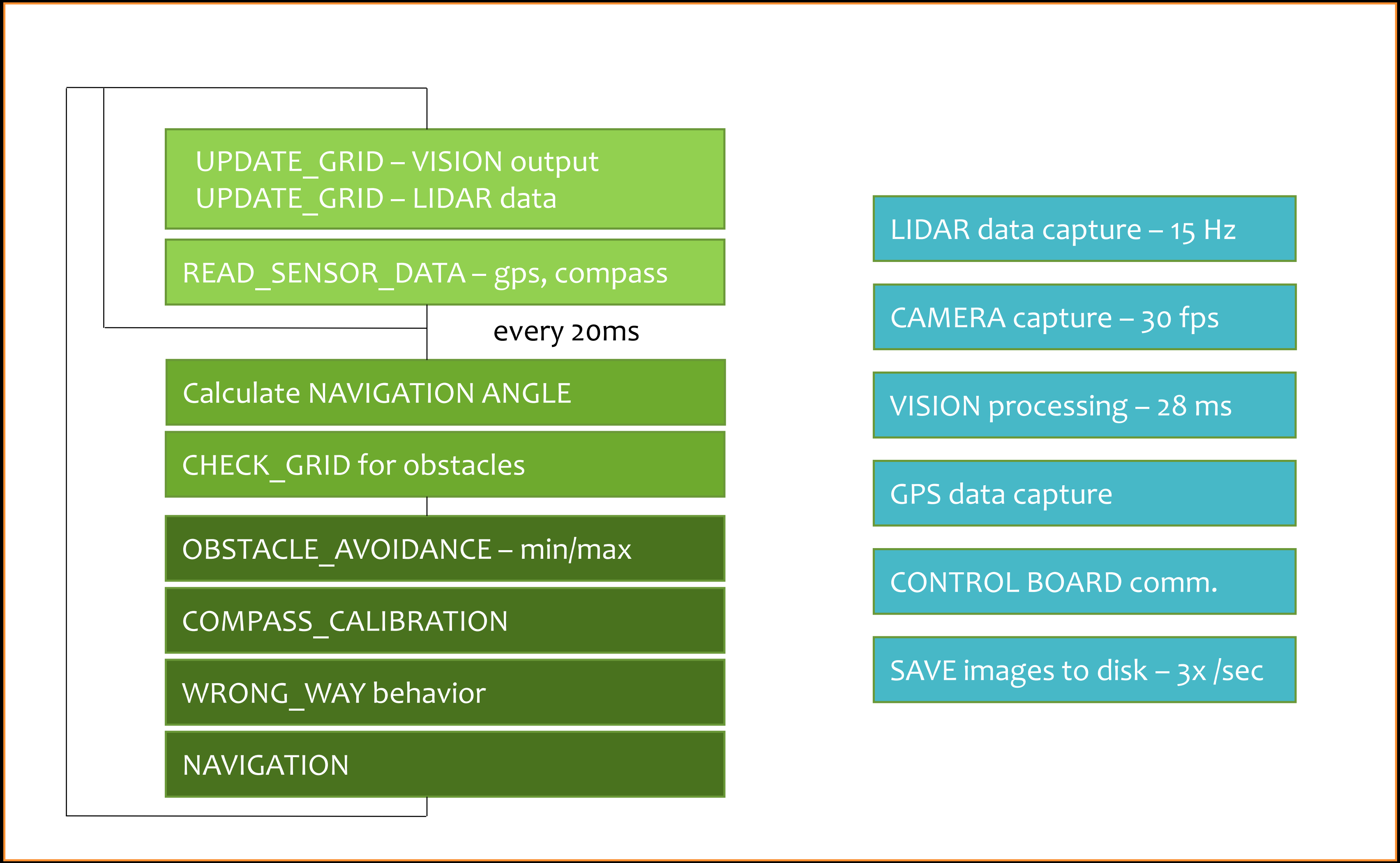
170FOV CAMERA

- **oCam : 5MP USB 3.0 Camera**
  - OmniVision OV5640 CMOS image sensor
  - Original lens Field Of View: 65 Degree
- Exchangeable Standard M12 Lens
  - Separate: 170 Degree Wide Angle
  - (standard accessory also for GoPro cameras)
- we 3d-printed an adjustable camera holder (fixed by screws)
- we broke the USB connector during the first test drive

