

## Projeto CaRINA: Desenvolvimento de Veículos Autônomos

Manaus, November 2014

**Prof. Dr. Fernando S. Osório – ICMC / USP**

ESSE Minicurso

IV Escola de Sistemas Embarcados



Laboratório de Robótica Móvel  
ICMC/USP - São Carlos




Instituto de Ciências Matemáticas e de Computação

| Universidade de São Paulo |



## **Projeto CaRINA: Desenvolvimento de Veículos Autônomos**

***Presented by Prof. Dr. Fernando S. Osório – ICMC / USP***

**Authors:** Prof. Dr. Fernando S. Osório      Prof. Dr. Denis F. Wolf  
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+ M.Sc. and Ph.D. Students of LRM Lab.

**Center for Robotics of USP São Carlos – CRob / USP-SC**

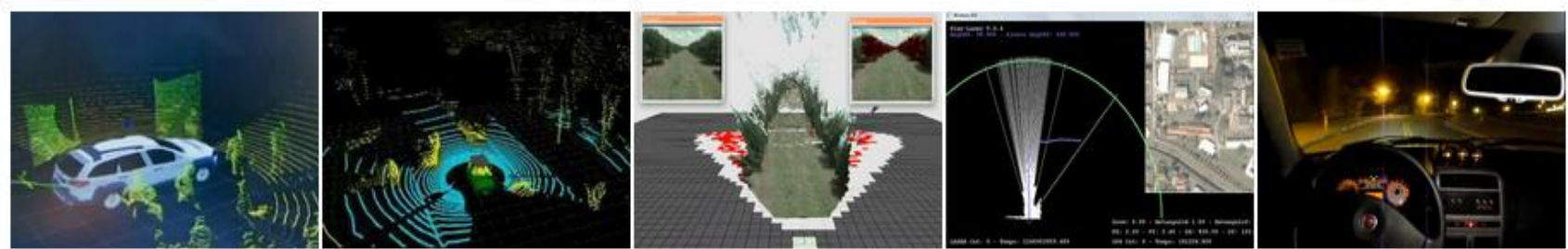


## Home

O Laboratório de Robótica Móvel desenvolve pesquisa em diversas áreas relacionadas à robótica. Dentre elas destacam-se: visão computacional, sistemas inteligentes, computação evolutiva, aprendizado de máquina, sistemas computacionais reconfiguráveis, robôs e veículos autônomos.

Atualmente, grande parte da pesquisa desenvolvida no laboratório está relacionada ao desenvolvimento de veículos inteligentes para ambientes urbanos e agrícolas. Mais informações sobre as linhas de pesquisa em andamento podem ser obtidas na página de projetos.

# <http://www.lrm.icmc.usp.br/>



# <http://www.youtube.com/lrmicmc>



## Robotic Platforms



Indoor Mobile Robots



The vehicular robotic platform CaRINA I



The vehicular robotic platform CaRINA II



## CARINA

Carro Robótico Inteligente para Navegação Autônoma



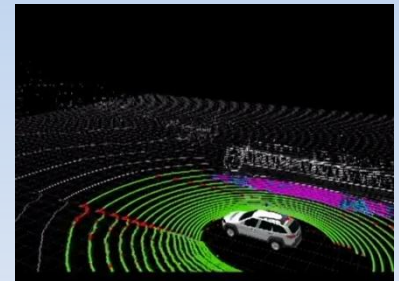
## How do we get there?

### Technologies

- **Platforms:** Mobile Robots and Ground Vehicles
- **Perception:** Monocular and Stereo Cameras  
Spherical Cameras, Thermal Cameras, Radar,  
Laser LIDAR (Light Detection And Ranging), ...
- **Localization:** GPS, IMU (Inertial Units), Encoders, ...
- **Path:** Planning, Navigation, Obstacle Avoidance
- **Global Map/Plan/Actions ; Local Map/Plan/Actions**

### Mobile Robotics: Research and Development

- Artificial Intelligence
- Machine Learning
- Computational Vision
- Pattern Recognition and Classification
- Networks, Security, RT-Operating Systems, Embedded Systems,...



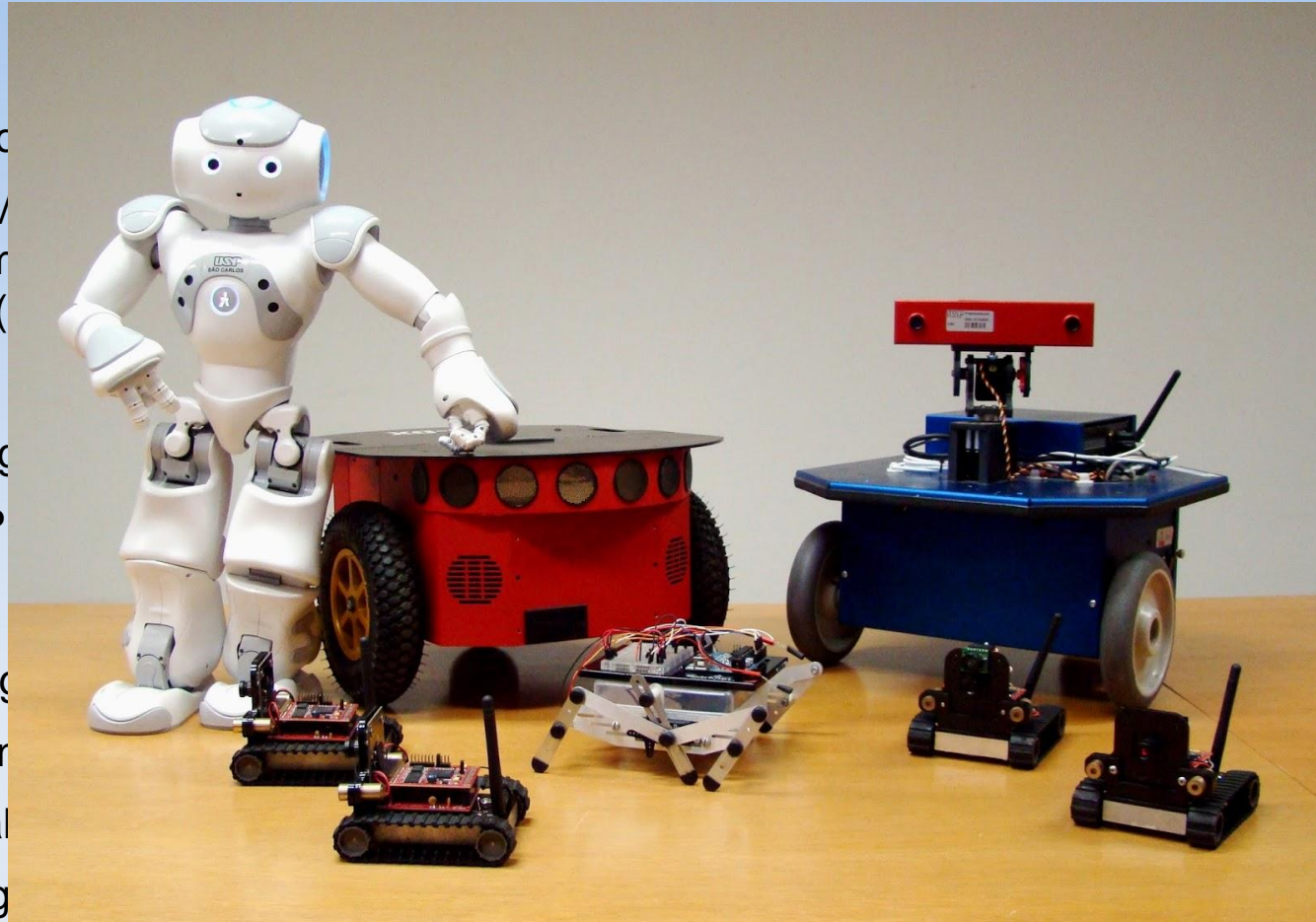
How do we get there?

## Technologies

- **Platforms:** Mo
- **Perception:** M  
Spherical Cam  
Laser LIDAR (
- **Localization:**
- **Path:** Planning
- **Global Map/P**

## Mobile Robotics:

- Artificial Intellig
- Machine Learn
- Computational
- Pattern Recog
- Networks, Security, RT-Operating Systems, Embedded Systems,...



# Intelligent Robotics / Service Robots

## Research and Development...





# Service Robots / Intelligent Robots



- **Research & Development of Service Robots:  
Growing Market ...**

“The market for **personal and service robots** is about **\$3 billion now** but is expected to reach **\$15 billion by 2015**, according to the Japan Robotics Association and market analysts like ABI Research. In 10 years or so, experts predict, sales of personal robots could surpass sales of industrial robots, now about \$4.6 billion a year.”

[NewsWeek August 09, 2008 by Katie Baker]

- **Applications of this technology \*:**

- |                             |                    |                    |
|-----------------------------|--------------------|--------------------|
| :: Cleaning & Housekeeping  | :: Edutainment     | :: Humanoids       |
| :: Humanitarian Demining    | :: Rehabilitation  | :: Inspection      |
| :: Agriculture & Harvesting | :: Lawn Mowers     | :: Surveillance    |
| :: Medical Applications     | :: Mining          | :: Construction    |
| :: Automatic Refilling      | :: Guides & Office | :: Fire Fighters   |
| :: Picking & Palletising    | :: Food Industry   | :: Search & Rescue |

\*IEEE Technical Committee on Service Robots

# Service Robots / Intelligent Robots

## • Research & Development of Service Robots: Growing Market ...

~~“The market for **personal and service robots** is about **\$3 billion now** but is expected to reach **\$15 billion by 2015**, according to the Japan Robotics Association and market research firm ABI Research. In 10 years or so, experts predict, sales of personal and service robots will surpass sales of industrial robots, now about \$4.6 billion a year.”~~

**UPDATED**

[NewsWeek August 09, 2008 by Katie Baker]

\*CGAR: Compound Annual Growth Rate

The global **service robotics market in 2011** was worth **\$18.39 billion**.  
This market is valued at **\$20.73 billion in 2012** and  
expected to reach **\$46.18 billion by 2017**  
at an estimated CAGR\* of 17.4% from 2012 to 2017.

Service Robotics Market (Personal & Professional)

Global Forecast & Assessment by Applications & Geography (2012 – 2017)

By: marketsandmarkets.com - Publishing Date: July 2012 - Report Code: SE 1146

\*IEEE Technical Committee on Service Robots

# Introduction: Intelligent Robotics

BLOGS // AUTOMATON

Amazon Acquires Kiva Systems for \$775 Million - IEEE Spectrum

Amazon Acquires Kiva Systems for \$775 Million

POSTED BY: ERICO GUIZZO / SEG, MARÇO 19, 2012



Photo: Joel Eden Photography/Kiva Systems

Looks like Amazon is getting some robots. LOTS of robots.

The giant online retailer announced today that it is acquiring Kiva Systems, a North Reading, Mass.-based company that invented a revolutionary way of managing vast warehouses by using fleets of mobile robots to sort, organize, and transport inventory.

Amazon agreed to acquire all of the outstanding shares of Kiva for approximately US \$775 million in cash. The companies expect to close the acquisition in the second quarter of 2012.

## Intelligent Robotics: Industry Jobs and Companies

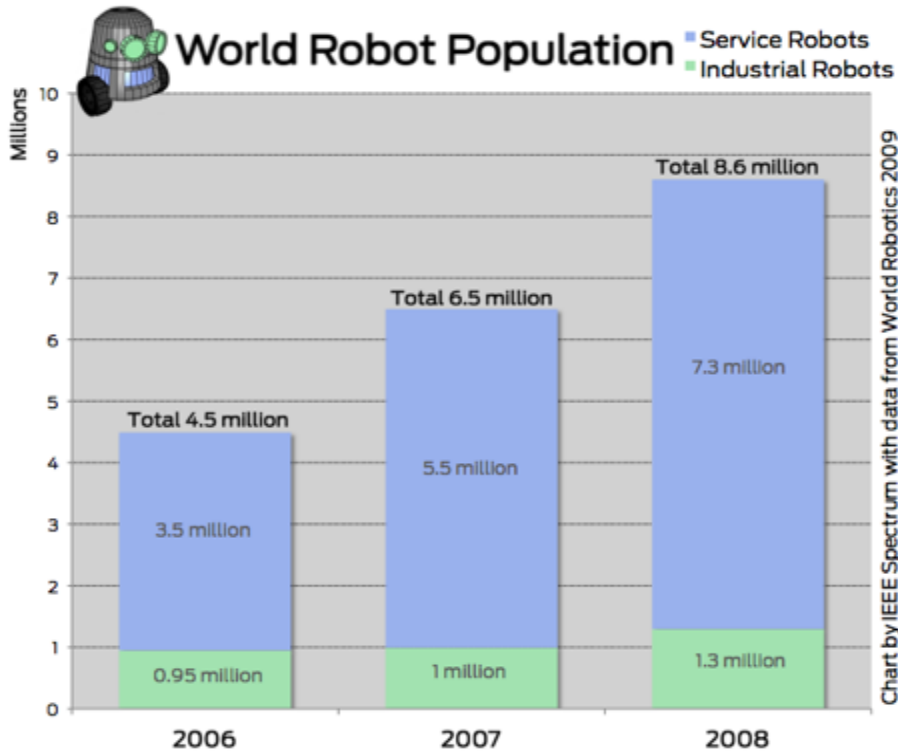
# Introduction: Intelligent Robotics

**AUTOMATON** *The future of robots*

BLOGS // AUTOMATON

## World Robot Population Reaches 8.6 Million

POSTED BY: ERICO GUIZZO / QUA, ABRIL 14, 2010



The world's robot population has reached 8.6 million. That's more than one

### TOP SELLER:

iRobot Roomba® 780  
Vacuum Cleaning Robot



## Intelligent Robots: Industry, Jobs, Companies & Opportunities!

### ABOUT IROBOT



**7.5 Million home robots!**

### About Our Robots

iRobot has made some of the world's most important robots.

#### iRobot Home Robots: The smarter way to get it done

iRobot's home robots are revolutionizing the way people clean – inside and out. More than 7.5 million home robots have been sold worldwide. The award-winning iRobot® Roomba® vacuum cleaning robot is leading the charge. Roomba made practical robots a reality for the first time and showed the world that robots are here to stay. iRobot's acclaimed line of home robots also includes the iRobot Scooba® floor washing robot, the iRobot Verro® pool cleaning robot and the iRobot Looj® gutter cleaning robot.

[http://www.irobot.com/filelibrary/ppt/corp/cool\\_stuff\\_ppt/cool\\_stuff\\_ppt.html](http://www.irobot.com/filelibrary/ppt/corp/cool_stuff_ppt/cool_stuff_ppt.html)



**Scientific American  
January 2007**

**A Robot in Every Home**

**The leader of the PC revolution predicts that the next hot field will be robotics**

**By Bill Gates**

# Introduction: Intelligent Robotics



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## Microsoft Shuts Down Its Robotics Group

By Erico Guizzo

Posted 25 Sep 2014 | 21:45 GMT

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## Microsoft Shuts Down Its Robotics Group

By Erico Guizzo

Posted 25 Sep 2014 | 21:45 GMT

In 2007, Bill Gates wrote his influential "[A Robot in Every Home](http://www.scientificamerican.com/article/a-robot-in-every-home/)" article in *Scientific American*\*, envisioning a future "in which robotic devices will become a nearly ubiquitous part of our day-to-day lives." The article reflected his belief that robotics was going to be hugely important, and Microsoft had to have a major role in it. Two years earlier, Gates had asked one of his top lieutenants, Tandy Trower, also a big believer in robotics, to lead a group with the bold mission of [bringing robots into the mainstream](http://spectrum.ieee.org/robotics/robotics-software/robots-incorporated) (<http://spectrum.ieee.org/robotics/robotics-software/robots-incorporated>).

This week, [word got out](http://www.neowin.net/news/microsoft-layoffs-claims-robotics-research-team-over-the-weekend) (<http://www.neowin.net/news/microsoft-layoffs-claims-robotics-research-team-over-the-weekend>) that, as part of its [current restructuring](http://www.bloomberg.com/news/2014-09-18/microsoft-cuts-2-100-workers-as-part-of-restructuring.html) (<http://www.bloomberg.com/news/2014-09-18/microsoft-cuts-2-100-workers-as-part-of-restructuring.html>), Microsoft decided to shut down its robotics group. (Two sources at Microsoft have since confirmed the news to *IEEE Spectrum*.) At a moment when excitement about the future of robotics seems to have reached an all-time high ([just ask Google](http://spectrum.ieee.org/automaton/robotics/industrial-robots/google-acquisition-seven-robotics-companies) (<http://spectrum.ieee.org/automaton/robotics/industrial-robots/google-acquisition-seven-robotics-companies>) and Amazon (<http://spectrum.ieee.org/automaton/robotics/industrial-robots/apple-amazon-and-now-google-an-exciting-time-for-robotics>)), Microsoft has given up on robots.

# Introduction: Intelligent Robotics



Automaton | Robotics | Industrial Robots

## Google Acquires Seven Robot Companies, Wants Big Role in Robotics

By Evan Ackerman

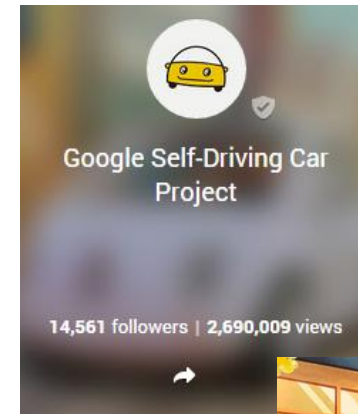
Posted 4 Dec 2013 | 14:52 GMT

Share | Email | Print



Here is the list of companies Google has acquired:

- Schaft Inc.
- Industrial Perception, Inc
- Redwood Robotics
- Meka Robotics
- Holomini
- Bot & Dolly
- Boston Dynamics
- DeepMind Technologies



# DRC Darpa Robotics Challenge

**DRC – Darpa Robotics Challenge**  
**2013-2015 / US\$ 2M Prize**





# DRC Darpa Robotics Challenge

## DRC – Darpa Robotics Challenge TASKs

- ◎ Drive a utility vehicle at the site.
- ◎ Move/Walk across ruins/debris.
- ◎ Remove debris blocking an entryway.
- ◎ Open a door and enter a building.
- ◎ Climb an industrial ladder and traverse an industrial walkway.
- ◎ Use a tool to break through a concrete panel.
- ◎ Locate and close a valve near a leaking pipe.
- ◎ Connect a fire hose to a standpipe and turn on a valve.



[http://en.wikipedia.org/wiki/DARPA\\_Robotics\\_Challenge](http://en.wikipedia.org/wiki/DARPA_Robotics_Challenge)

<http://www.theroboticschallenge.org/overview>

## **DRC – Darpa Robotics Challenge**

How to Win?

1. First:

Finish the Tasks

2. Second:

Time to Finish the Task

3. Third:

Amount of Data Required to Finish the Task  
(bits uplinked + bits downlinked)

## DRC – Darpa Robotics Challenge

How to Win?