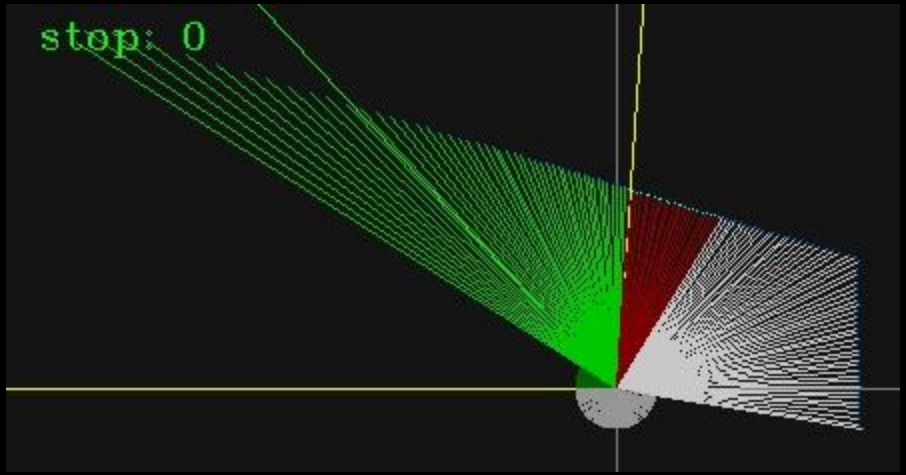
SOFTWARE

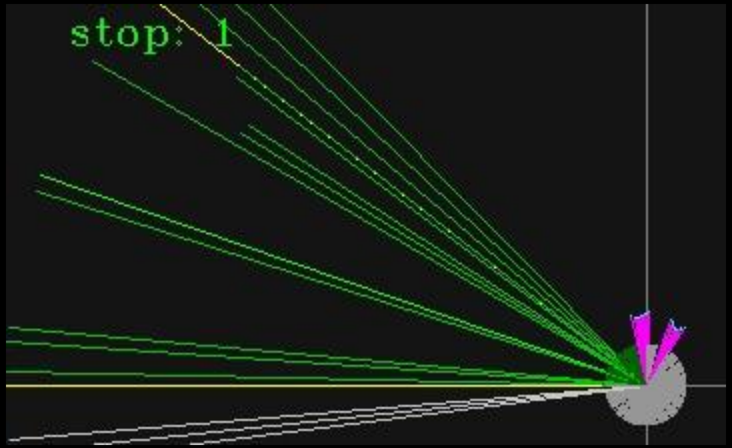
- Operating system: Ubuntu 16.04 Mate
- Source codes: C++, 430kB
  - 2017: 340kB, 2016: 180kB
- Libraries: OpenCV (vision), GeographicLib (Geo), Zbar (QR-Codes), Libxml2 (.osm), log4cxx (logging)
- Main application + 8x pthreads
  - 4x sensors (Camera, Lidar, GPS , Compass)
  - image capturing + vision processing
  - output: image saving (1GB of data/ round)
  - control board (Compass)