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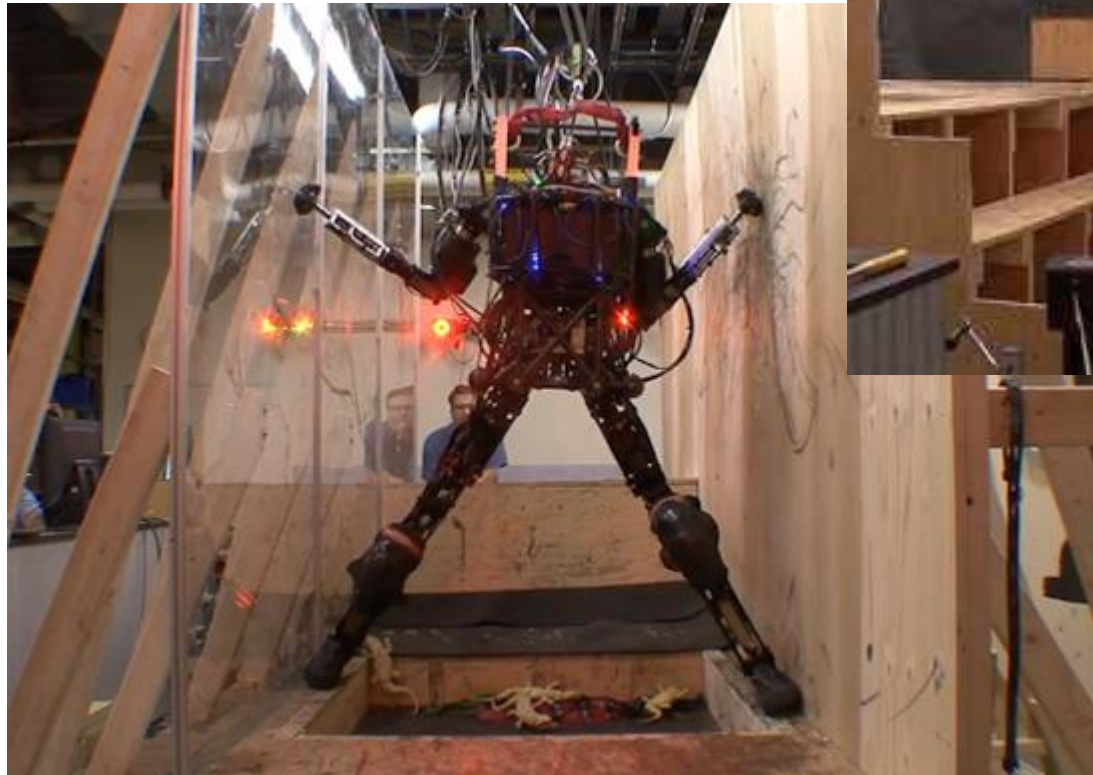
**Increase AUTONOMY**

## DRC – Darpa Robotics Challenge

**Humanoids:**

**Walking, Avoid Obstacles, Stairs**

**Use tools, Manipulate objects**



# DRC Darpa Robotics Challenge

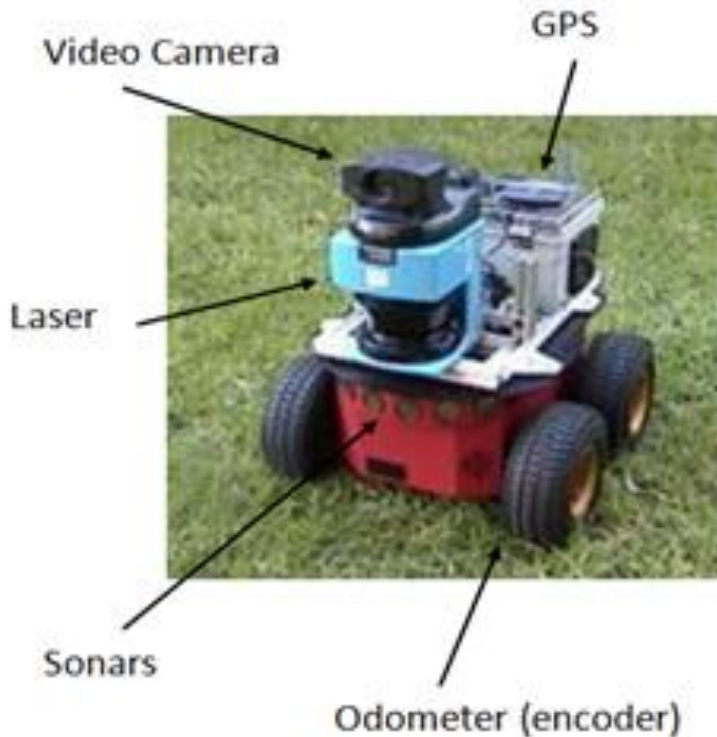
## DRC – Darpa Robotics Challenge

Humanoids:  
Driving Cars

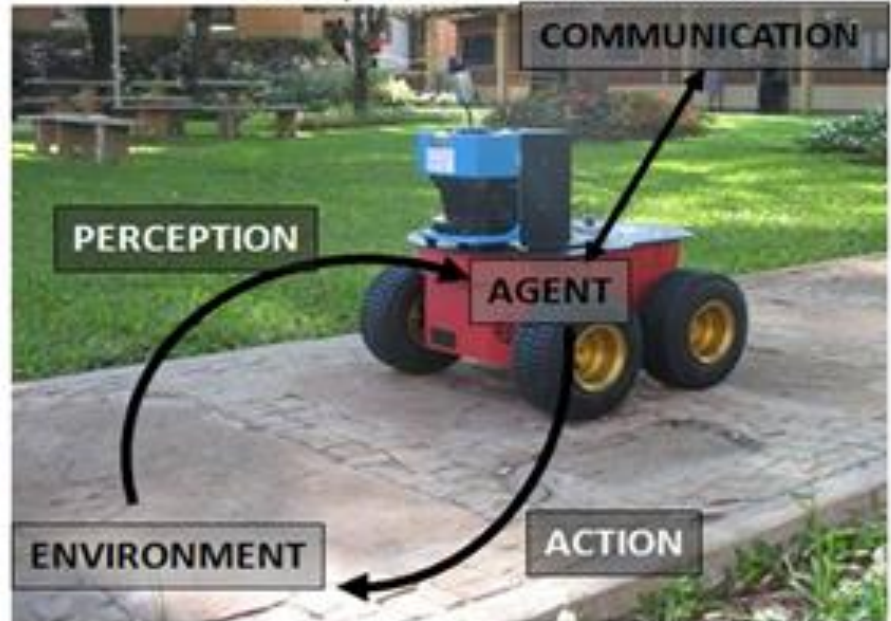


# Intelligent Robots

Sensors + Agent (Knowledge, Planning, Decision) + Action



**Network:** \* Robot x Robot  
\* Tele-Operation Station x Robot



**Tele-Operated:** Receive Sensor Data => Decide [Human] => Send Action Commands  
**Autonomous :** Receive Sensor Data => Decide [Computer] => Send Action Commands

# Intelligent Robots

## Sensors



(a) Laser Sick LMS 2xx



(b) Video Camera



(c) Inertia Unit IMU - MicroStrain



(d) Laser Hokuyo URG-04LX



(i) Kinect (Microsoft Xbox) Indoor only (or at night)



(e) STOC Video Camera Stereo-on-a-Chip



(f) Thermal Camera FLIR PathFindIR



(g) Compass Module HMC6352



(h) Sonar Module Maxbotix LV-EZ0



(j) GPS Garmin (Outdoor only)



Velodyne HDL-32E



PointGray LadyBug 2



PointGray Bumblebee 2



Xsens Mti-G



Laser Hokuyo URG-30LX

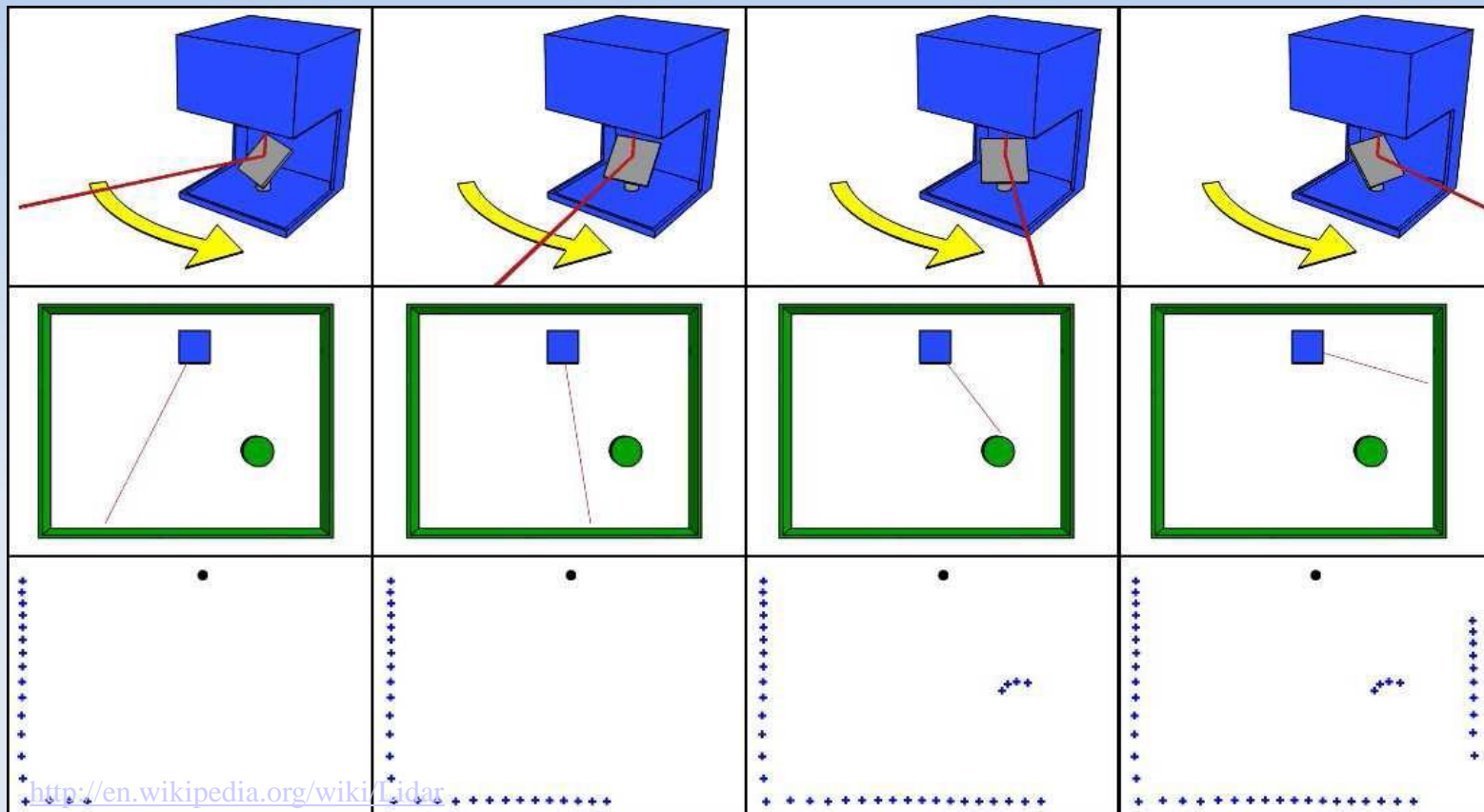
# Intelligent Robots



## Sensors



**Laser LIDAR (Light Detection And Ranging) – SICK LMS 200**  
**Single Laser Beam – Max. Distance: 80 mts – Max. Speed: 75 Hz**  
**View of 180° degrees – Resolution: 0.5 degree (360 scans) – Precision > 0.5 cm**



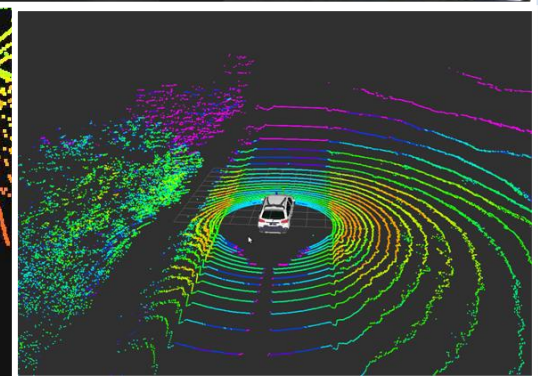
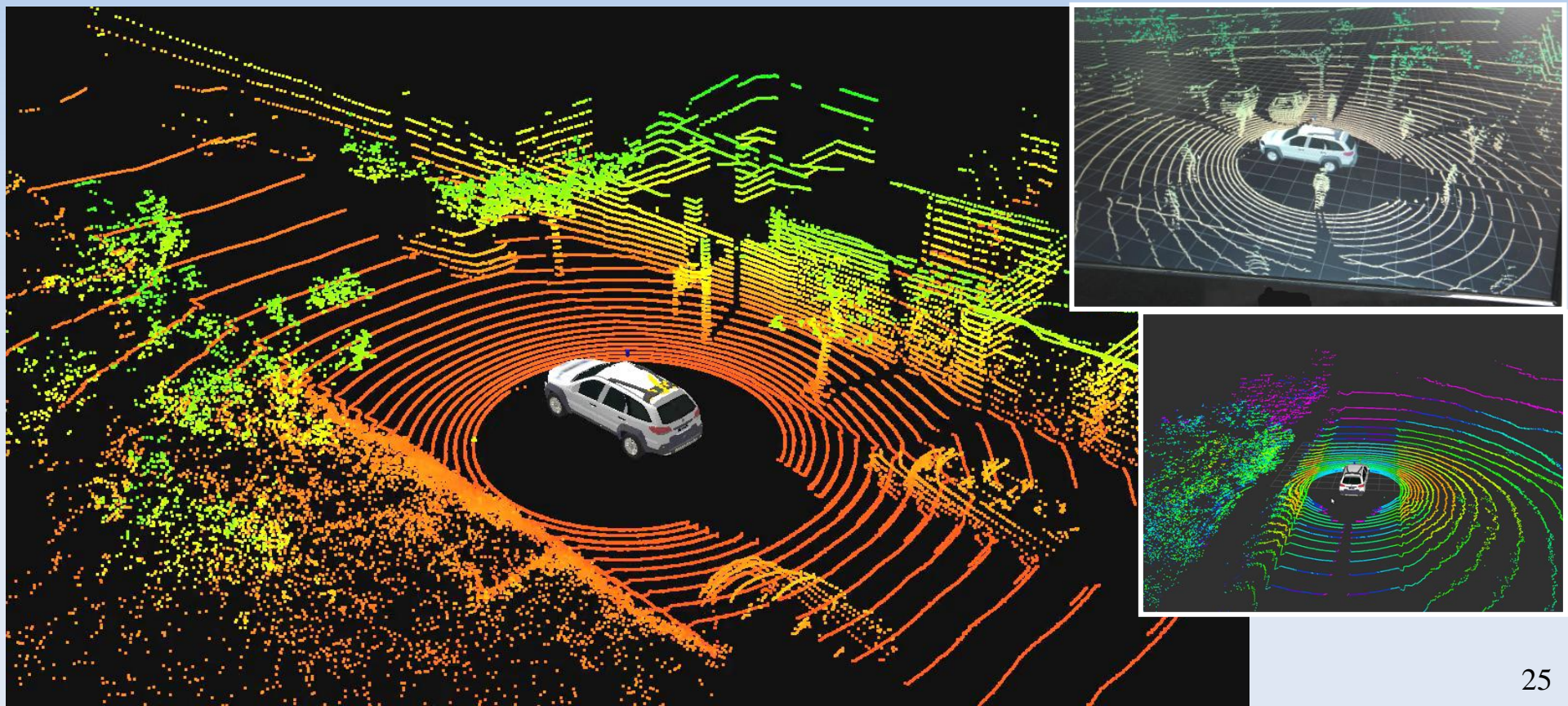


# Intelligent Robots



Sensors: Velodyne

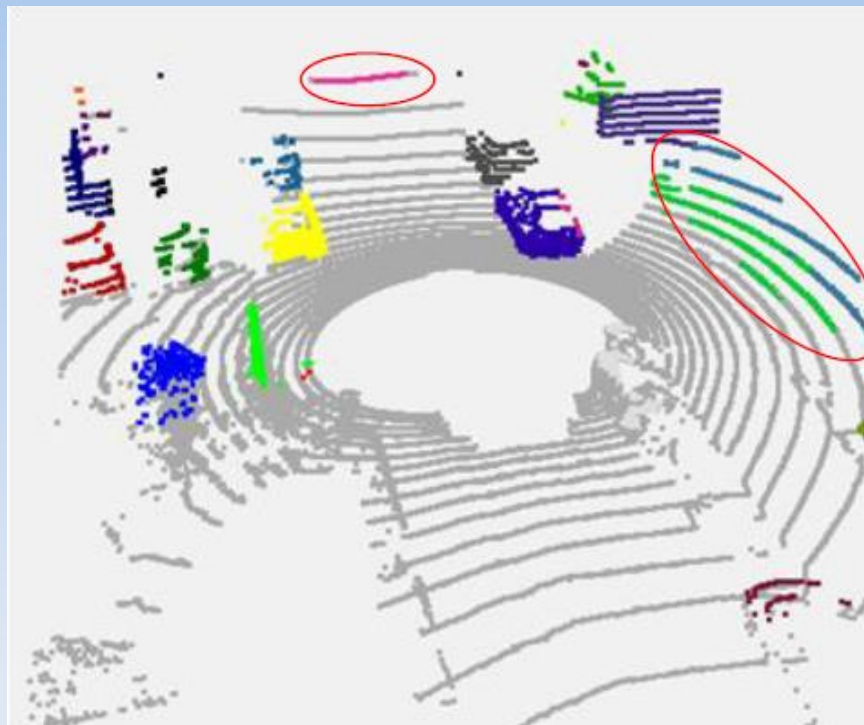
**Laser LIDAR (Light Detection And Ranging) – Velodyne HDL32**  
**32 Laser Beams – Max. Distance: 100 mts – Speed: 10 Hz - 700.000 points/sec**  
**View of 360° degrees – Resolution: 70.000 Points3D (XYZ) per frame**