SOFTWARE DESIGN – PROCESSING



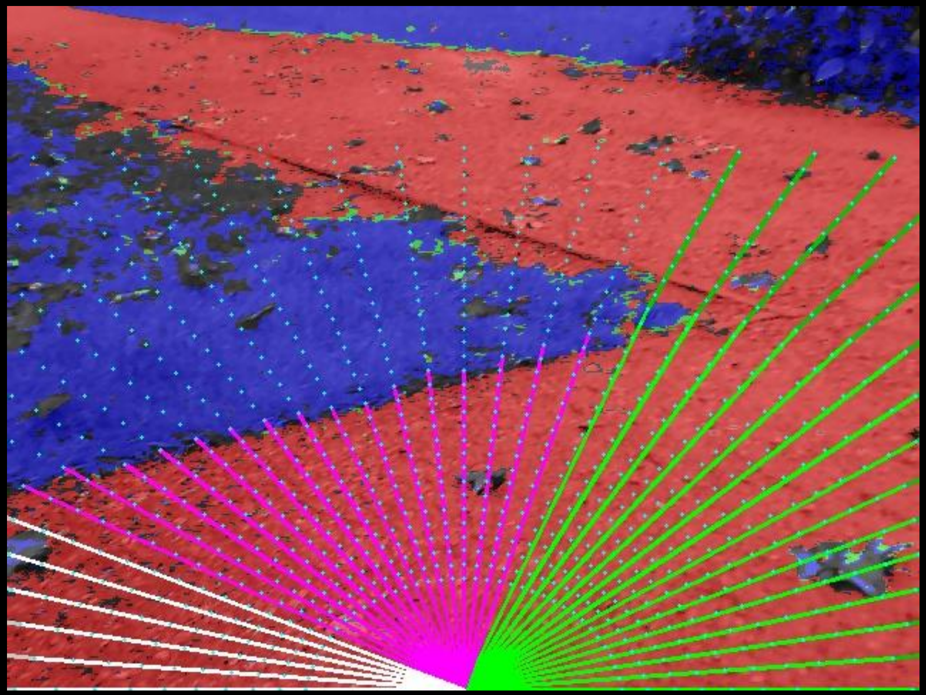
LIDAR – obstacle detection





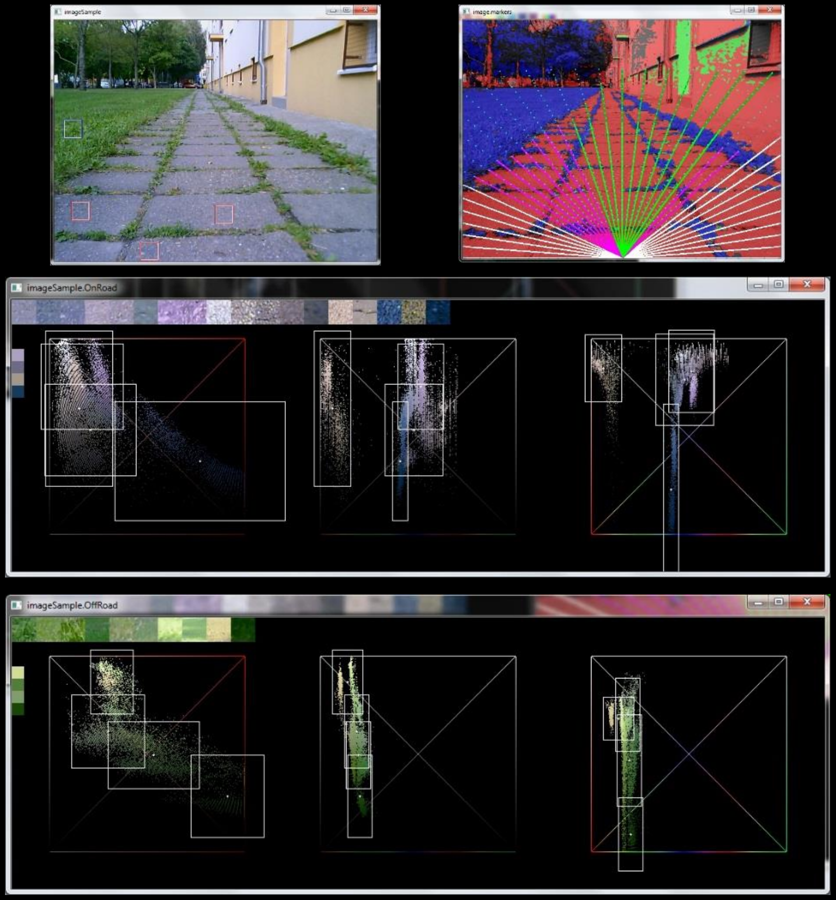
- Obstacle detection condition (red):
  - If distance is < 100 cm
  - Filtering: distance < 1cm (grey)
- Stop condition (pink):
  - Check angle: -45 to +45 degrees
  - If distance is < 50 cm at 3 diff. degs
  - Sonars were also used (rain issue)
- Obstacle avoidance (green/white)
  - Find OK intervals of > 20 degrees
  - Choose the closest to going straight