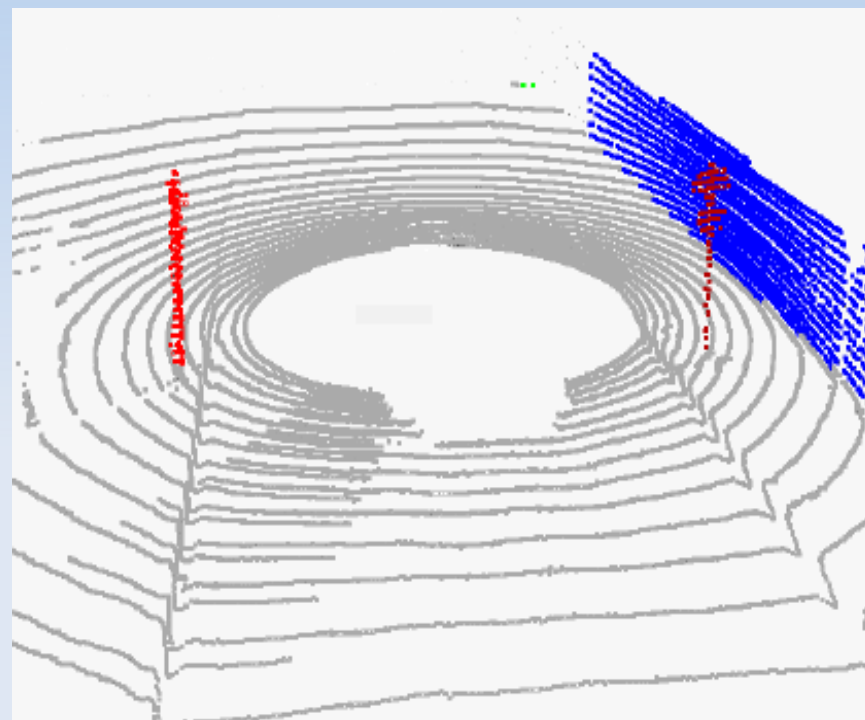
# Intelligent Robots



## Velodyne: Obstacles Recognition



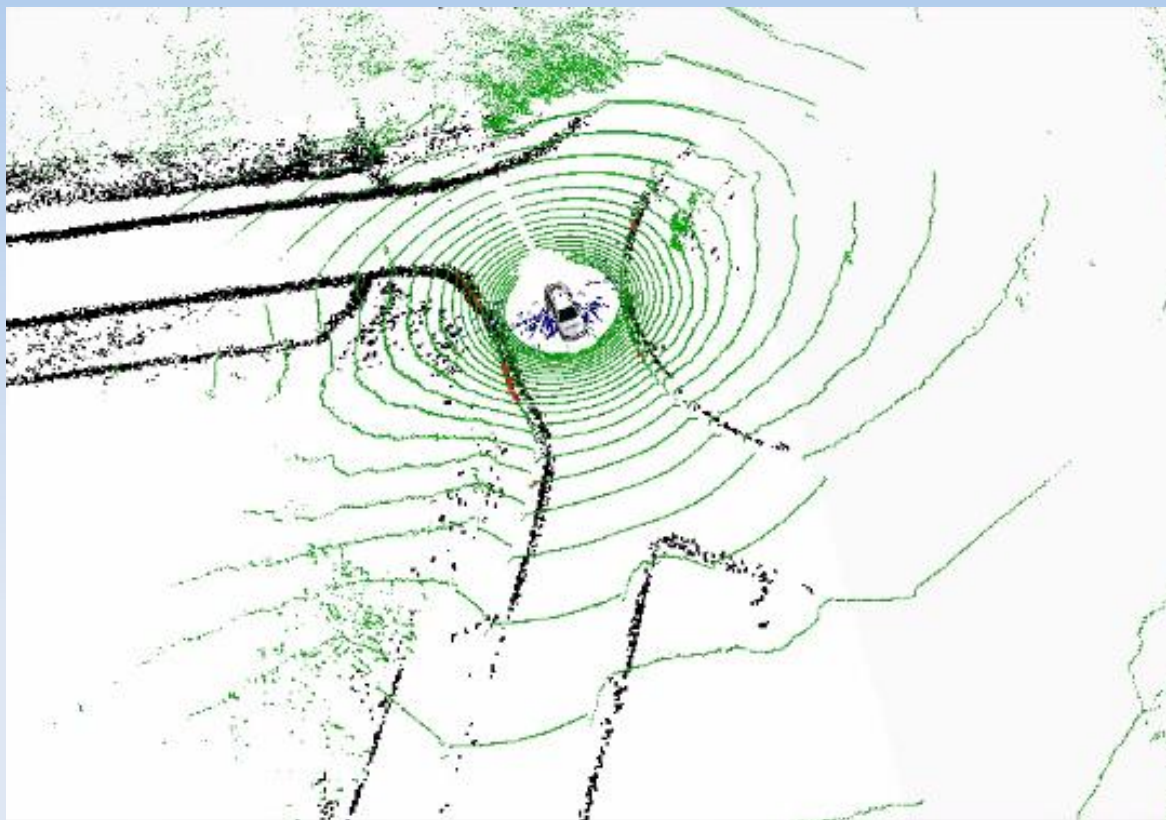
[D. Habermann]



# Intelligent Robots



## Velodyne: Curb Detection, Localization, Maps



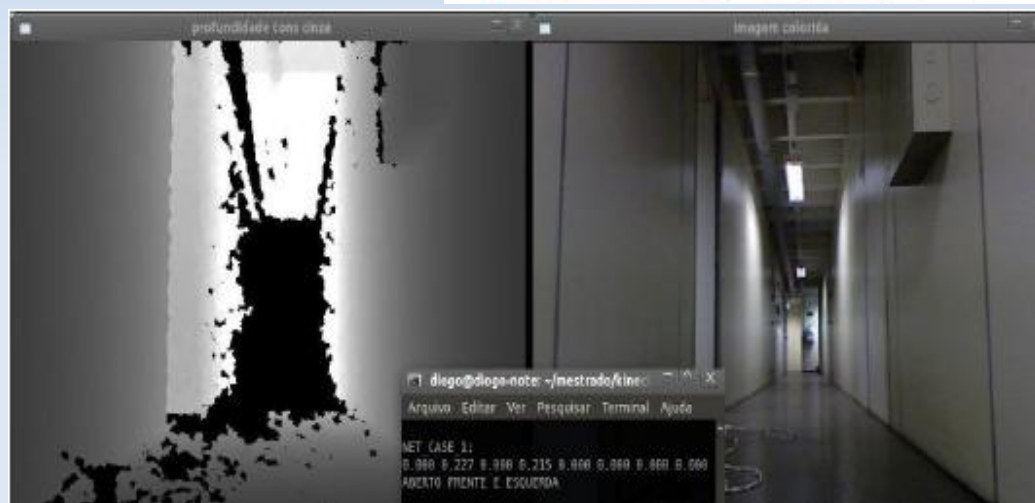
[A. Hata]

# Intelligent Robots

## Robots and Sensors: Kinect



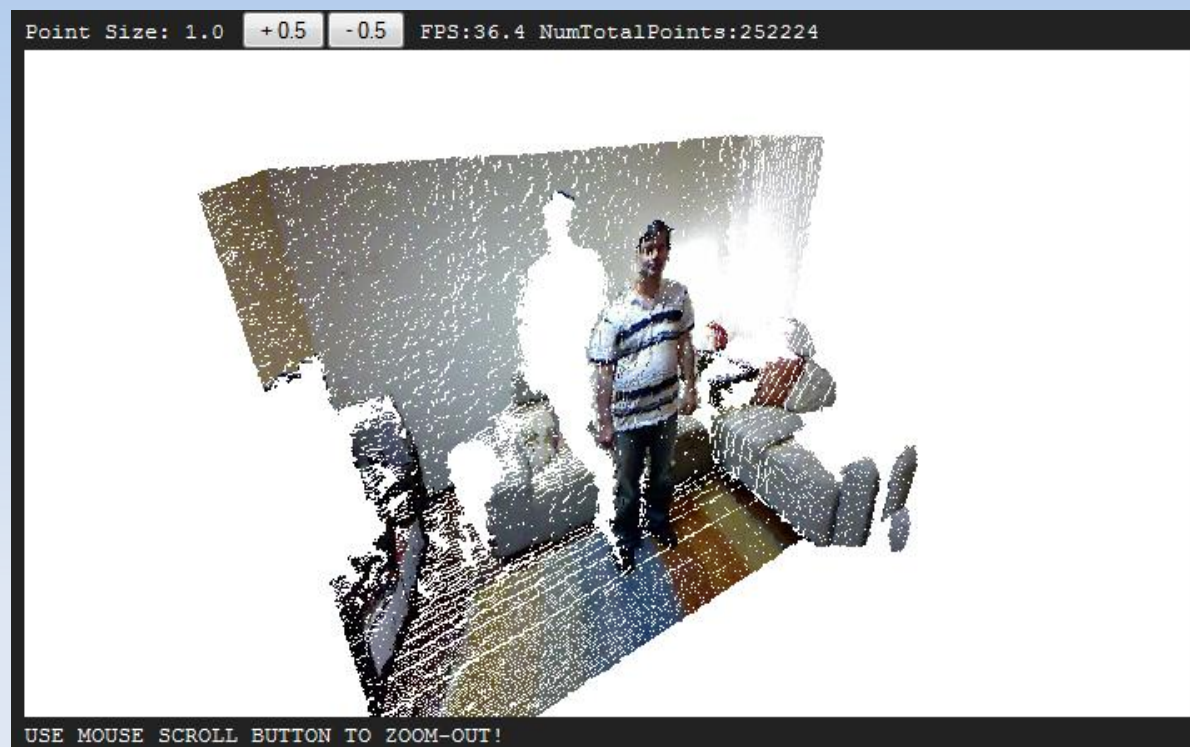
Kinect



[D.Correa]

# Intelligent Robots

## Robots and Sensors: Kinect



<http://www2.icmc.usp.br/~fosorio/webgl/>  
or <http://www.icmc.usp.br/~fosorio/>

# Intelligent Robots



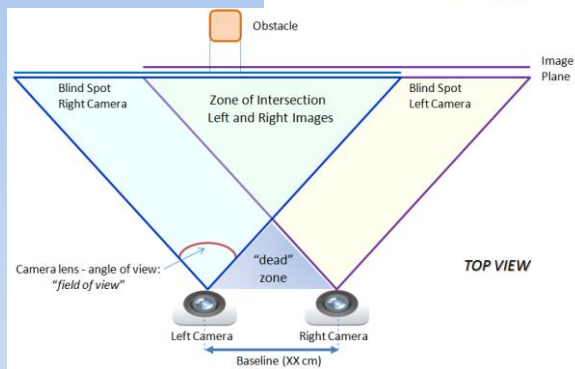
## Robots and Sensors: Stereo Vision



### Stereo Vision

Closer objects  
+ displaced

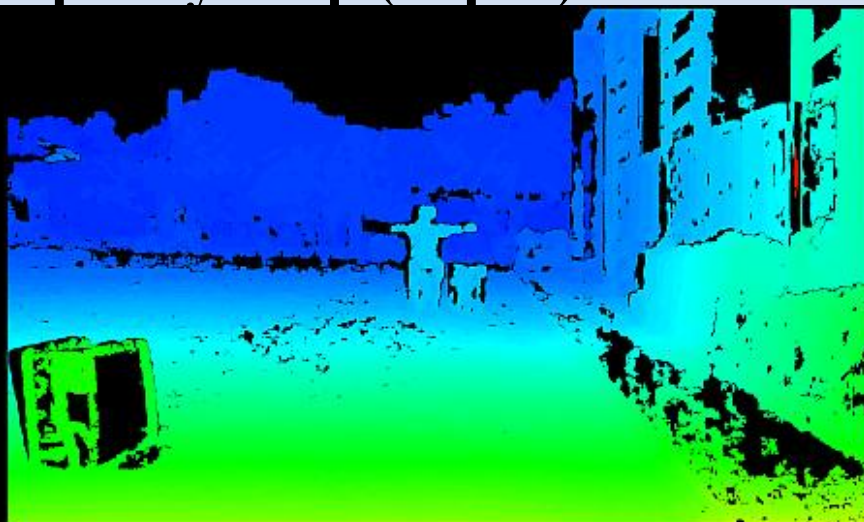
Distant objects  
- displaced



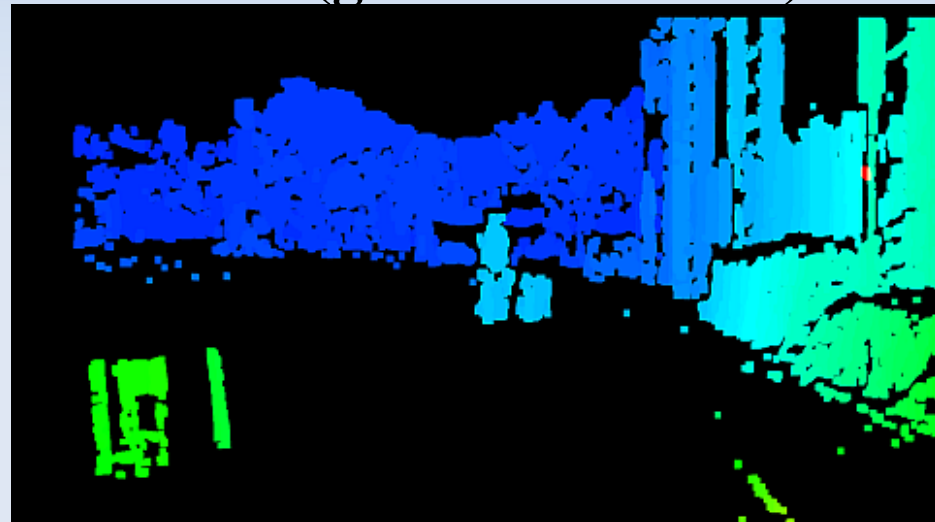
## Original scene



## Disparity Map (depth)



## Obstacles (ground removed)



# Intelligent Robots

## Robots and Sensors: Thermal (FLIR)

### Intrusion Detection

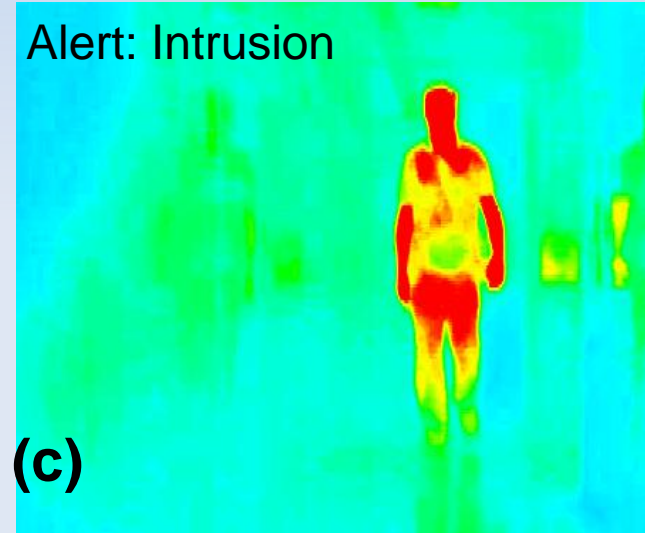
#### Thermal Camera:

(a) Color Image

(b) Thermal Image

(c) Segmentation of “hot spots”

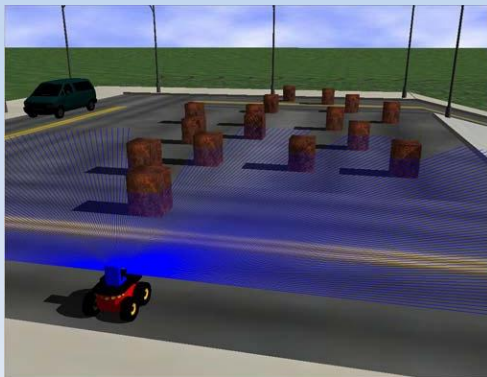
Detection of abnormal situations



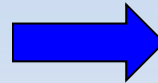
## Research and Development

### Design of Intelligent Robots:

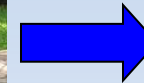
1. Modeling (sensors, actuators, kinematics, dynamics)
2. Virtual Simulation
3. Real Robots Validation



Simulation



Small Robots  
Test / Validation



Large Scale Robots  
Tests / Sw Validation

**TOOLS:** Player-Stage  
Gazebo  
ROS

OpenCV  
Player  
ROS

OpenCV  
ROS  
[Player]



## Why to do it ?



Problems:  
**Drink & Drive!**  
**Sleepiness / Tired!**  
**Sickness!**

- Road traffic injuries are the leading cause of death among young people, aged 15–29 years (WHO 2012).

- In Brazil, number of car accidents: 1,5 million per year, with ~ 35.000 deaths.



Problems: **Age!**  
Difficulties of **elderly people**  
(vision, perception, fast reaction)

- Motorcycles in Brazil: 43 thousand deaths/year. Same as we have 215 big airplane crashes every year in Brazil!



**Handicaped people,**  
Machine and Human Fails,  
Vision problems:  
Occlusion, Fog, Dark, Rain, ...

# Intelligent Vehicles

## Why to do it ?

Lack of Education: Pedestrian / Conductors



# Intelligent Vehicles

## Why to do it ?

Lack of Education: Pedestrian / Conductors



## Autonomous Driving: Challenges!

Line follower

CoRA

Autonomous  
Robots

Competition

[UFMG]

[FAPEMIG]



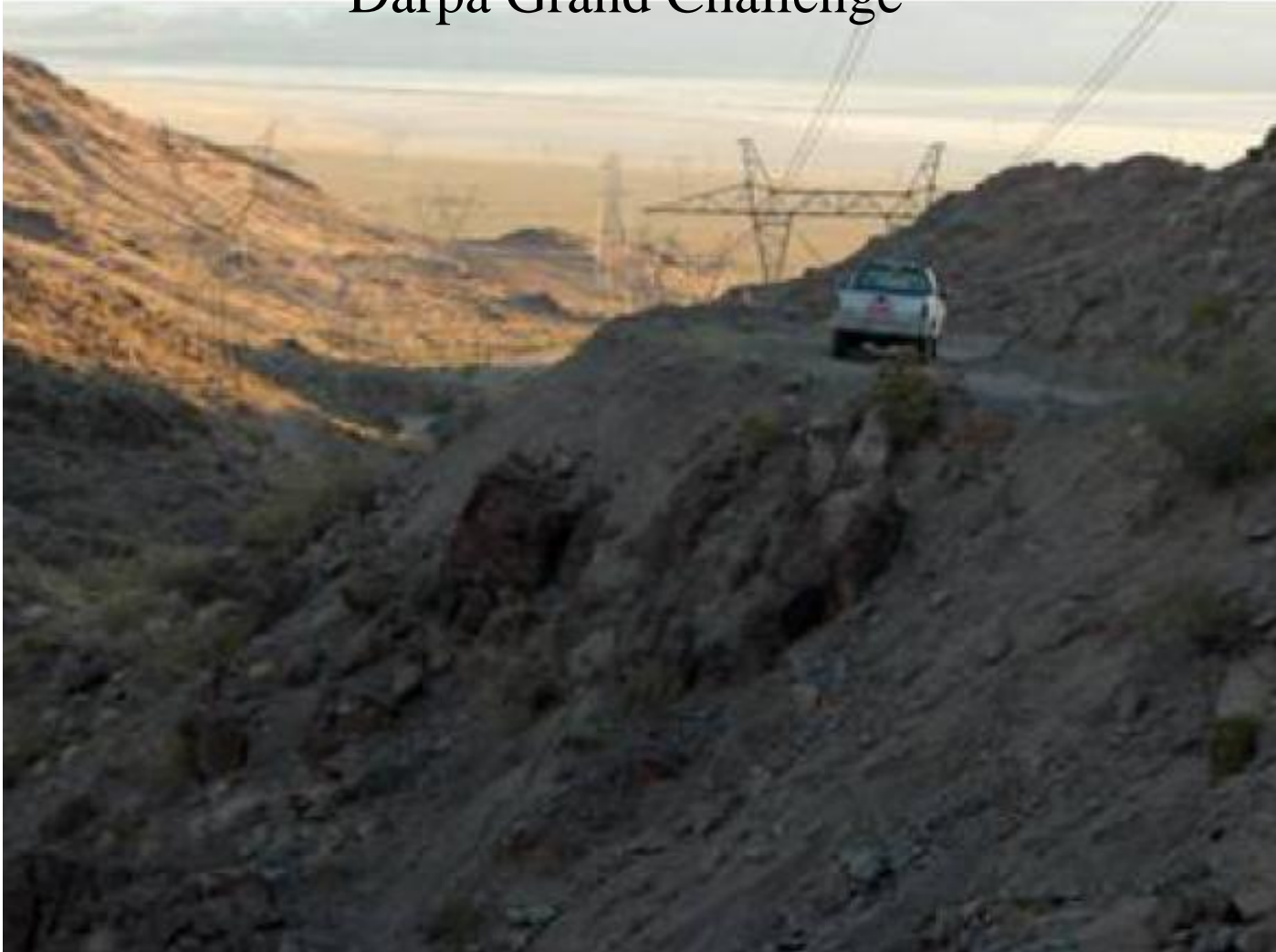
## Autonomous Driving: Challenges!

### COMPETITIONS:

- **DARPA Grand Challenge 2004 (Desert / *No winners*)**
- **DARPA Grand Challenge 2005 (Desert)**  
**Winner: Stanley - Stanford Racing Team (S.Thrun)**
- **DARPA Urban Challenge 2007 (Urbano)**  
**Winner: Boss - CMU (Tartan Racing / Carnegie Mellon University)**
- **ELROB – The European Robot Trial**  
**M-ELROB: Military (2006, 2008, 2010, 2012)**  
**C-ELROB: Civilian (2007, 2009, 2011, 2013)**
- **AUVSI Competition (IGVC - Intelligent Ground Vehicle Competition)**
- **DARPA Robotics Challenge (DRC) 2013/14 – Humanoid Robot Driving a Car**

## Autonomous Driving: Challenges!

Darpa Grand Challenge



## Autonomous Driving: Challenges!

Darpa Grand Challenge  
Waypoint – GPS Coordinates



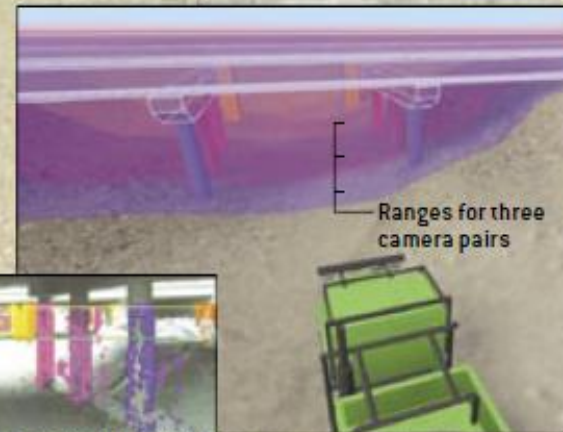
# Intelligent Vehicles

## DARPA Grand Challenge

### VISION LINKED TO SPEED

Smart speed switch, which helped Stanley win the 2005 Grand Challenge, combines laser and video sensors in a four-step process. First, the robot filters its laser data to identify a section of terrain ahead that is smooth and relatively flat (green). Second, a program finds the corresponding patch of road in the video frame sent by the onboard camera (blue outlines). Next, the system highlights all other areas in the same video frame that match that pattern, which it equates with good, drivable road (pink areas). Finally, the software checks whether the matching area completely fills the robot's intended path for the next 130 feet (orange). If it does, then the system concludes that a long stretch of open road lies ahead, and it informs the onboard planning computer that it is safe to step on the gas.

Trinocular Terramax (right) can build a 3-D stereo view of the world from any of three pairs (arrows) of color video cameras. The closest cameras (purple), used at slow speeds, can detect obstacles up to 50 feet away. At fast speeds the robot selects its widest pair (orange), which can pick up objects 65 to 165 feet ahead. The third pair (pink) offers a happy medium.



Video from onboard camera



Laser scan lines

Camera and five laser scanners

Video from onboard camera

Terramax might first detect the pillars of an underpass with its long-range stereo cameras (orange zone above). As the vehicle slows, it will switch to medium- and then short-range camera pairs to make certain it notices all the obstacles in its video scene (inset).



# Intelligent Vehicles

## DARPA Grand Challenge

### Winner – Stanley / Stanford University

**Sebastian Thrun**, Mike Montemerlo, Hendrik Dahlkamp, David Stavens, Andrei Aron, James Diebel, Philip Fong, John Gale, Morgan Halpenny, Gabriel Hoffmann, Kenny Lau, Celia Oakley, Mark Palatucci, Vaughan Pratt, and Pascal Stang, Sven Strohsand, Cedric Dupont, **Stanford Artificial Intelligence Laboratory**- Stanford University - Stanford, California 94305, Lars-Erik Jendrossek, Christian Koelen, Charles Markey, Carlo Rummel, Joe van Niekerk, Eric Jensen, and Philippe Alessandrini **Volkswagen of America, Inc.** - Electronics Research Laboratory - Palo Alto, CA Gary Bradski, Bob Davies, Scott Ettinger, Adrian Kaehler, and Ara Nefian **Intel Research** - 2200 Mission College Boulevard, Santa Clara, California 95052, Pamela Mahoney ...



## Autonomous Vehicles – Urban Spaces

DARPA Urban Challenge

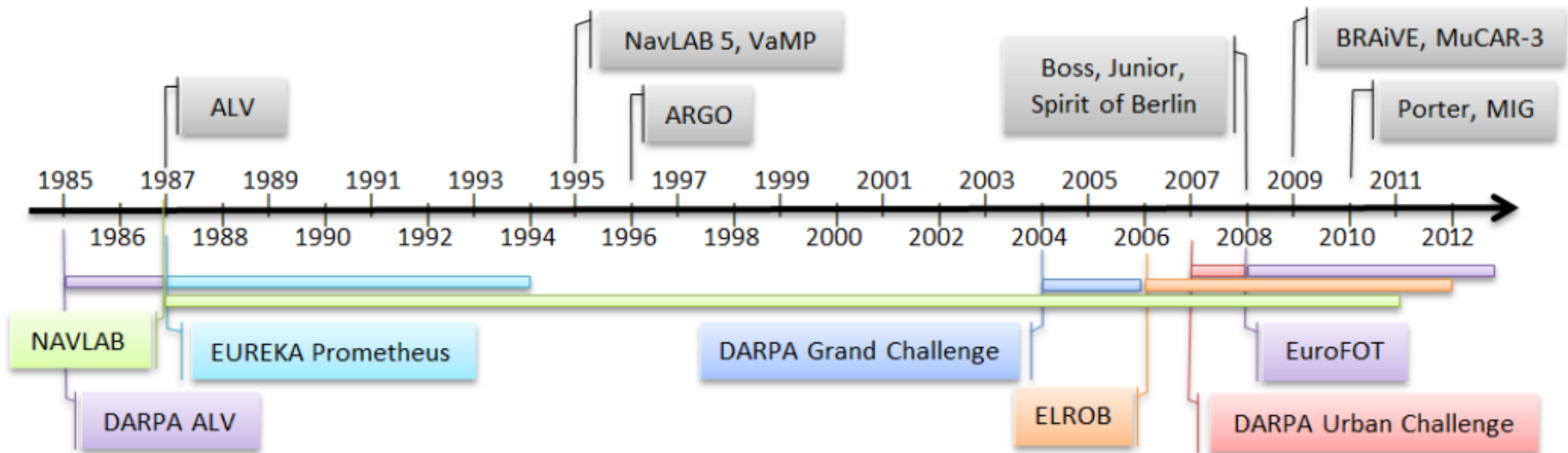
Boss, the autonomous Chevy Tahoe that won the 2007 DARPA Urban Challenge

Tartan Racing – CMU Carnegie Mellon University

Pittsburgh, Pennsylvania



## The quest for Autonomous Vehicles



### LRM Laboratory :)

2009: INCT-SEC was created and start its activities

2010: April / Acquisition of our 1st vehicle (Electric Car) Club Car CarryAll **CaRINA 1**

2010: October / Autonomous Driving on Campus 2 using CaRINA 1

2011: July / Acquisition of our 2nd vehicle - Fiat Palio Adventure - **CaRINA 2**

2012: September / CaRINA 2 at USP/SC Campus 2 - **Fully autonomous!**

## State of the Art

- Reference Challenges:
  - DARPA Urban Challenge
  - Elrob
- Projects:
  - Boss, Junior e Spirit of Berlin
  - MIG e MuCAR-3
  - BRAiVE e Porter
  - Google Autonomous Car



## State of the Art



# Intelligent Vehicles

## State of the Art



# Intelligent Vehicles

## State of the Art



## Brazilian Initiatives

### **Automated Vehicles: Assisted conduction, Drive-by-wire**

- **GPVA** – Grupo de Pesquisa em Veículos Autônomos / RS  
Automated Baja Buggy, drive-by-wire e sist. de visão - 2002/2008
- **USP SC** – EESC/ICMC - Projeto SENA (Fiat Stilo instrumented w/sensors)  
Sistema Embarcados para Navegação Autônoma 2008/2011
- **UNIFEI /MG** - Grupo de Automação e Tecnologia da Informação / UFJF  
Projeto Driving4u - Chevrolet Zafira 2008/2011

### **Autonomous Vehicles: Perception e Actuation**

- **UFMG DEE** – R&D Group: Veículos Autônomos (PDVA) - GM Astra  
CADU Carro Autônomo Desenvolvido na UFMG – final 2007/2012
- **CTI CenPRA** - DRVC Divisão de Robótica e Visão Computacional - “Freedom”  
Projeto VERO - Veículo Robótico Terrestre de Exterior – 2008/2012
- **USP SC** – ICMC / LRM – Projeto CaRINA I e II - Club Car, Palio Adventure  
Carro Robótico Inteligente para Navegação Autônoma – 2010/2012
- **UFES**: LCAD carro adquirido em Setembro/2012- TorcRobotics Bywire-XGV



## Brazilian Initiatives



### Autonomous Vehicles:

- **GPVA** –Baja Buggy - 2002/2008
- **USP SC- SENA** – Fiat Stilo - 2008/2011
- **UNIFEI /MG** - Projeto Driving4u  
Chevrolet Zafira 2008/2011



## Brazilian Initiatives

### Autonomous Vehicles:

- **UFMG DEE** - GM Astra - CADU 2007/2012
- **CTI CenPRA** - DRVC - Freedom Elétrico VERO - 2008/2012
- **USP SC** – ICMC / LRM – Club Car CarryAll CaRINA I - 2010/2012



## Brazilian Initiative @ USP São Carlos



Laboratório de Robótica Móvel  
ICMC/USP - São Carlos



**CARINA**

Carro Robótico Inteligente para Navegação Autônoma

### Experimental Platforms



**CARINA 1**  
(may 2010)



**CARINA 2**  
(july 2011)

## CaRINA Platform

- Carryall 232 (Original Platform from: Clubcar)
  - Electric Powered: 10 HP
  - Battery Source: 48V (8 x 12V)
  - Velocities up to 30 Km/h
  - Transportation utility car (up to 360Kg)
- Perception:
  - Lasers SICK (front), Hokuyo (back)
  - Monocular and Stereo Camera
  - GPS, Compass, IMU and odometry
- Actuators: RoboteQ + Microcontroller
  - Steering Wheel (+ encoders)
  - Speed Control (“gas pedal”) / Breaking System



# Project CaRINA I : R&D



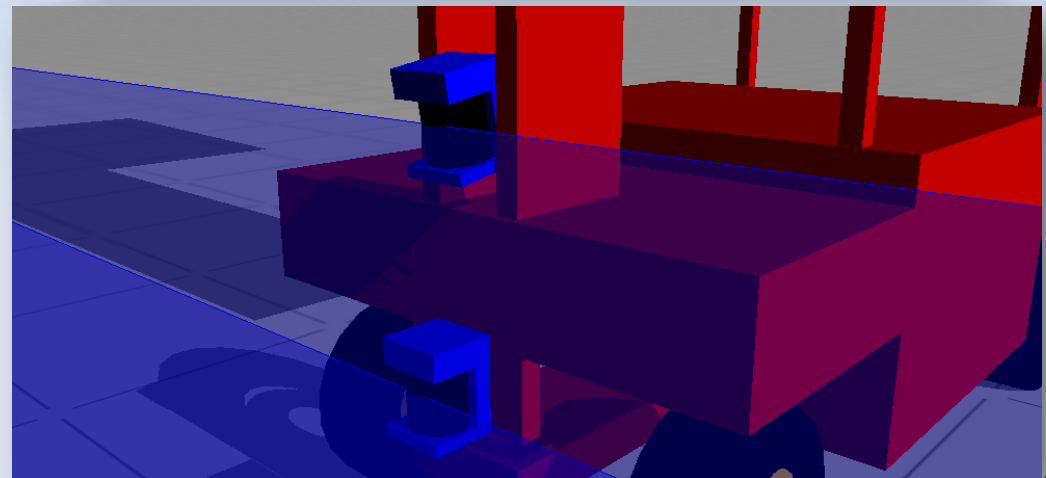
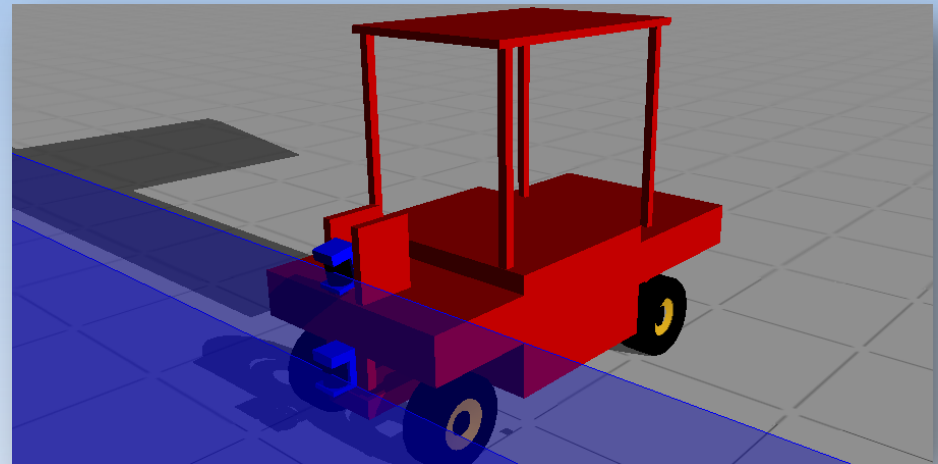
## Perception



# Project CaRINA I : R&D



CaRINA 1



## Computational Model

### CaRINA I

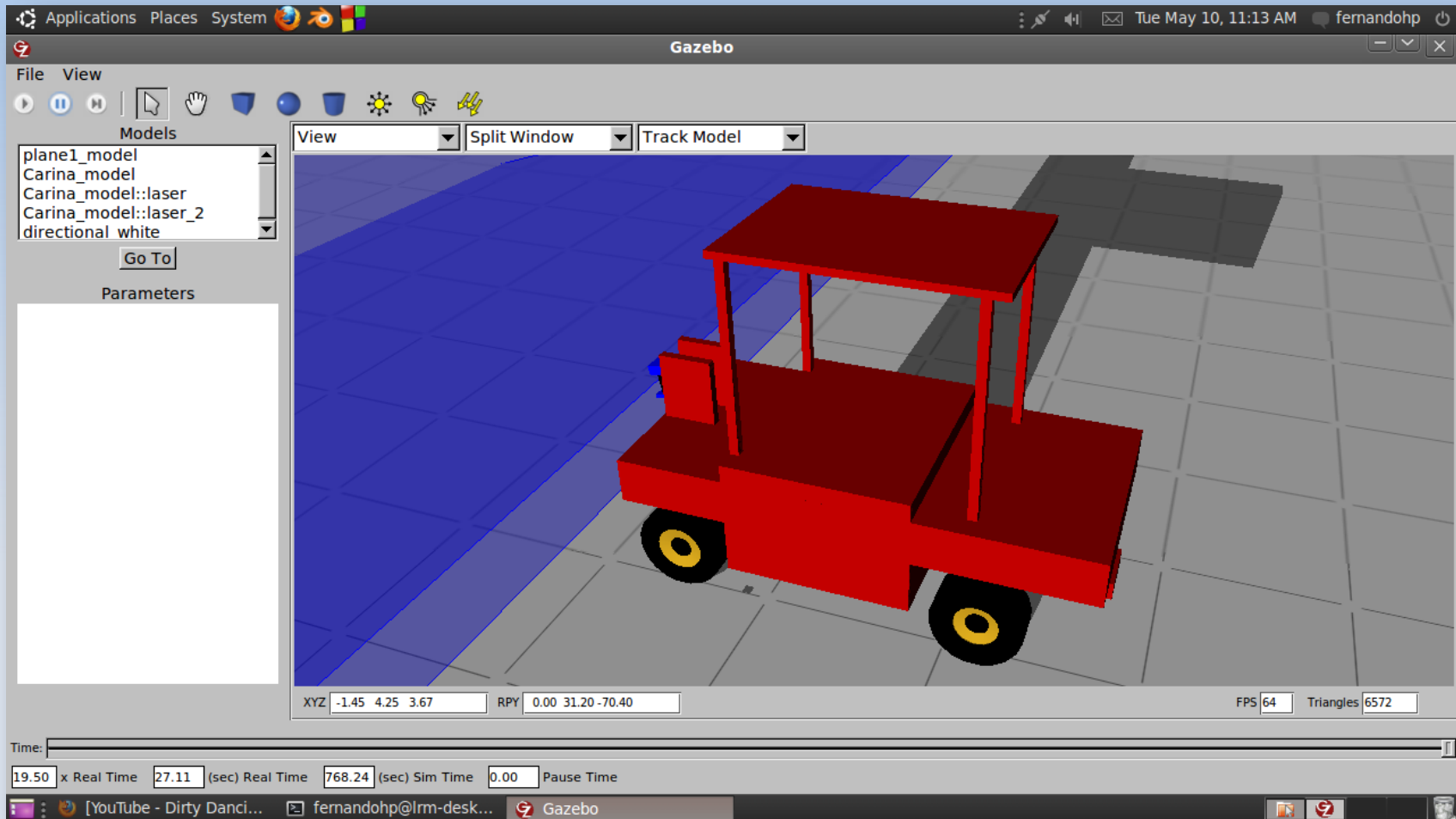




# Project CaRINA I: R&D

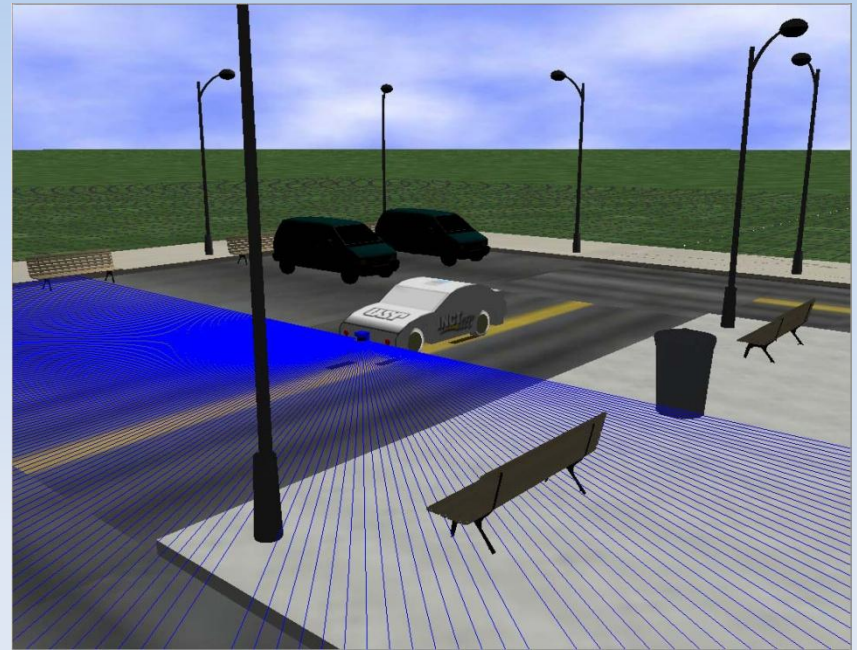
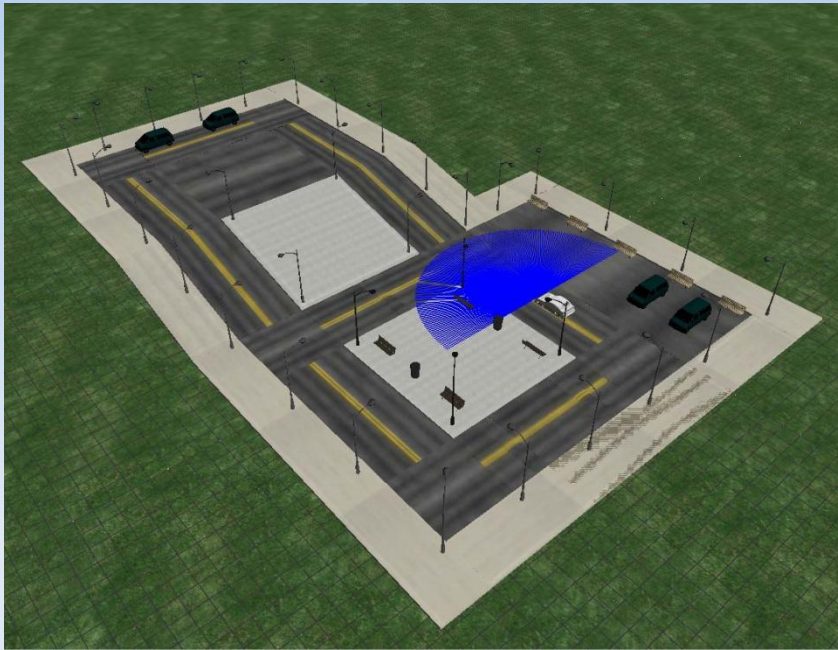