VISION – approach



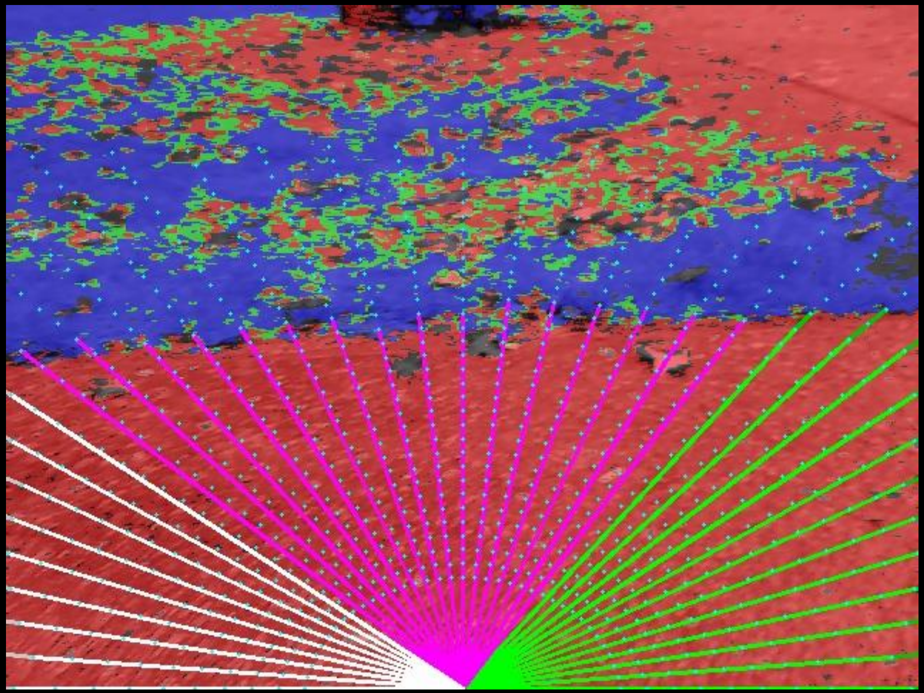
- Our approach: **lidar-like local map**
  - For any seen angle is obstacle closer than 1 meter?
  - 1 meter or to the image border
- Algorithm:
  - Pixel color classification
  - Evaluate grid points
  - Calculate distance to obstacle
  - Find OK intervals – same like LIDAR

VISION – Pixel color classification



- Approach:
  - Choose sample pixel blocks (32x32) from training images
  - Calculate 4 clusters centers in color space (OpenCV kmeans)
  - Calculate cluster radius (histogram based)
  - Repeat for 2 classifiers : road and off-road (grass)
- HSV color space + Euclidian distance
- Tool was developed - to define pixel blocks and evaluate images

VISION – Algorithm



- Pixel color classification - 4 results:
  - Road (red)
  - Off-road (blue)
  - Both (green)
  - None (grey)
- Evaluate grid points
  - Cca 1000 points in 37 lines (5 deg)
  - Evaluating nearby pixels (80x80)
  - Majority of “Road” pixels is checked
- Calculate distance to obstacle
- Find OK intervals + merge with LIDAR