## Gazebo



# Autonomous Vehicles Simulation

## 3D Simulation Tool: Gazebo



# Project CaRINA I: R&D

## SENSORS



(a) Laser Sick  
LMS 2xx



(b) Video Camera



(c) Inertia Unit  
IMU - MicroStrain



(d) Laser Hokuyo  
URG-04LX



(i) Kinect (Microsoft Xbox)  
Indoor only (or at night)



(e) STOC Video Camera  
Stereo-on-a-Chip



(f) Thermal Camera  
FLIR PathFindIR



(g) Compass Module  
HMC6352



(h) Sonar Module  
Maxbotix LV-EZ0



(j) GPS Garmin  
(Outdoor only)



Velodyne HDL-32E



PointGray LadyBug 2



PointGray Bumblebee 2



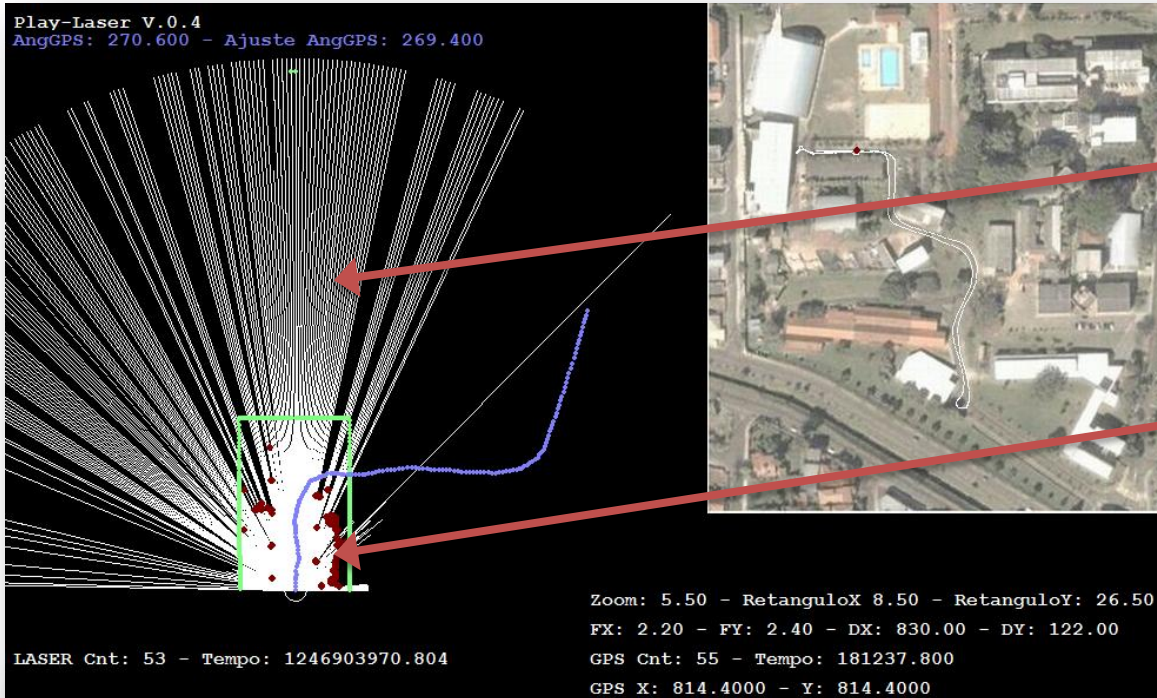
Xsens Mti-G



Laser Hokuyo  
URG-30LX

# Project CaRINA I: R&D

## SENSORS



Laser Beams

Laser: Real Data

Obstacles



<http://en.wikipedia.org/wiki/Lidar>

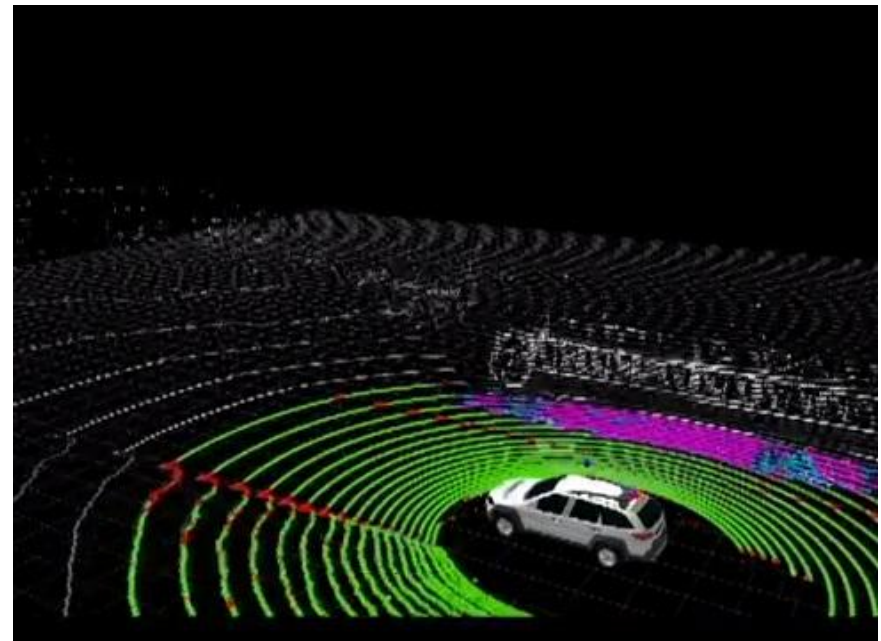
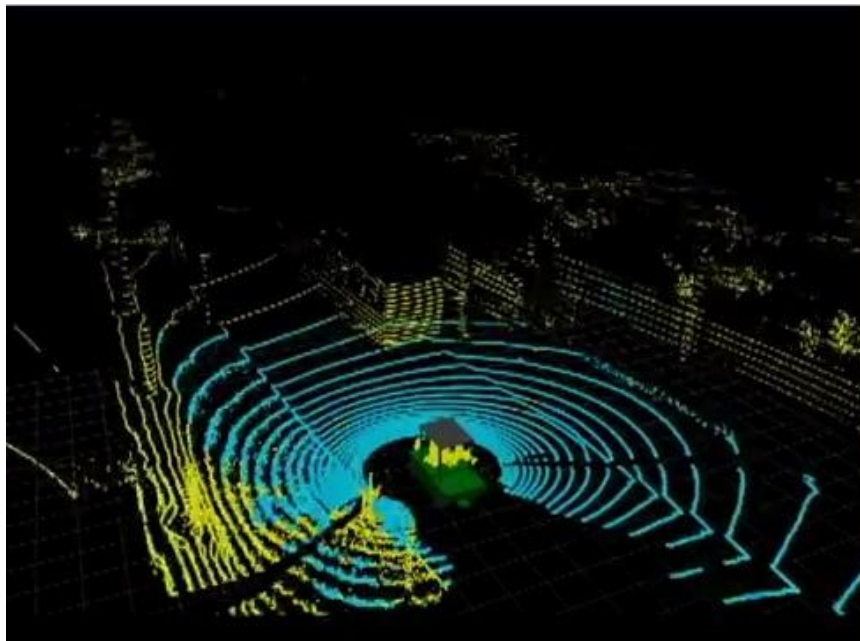
## SENSORS

### Laser Velodyne HDL 32

32 Laser beams – Max distance.: 100 mts – Max speed: 10 Hz

Wide view of 360° degrees – Precision > 0.5 cm

3D Cloud of Points - 70.000 xyz points x 10 Hz = 700.000 points / sec

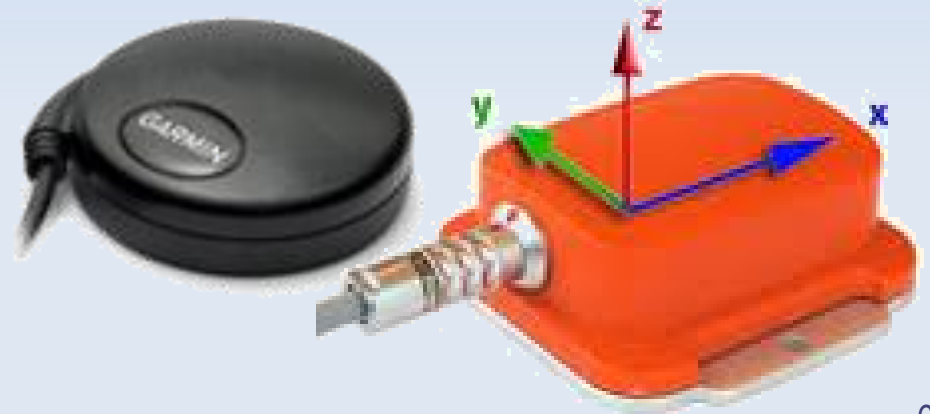
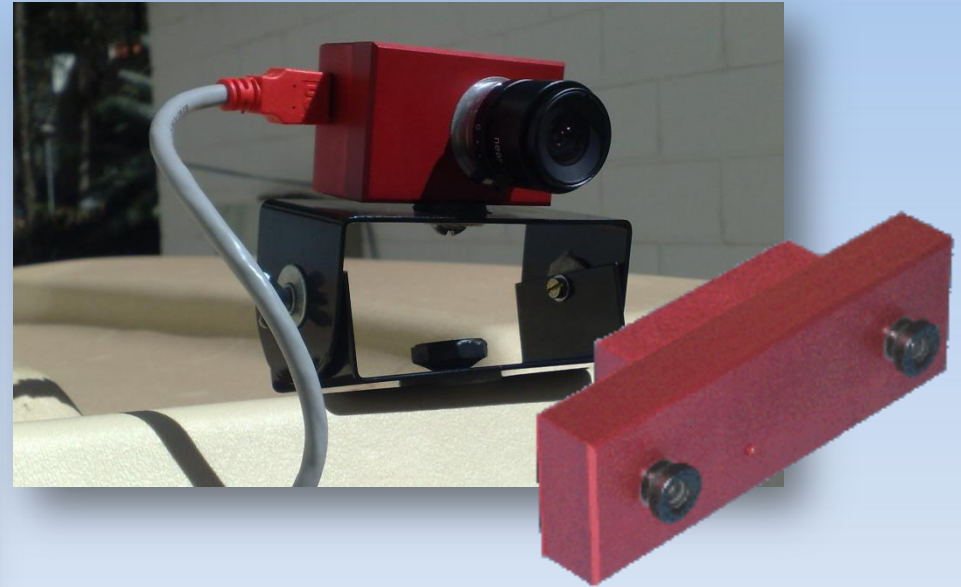


Sensores que permitem obter “Nuvens de Pontos 3D” (Cloud of Points):  
Velodyne, Câmera de Vídeo Estéreo (PointGray Bumblebee), Kinect XBox  
Sensor laser tipo Sick de feixe único + Deslocamento (composição)

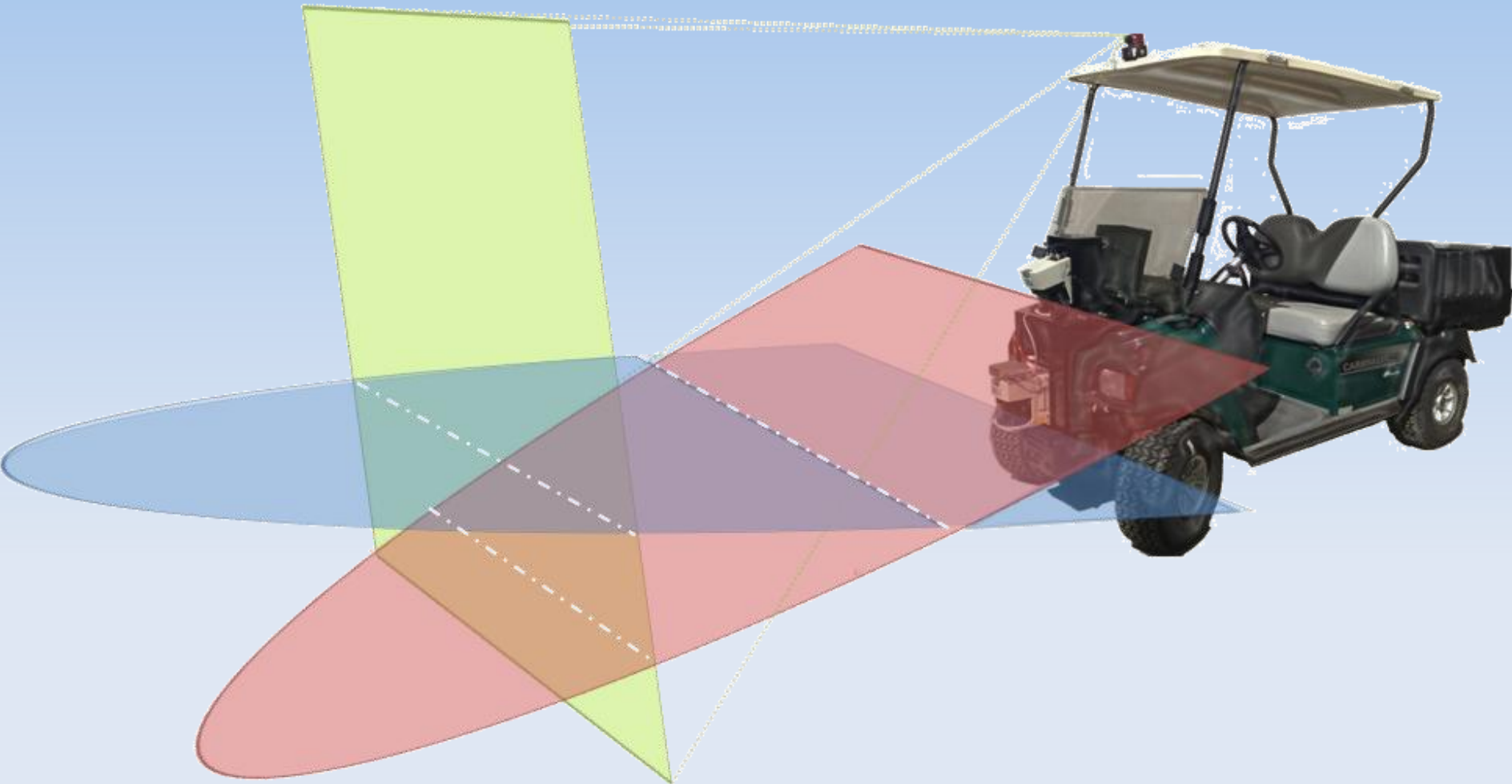
## Perception Systems



## Perception Systems

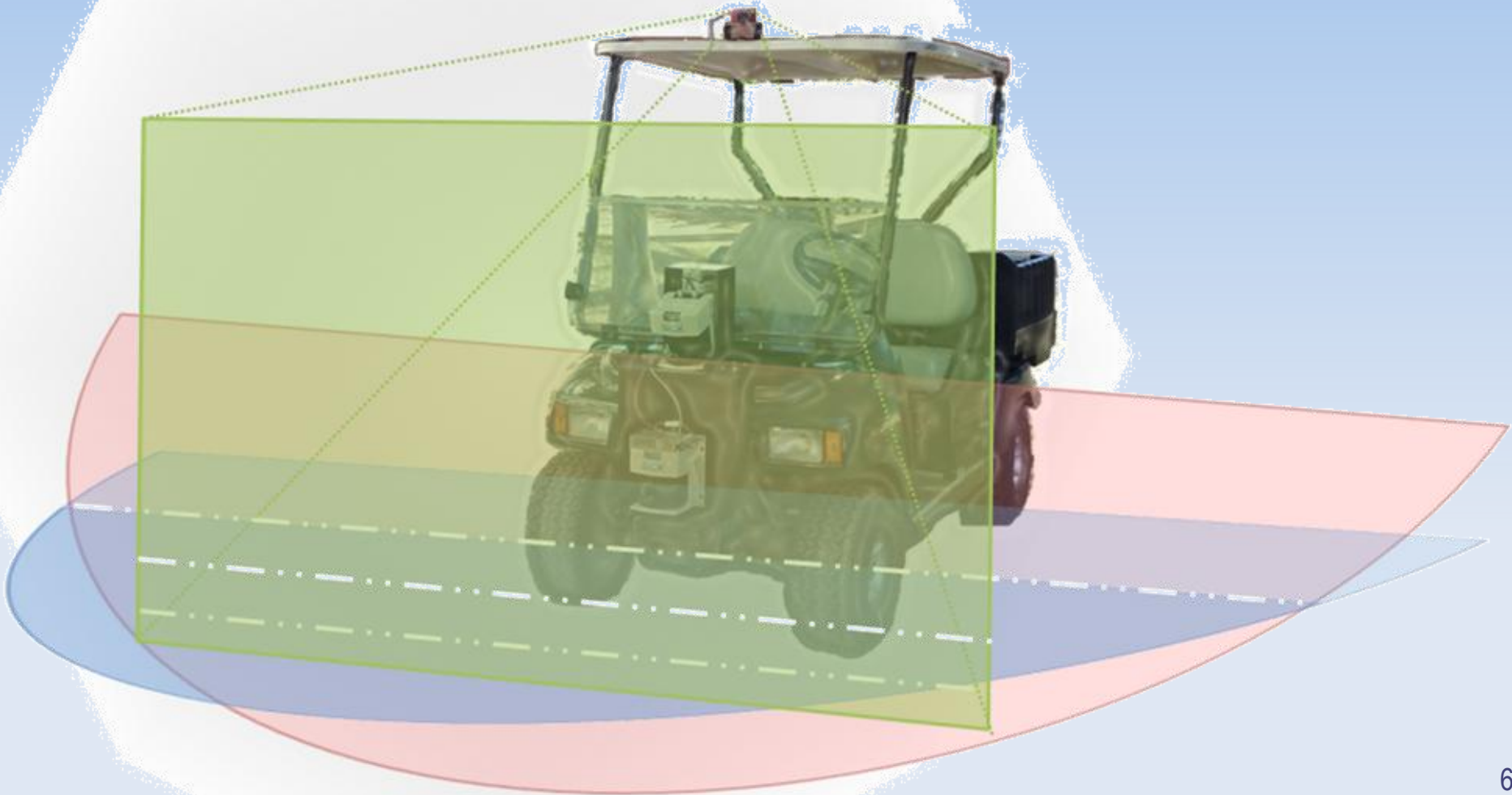


## CaRINA I – Perception

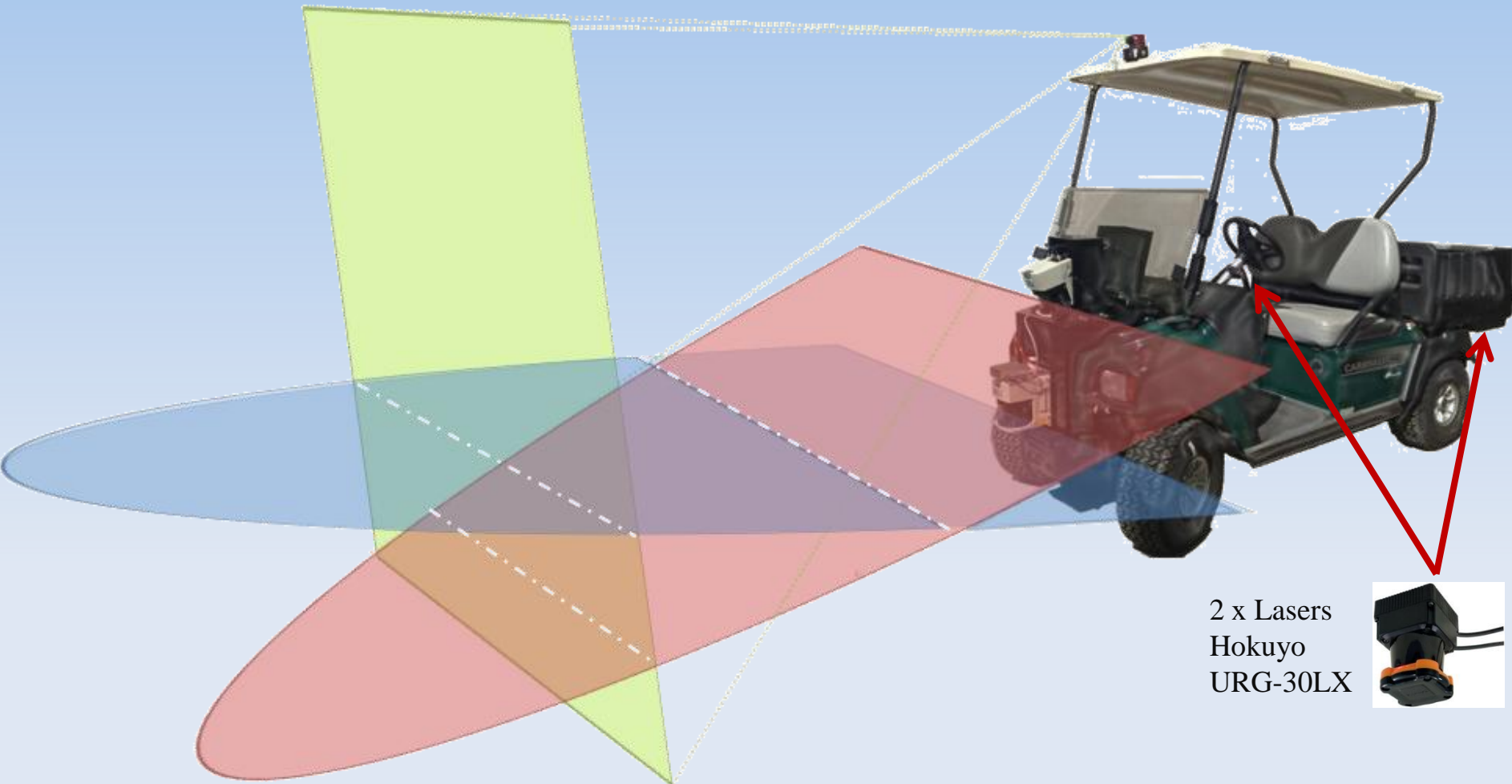




## CaRINA I – Perception



## CaRINA I – Perception

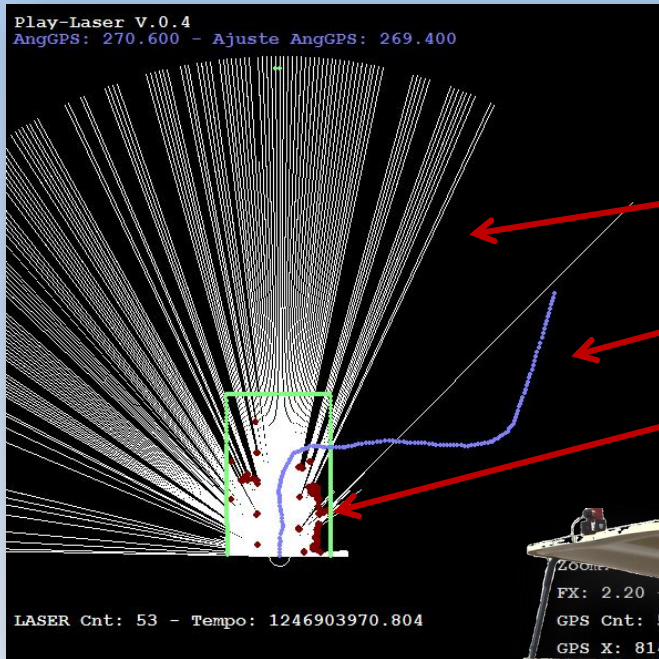


## Main Results

<http://www.lrm.icmc.usp.br/wiki/index.php/Publications>

- **Motor Control: Steering Control, Speed Control, Breaking System**
- **Software Integration into CaRINA I: Player, Stage e Gazebo + ROS (more recently)**
- **Computer Assisted Driving**
  - Intelligent obstacle detection (remove false positives)
- **Navigable and Safe Region Classification and Detection**
  - Image processing using single (monocular) cameras and stereo cameras
  - Laser: lane detection, borders of sidewalk, turns, crossings
- **Navigation and Obstacle Detection**
  - Using vision to navigate and to avoid obstacles (navigable region, templates)
- **Mapping and Representation of Environment Models**
  - Mapping the environment using laser and vision systems
- **Finite State Machine (FSM) based Navigation**
  - Detecting situations (context) and taking actions
- **Application into Agricultural Environments**
  - Autonomous pesticide spraying machines
- **Tele-operation (i-CaRINA)**

## Fusion of Sensors: Laser + GPS + Compass



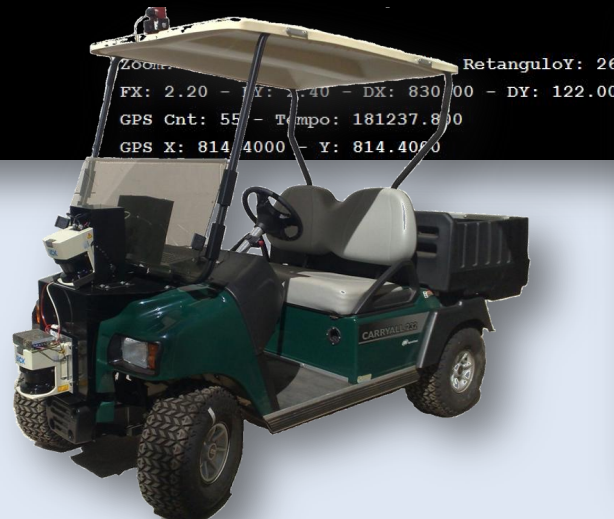
Vehicle localization

Actual Laser Data

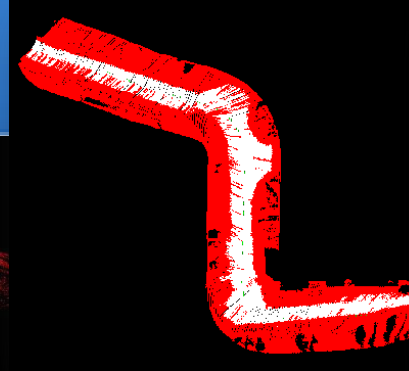
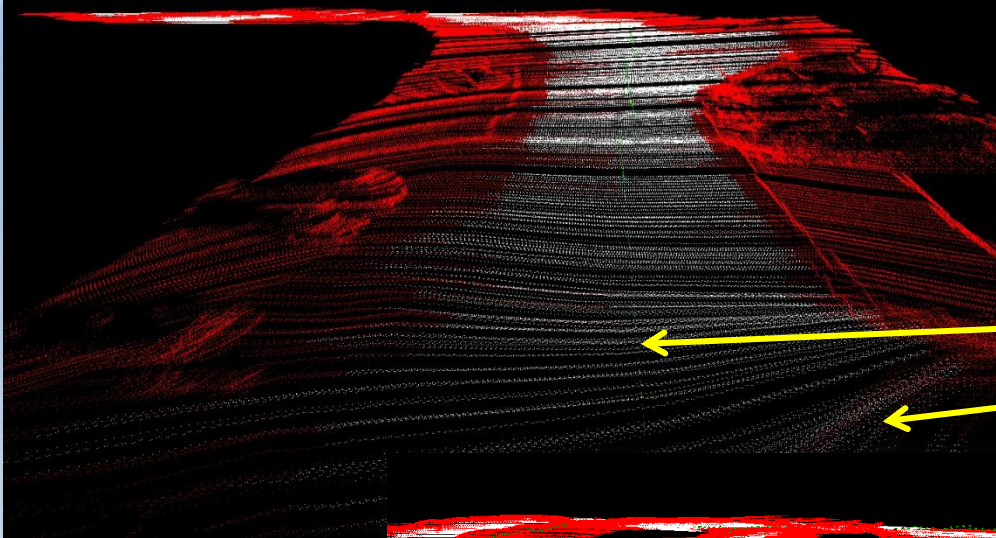
Planned Path

Detected Obstacles

Camera Image



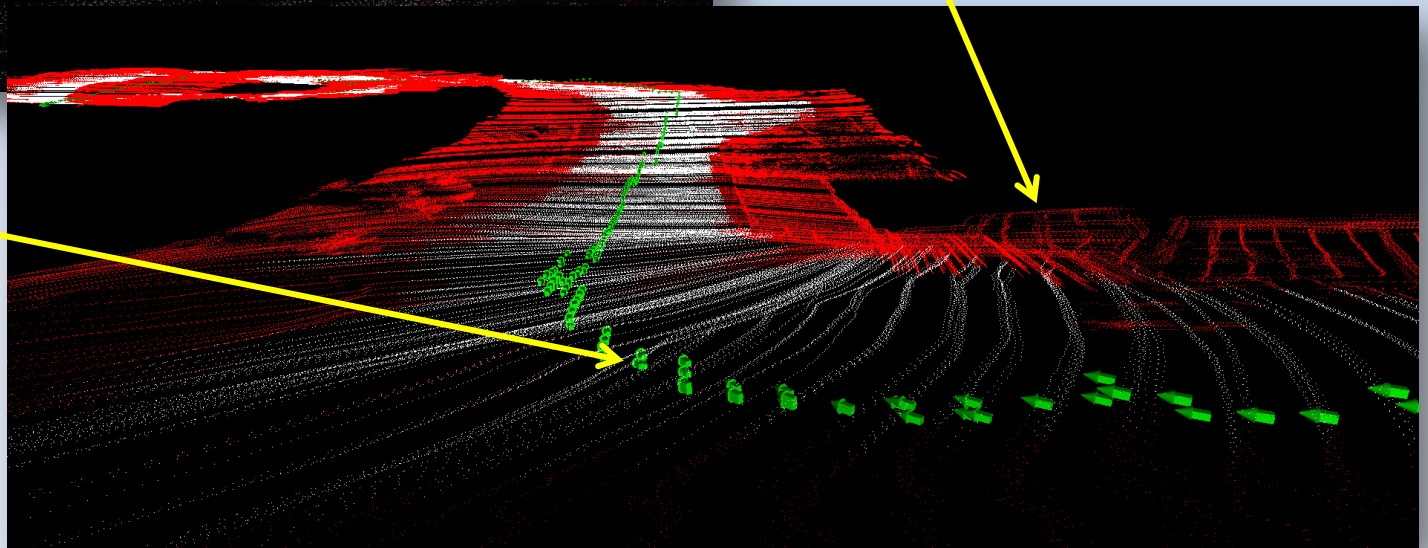
## 3D Reconstruction



Vehicle Position  
Laser Data

3D Pose  
(Position and  
Orientation)

Integration:  
Laser\_2D +  
GPS + IMU + KF



# Terrain Mapping and Reconstruction (laser)

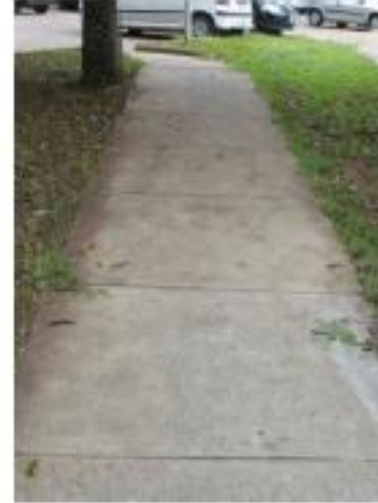
[Alberto Hata]



(a) Cenário I



(b) Cenário II



(c) Cenário III



(d) Cenário IV

# Terrain Mapping and Reconstruction (laser)

[Alberto Hata]



(a) Cenário I

(b) Cenário II

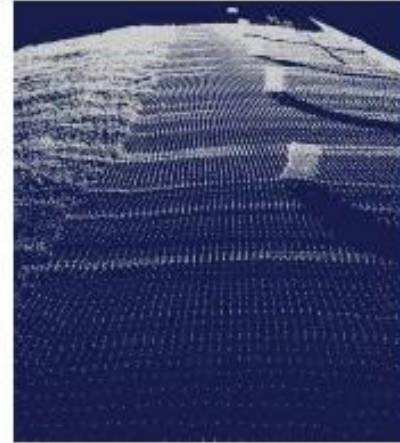
(c) Cenário III



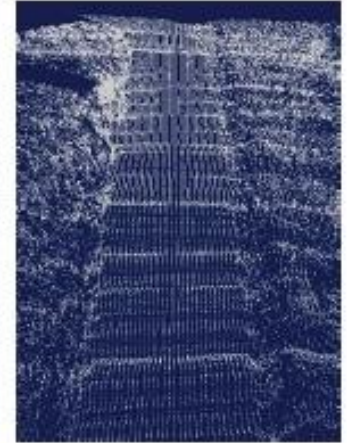
(d) Cenário IV



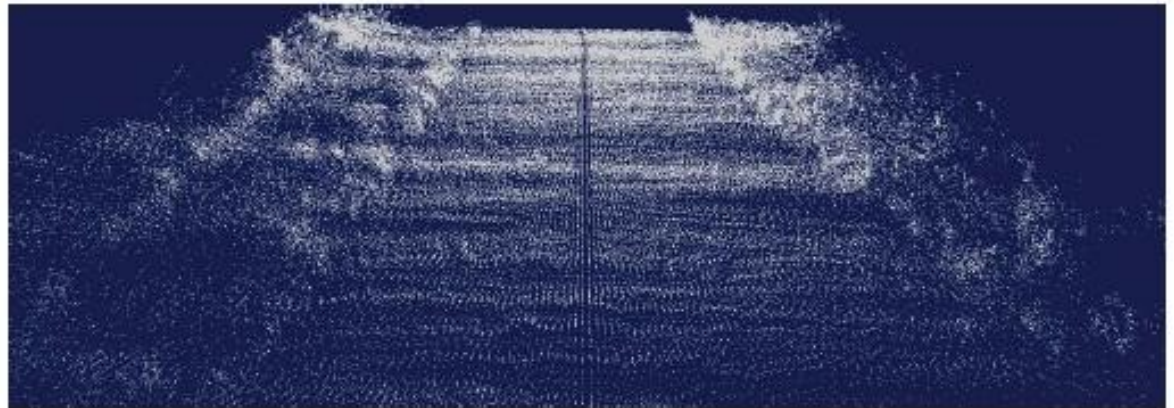
(a) Mapa I



(b) Mapa II



(c) Mapa III



(d) Mapa IV

# Terrain Classification – Safe/Unsafe (laser)

[Alberto Hata]



(a) Cenário I



(b) Cenário II



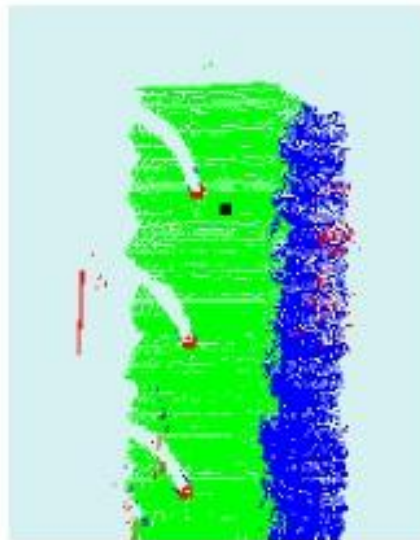
(c) Cenário III



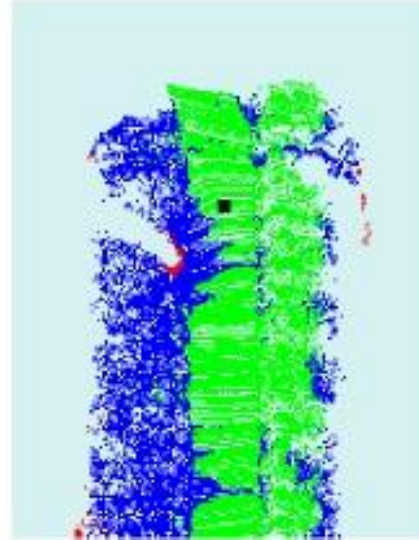
(d) Cenário IV



(a) Cenário I



(b) Cenário II



(c) Cenário III



(d) Cenário IV

Classification: Navigable x Non Navigable



## Where is safe?



**Computational  
Vision**



## Where is safe?

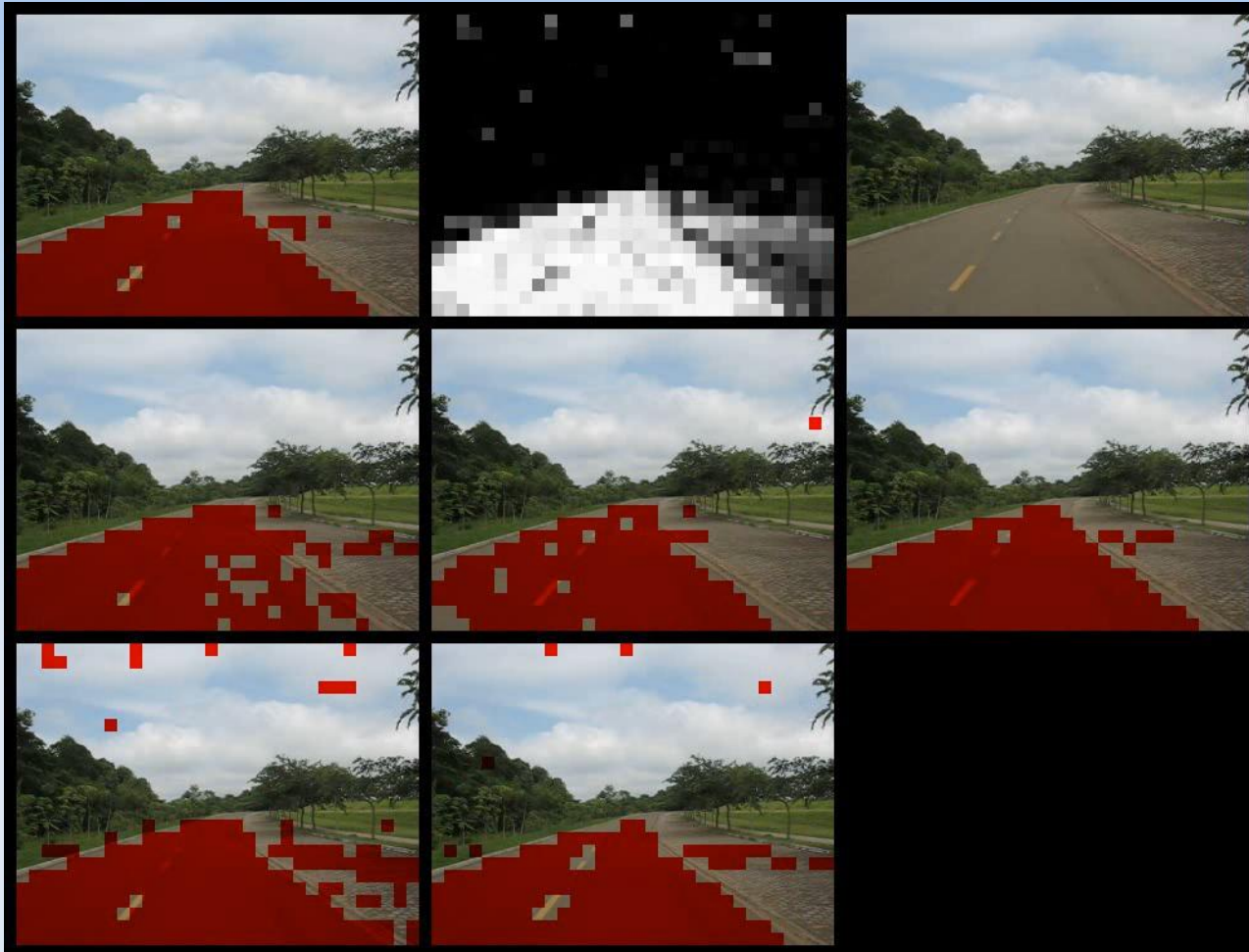


**Computational  
Vision**



## Vision based Navigation

[Patrick Shinzato]