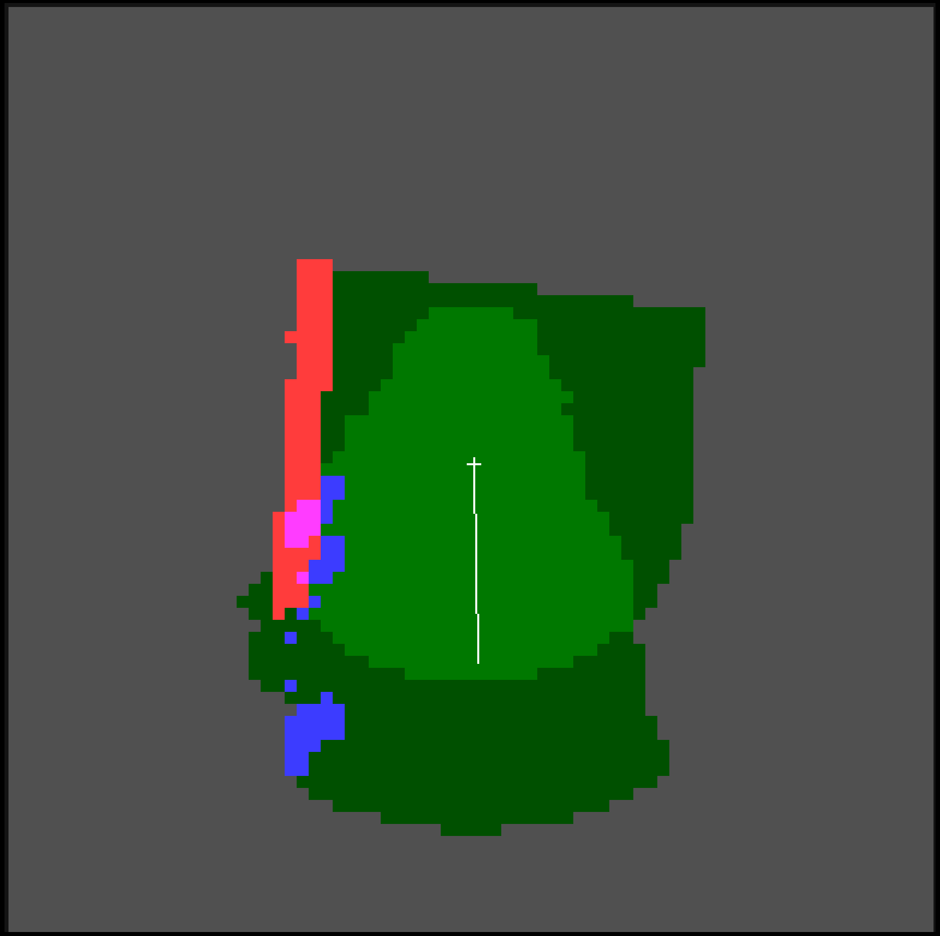
NAVIGATION – ROUTE PLANNING

- OpenStreetMap data export
  - filter segments: footway, track with <grade3
- **Dijkstra's Shortest Path Algorithm**
  - 418 nodes, 504 segments
- Performance: < 2ms
- Visualisation: kml export, cpp export
- Navigation: keep azimuth towards a point that is 10m along planned route