# Project CaRINA I : R&D



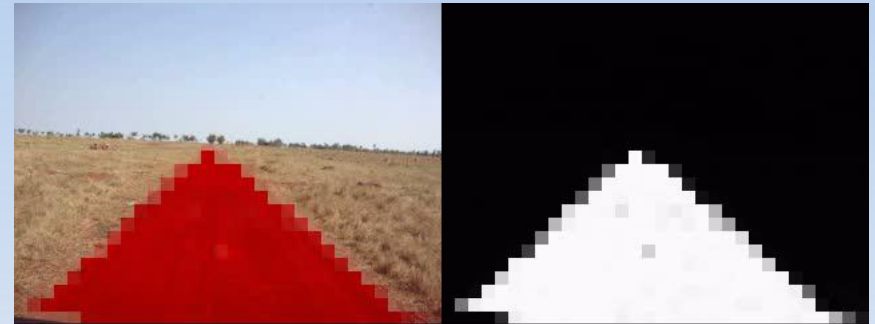
## Computational Vision

[Patrick Shinzato]

Urban Space



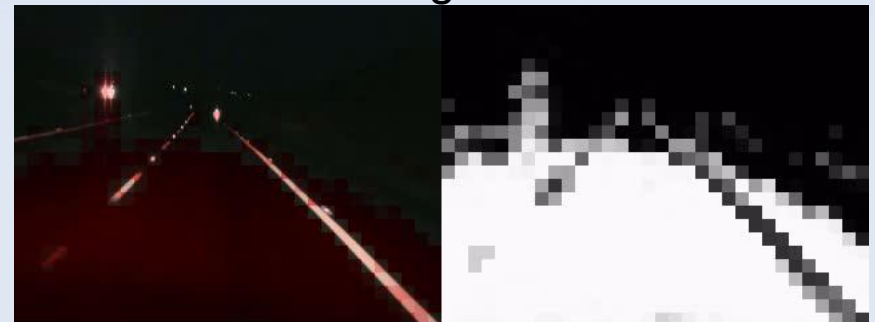
Country Space



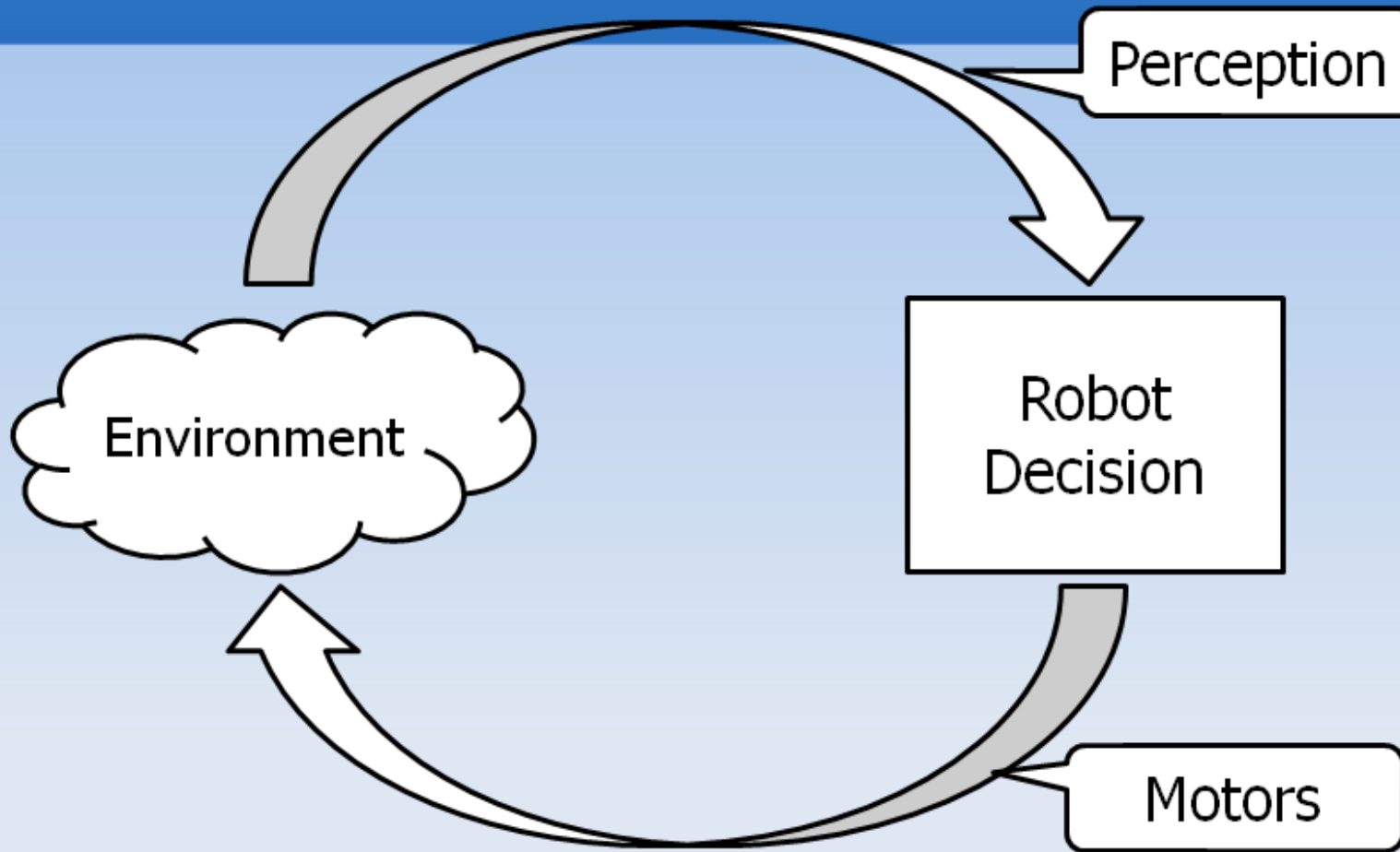
Rain

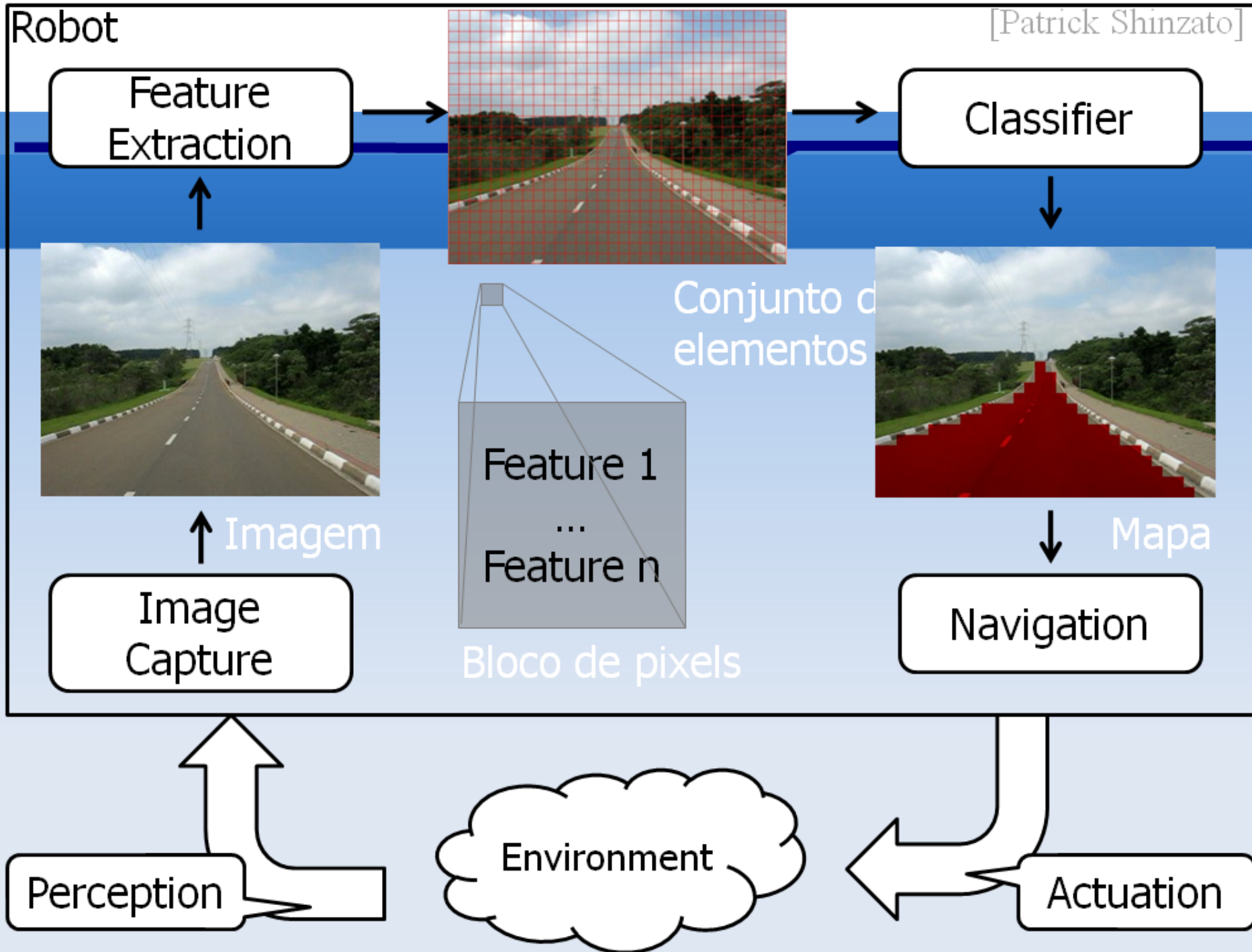


Night



# Methodology





## Autonomous Navigation

### Autonomous Navigation based on Computational Vision



October 2010



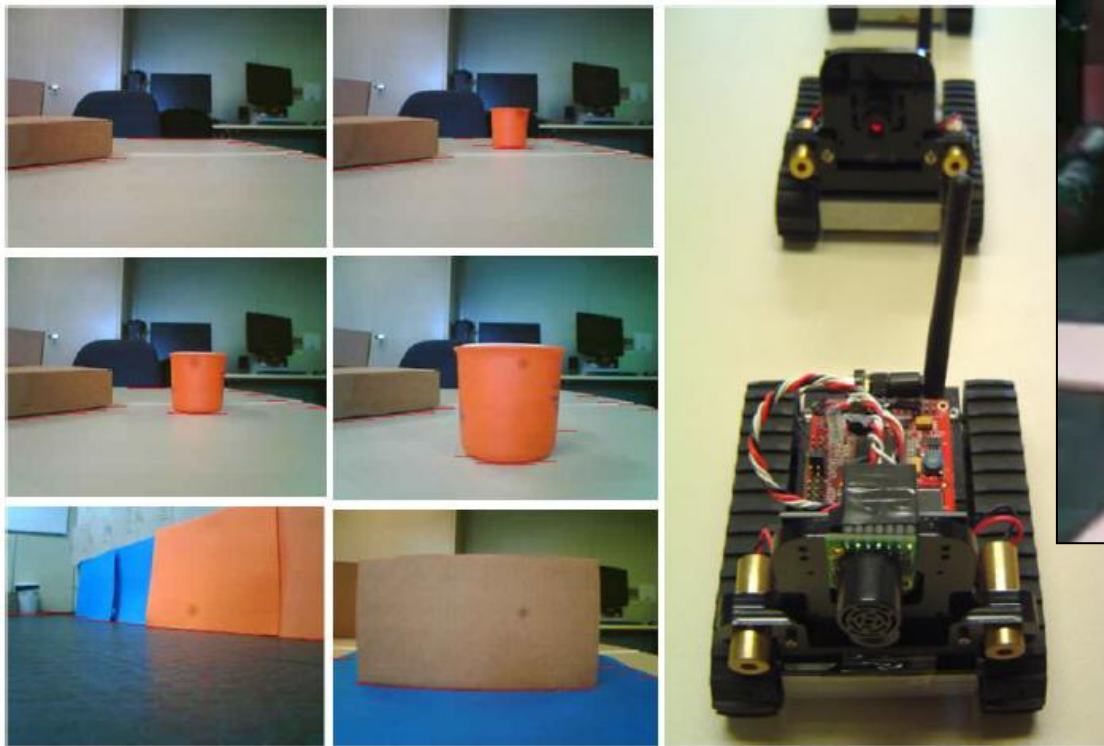
November 2010

<http://youtube.com/lrmicmc>

[Jefferson Souza, Daniel Sales, Gustavo Pessin, Patrick Shinzato]

## Autonomous Navigation

Using also small INDOOR robots...



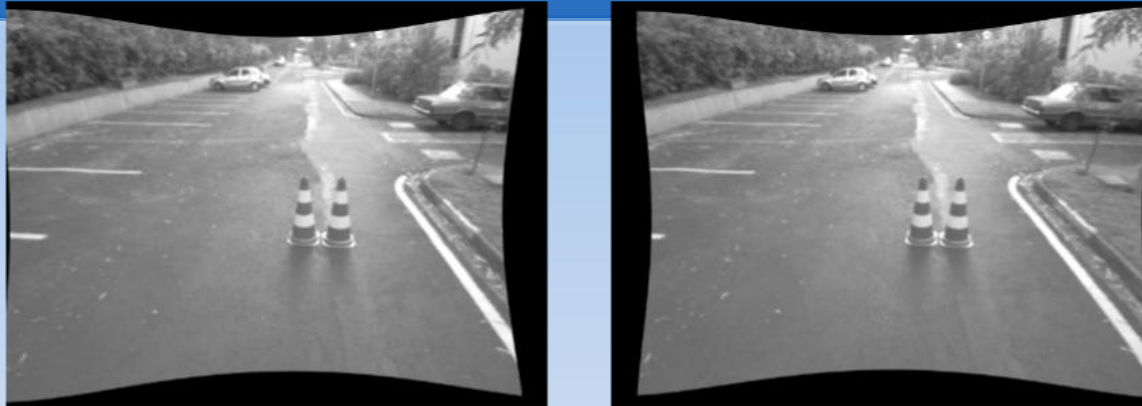
[Daniel Sales]



# Project CaRINA I : R&D

## Autonomous Navigation based on Stereo Vision

[Caio Mendes]



Método  
Semi-Global



Plano



VFH



Mapa de Disparidades

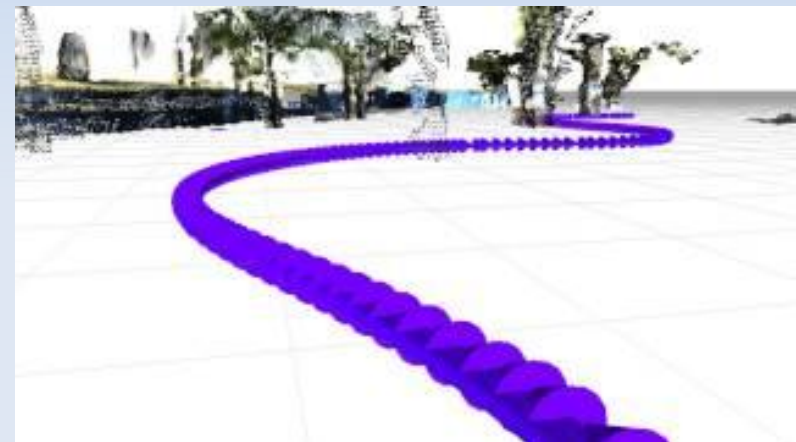
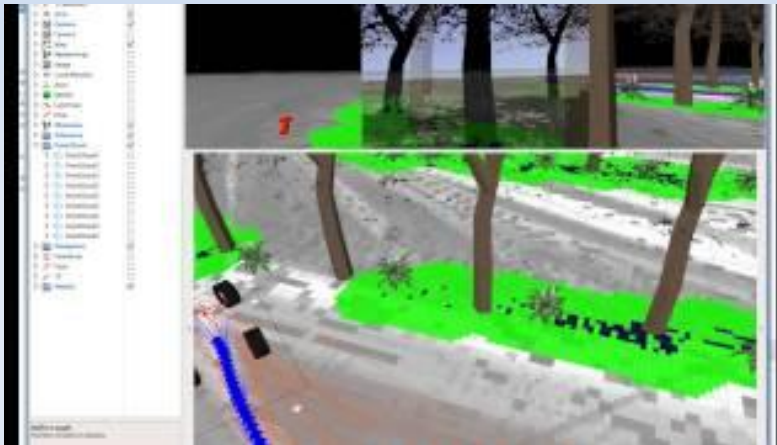
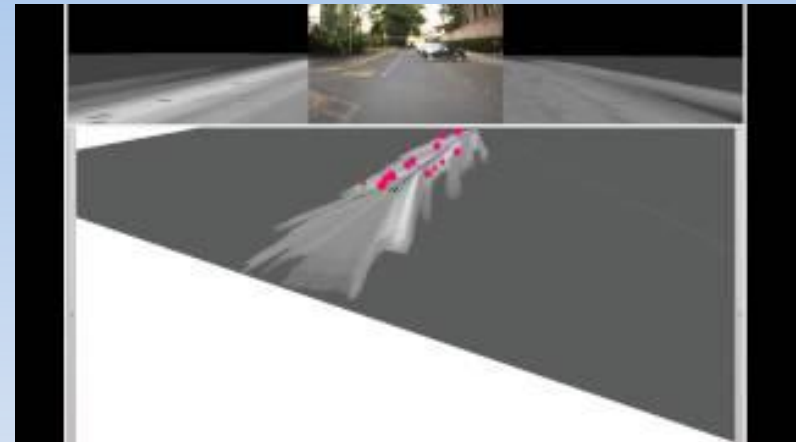
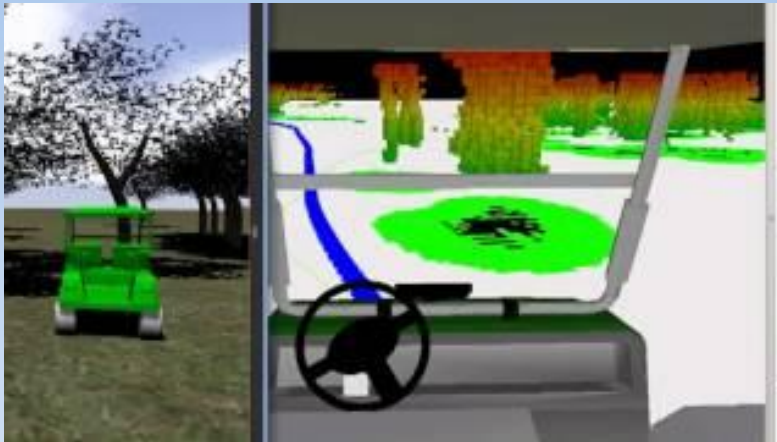
Mapa de Navegabilidade

Histograma Polar

# Project CaRINA I : R&D

## Autonomous Navigation based on Stereo Vision

[Rafael Klaser]



## Autonomous Navigation



October 2011:

Total path: 1,08 km

Autonomous Control Mode

## Autonomous Driving: Challenges!

Line follower

CoRA

Autonomous  
Robots

Competition

[UFMG]

[FAPEMIG]