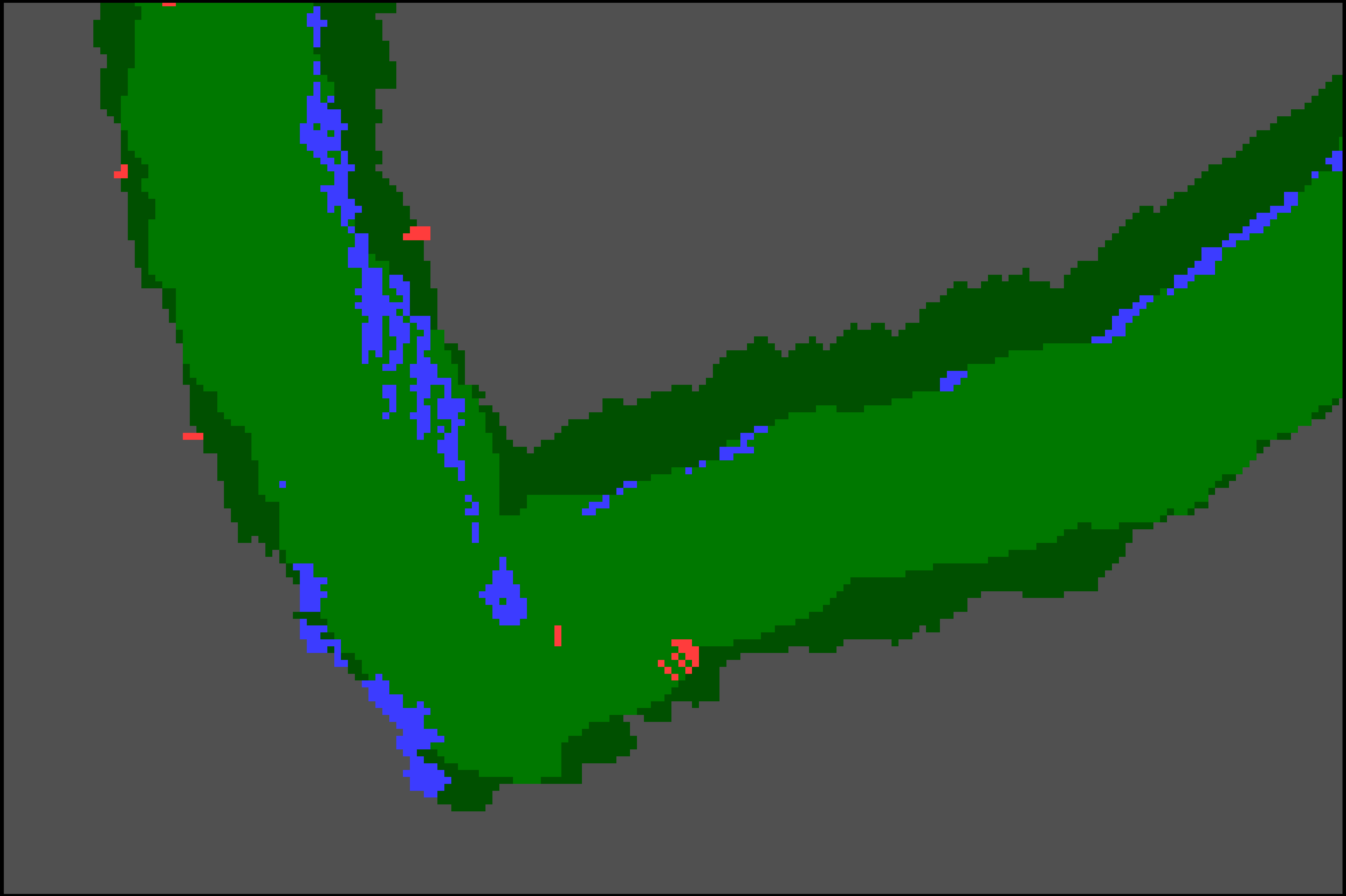
QR CODES

- **ZBar bar code reader**
  - open source software suite
  - supports: EAN-13/UPC-A, UPC-E, EAN-8, Code 128, Code 39, Interleaved 2 of 5 and QR Code
- Performance impact:
  - one execution: 50-200ms
  - our target 30-50ms per frame
- Solution: images are scanned for QR codes only when waiting for navigation coordinates

WORLD MAP – BUILDING LOCAL GRID

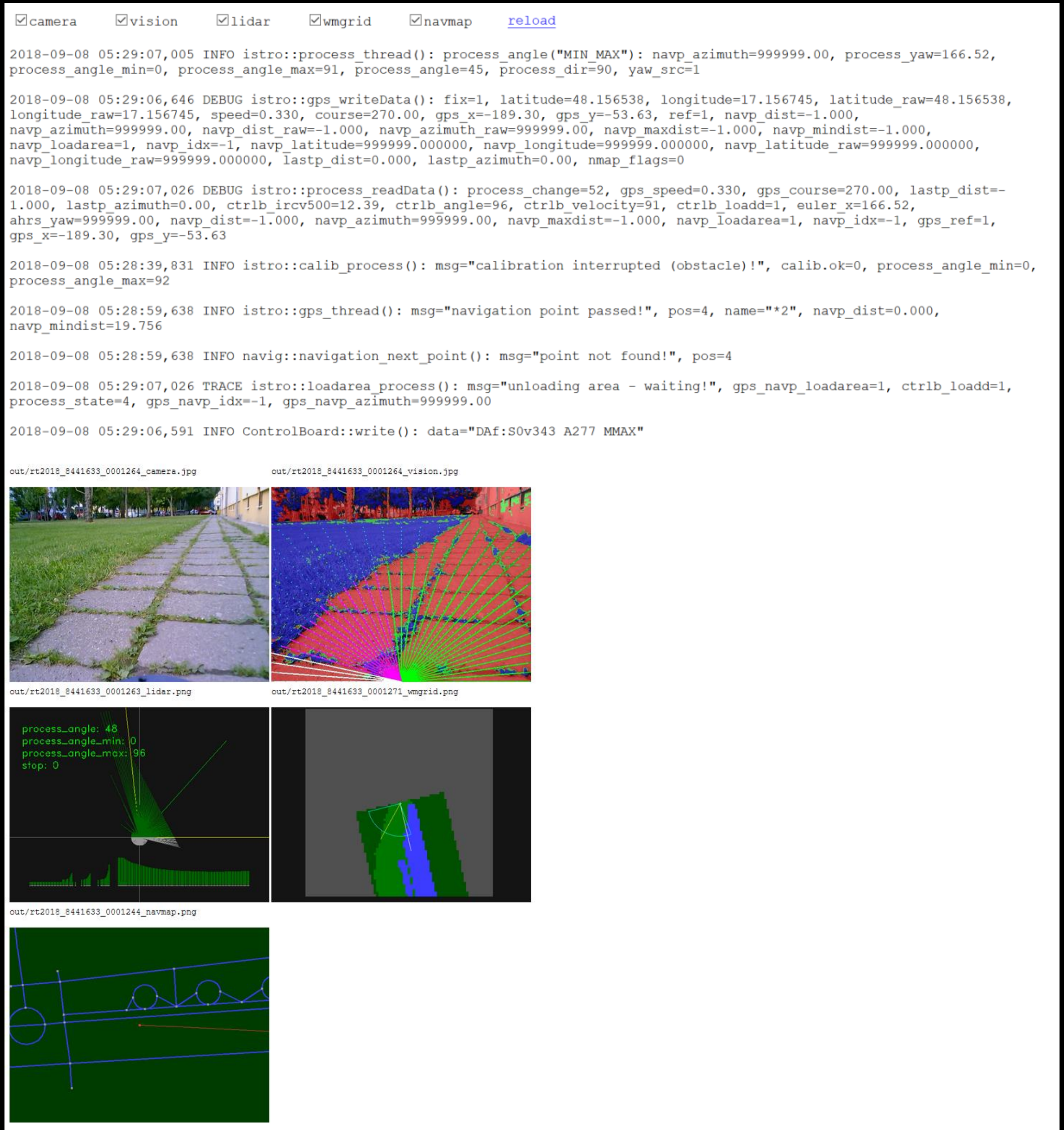


- Local grid map
  - to store polar information from lidar and vision
  - 1 cell: 10 x 10 cm, 1 byte pre cell, array[2000][2000]
  - always overwriting with new data - no heatmap
- Local position taken from GPS + odometry
  - wheel encoders provide speed information
- Colors used for visualization
  - Blue – grass (not-a-road) detected
  - Red – lidar obstacle
  - Green - no obstacle (light green = both sensors)



VISUALISATION

- Visualisation in web browser
  - works on notebook/tablet/phone
- Messages from log files
  - last set of lines matching selected substrings
  - Info: robot display, gps, processing, calibration
- Log parser is exporting interesting data do .json file
- Web page performs Ajax JSON requests every 1 sec
  - Images are only downloaded on demand (checkbox)



FREE SOURCE CODES

- Sources codes are available at GitHub as public project **Istro RT:**

  https://github.com/lnx-git/istro-rt

THANK YOU