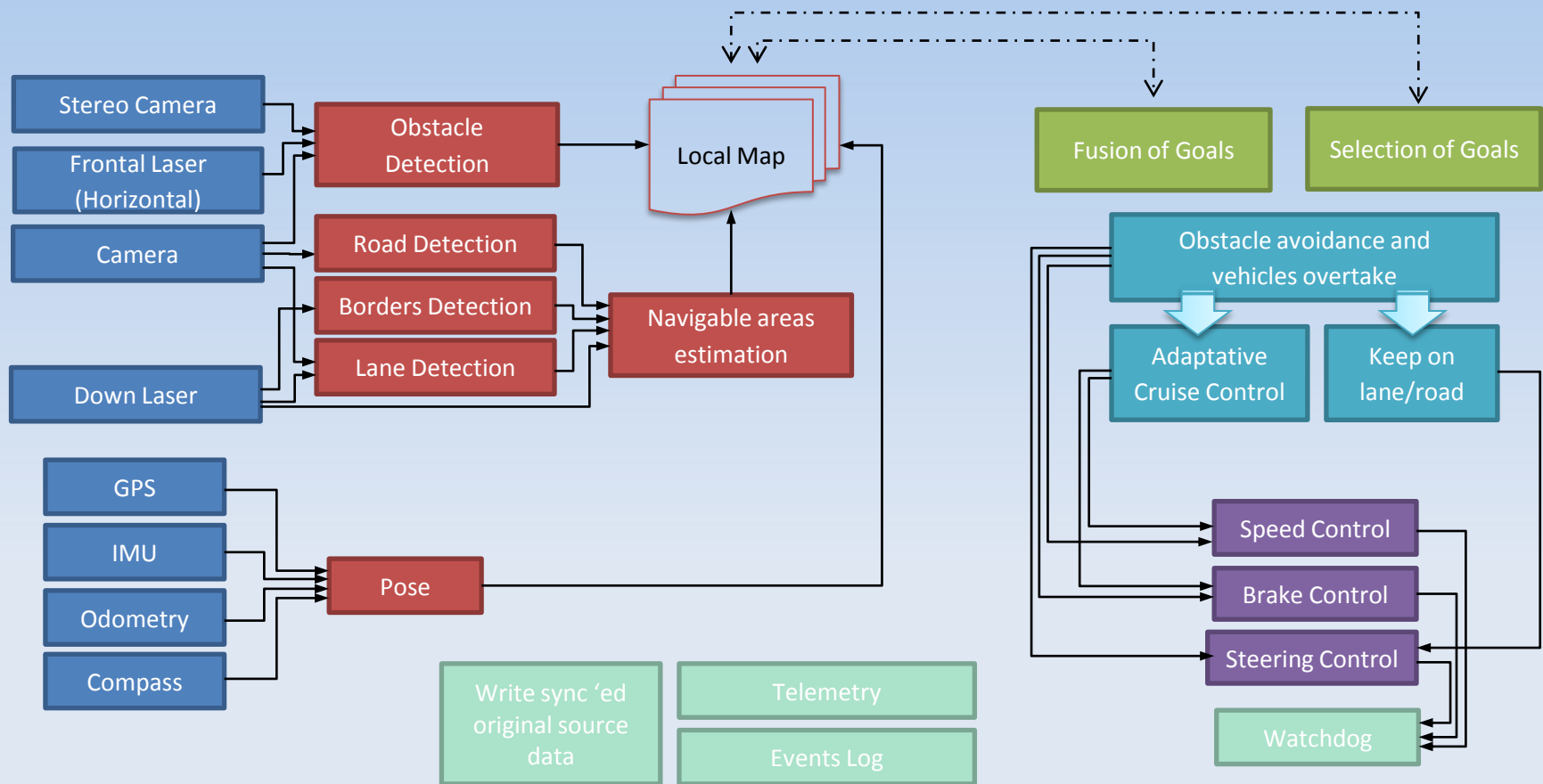
+ ADD +

Perception!!!

(obstacle detection,  
obstacle avoidance)



## Control Architecture Design



# Project CaRINA I and II : R&D



## Software

### TOOLS:

Player-Stage (Old)



GAZEBO

**Gazebo** – Gazebosim Robot Simulator

**ROS** – Robot Operating System



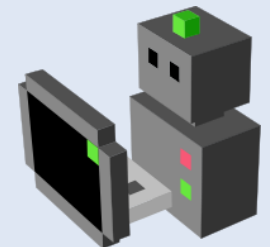
**OpenCV** – Open Source Computer Vision Library



**PCL** – Point Cloud Library



**Morse** - Modular OpenRobots Simulation Engine



Matlab, Weka, SNNS/JavaNNS, FANN, GALib, Python, ...

Morse

# CARINA II



**Autonomous Vehicle No. 2**



# CARINA II



**Laser SICK**

**Laser Velodyne**

**LadyBug 360° Camera (Pointgray)**

**Stereo Camera BumbleBee (Pointgray)**

**GPS + IMU**

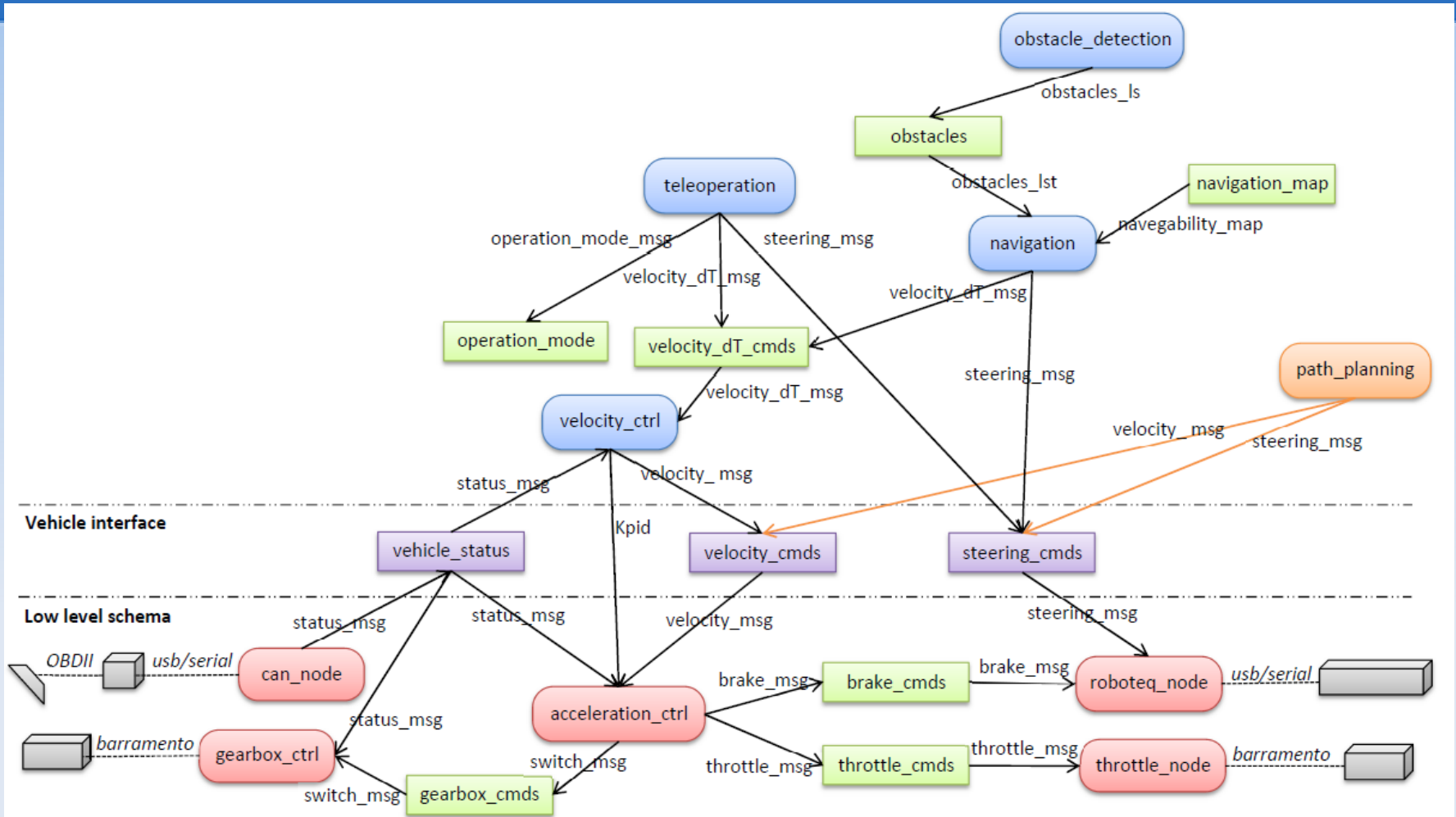
**Inerial Unit**



# CaRINA II: Sensors



# CaRINA: Software Architecture



# Project CaRINA II : R&D



## Computational Model

### CARINA II



# Project CaRINA II : R&D



## CARINA II - Automation

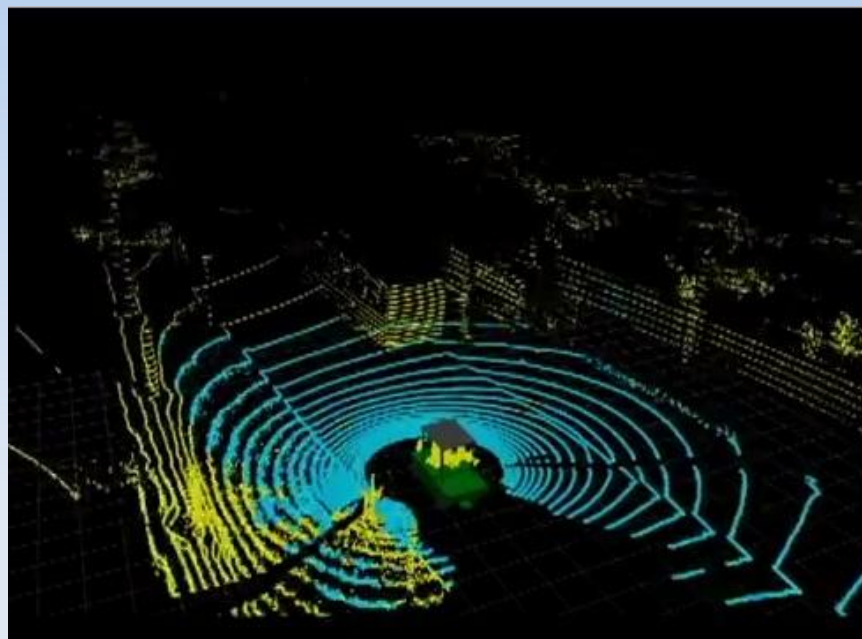


Sept.  
2012

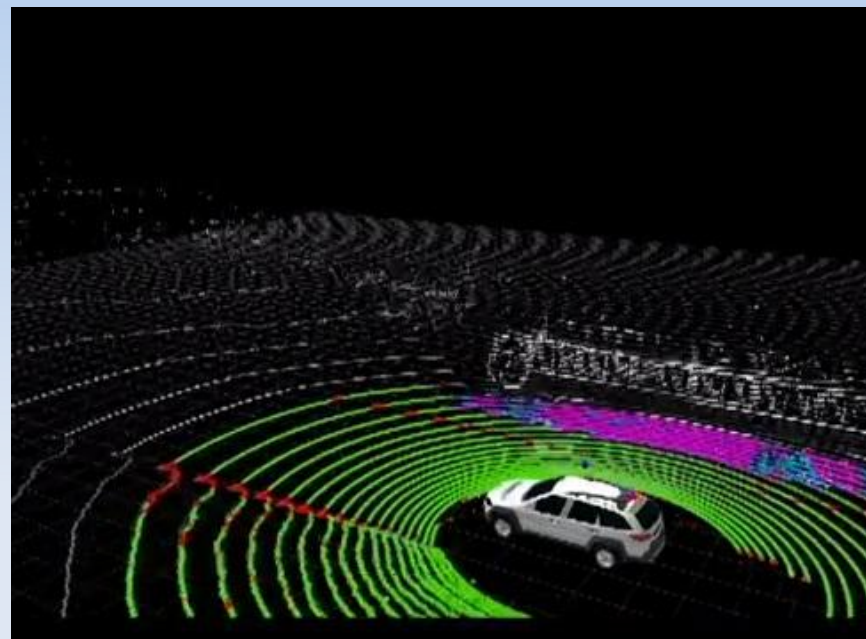
# Using LIDAR 3D



Actual data obtained with Velodyne HDL-32E



CaRINA I  
April 2012



CaRINA II  
May 2012

# CARINA II: Present Configuration



# Project CARINA: news coverage



TV Record – October 2010



EPTV – April 2012



Jornal Nacional – September 2012



Diário Oficial – May 2012



Portal G1 – April 2012



Revista Quatro Rodas – July 2012

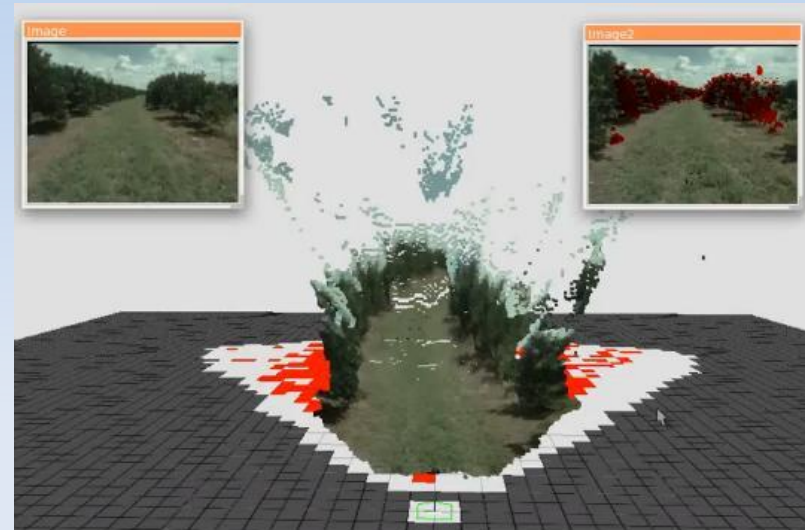
# NAV-AG Autonomous Navigation for Agribusiness Applications



**Research project in collaboration with JACTO company**

**Development of Agricultural Applications**

**JAV – Jacto Autonomous Vehicle (agricultural pesticides)**



Started in January 2012



# NAV-AG Autonomous Navigation for Agribusiness Applications



**Research project in collaboration with JACTO company**



Início em janeiro 2012

# NAV-AG Autonomous Navigation for Agribusiness Applications



Research project in collaboration with JACTO company



Início em janeiro 2012

# Project NAV-AG



JAV II - Agrishow 2013



# Project NAV-AG



## Jacto JAV II



<https://www.youtube.com/watch?v=kUVP9HsywDU> JAV 2



Prof. Fernando Osório

<http://www.icmc.usp.br/~fosorio>

E-mail: [fosorio@icmc.usp.br](mailto:fosorio@icmc.usp.br)

## Laboratório de Robótica Móvel – ICMC/USP

<http://www.lrm.icmc.usp.br/>

<http://www.lrm.icmc.usp.br/wiki/index.php/Publications>

**LRM Group** – Mobile Robotics Lab @ ICMC USP

Main Professors: **Prof. Dr. Denis Wolf, Prof. Dr. Fernando Osório**

External Profs: Prof. Dr. Valdir Grassi Jr. e Profa. Dra. Kalinka Castelo Branco

Graduate and Undergraduate Students (2012): ~ 30 people

- PhD Students: G. Pessin, L. Fernandes, M.Dias, D.Habermann, D.Sales  
J.Souza, P.Shinzato, A.Hata, C.Mendes, F. de Alencar
- MSc Students: D.Correa, R.Klaser, V.Utino, D.Sciotti, M.Gomes, A.Toshio
- Post-Doc: Edimilson Santos
- UnderGrad Studies: Iniciação Científica, Iniciação Tecnológica,  
Pré-Iniciação Científica, TCCs, Programas de Bolsas USP (Tutoria, PRG, PREx)

<http://youtube.com/lrmicmc>



Prof. Fernando Osório  
<http://www.icmc.usp.br/~fosorio>  
 E-mail: [fosorio@icmc.usp.br](mailto:fosorio@icmc.usp.br)

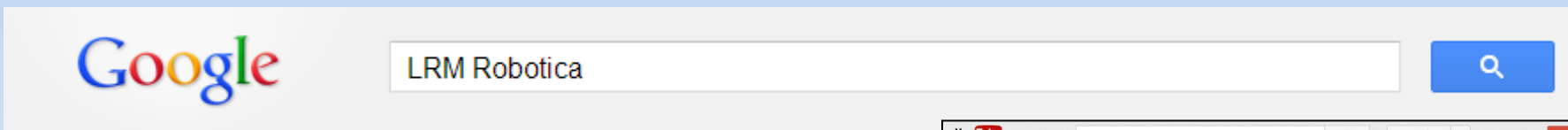
# Laboratório de Robótica Móvel – ICMC/USP

<http://www.lrm.icmc.usp.br/>

**LRM Group** – Mobile Robotics Lab @ ICMC USP



Main Professors: **Prof. Dr. Denis Wolf, Prof. Dr. Fernando Osório**




**LRM** Laboratório de Robótica Móvel  
 ICMC/USP - São Carlos

HOME MEMBROS PROJETOS ROBÔS PUBLICAÇÕES CONTATO

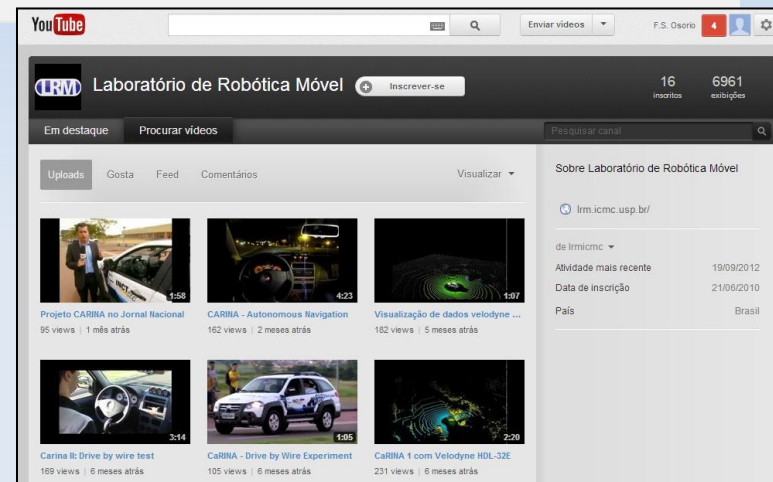
**Projetos**

- **CaRINA**
  - Veículos
  - Vídeos
  - Reportagens
  - Imprensa
- NAV-AG
- SEC-BOT

**Projeto CaRINA**



O projeto CaRINA (Carro Robótico Inteligente para Navegação Autônoma) visa o desenvolvimento de um veículo



**YouTube** Laboratório de Robótica Móvel

16 inscritos 6961 exibições

Em destaque Procurar vídeos

Uploads Gosta Feed Comentários Visualizar

Projeto CaRINA no Jornal Nacional 95 views | 1 mês atrás

CaRINA - Autonomous Navigation 162 views | 2 meses atrás

Visualização de dados velodyne... 162 views | 5 meses atrás

CaRINA II: Drive by wire test 185 views | 6 meses atrás

CaRINA - Drive by Wire Experiment 105 views | 6 meses atrás

CaRINA 1 com Velodyne HDL-32E 231 views | 6 meses atrás

Sobre Laboratório de Robótica Móvel

lrm.icmc.usp.br/

de lrmicmc

Atividade mais recente 19/09/2012

Data de inscrição 21/08/2010

País Brasil

<http://www.youtube.com/user/lrmicmc/videos>



Prof. Fernando Osório

<http://www.icmc.usp.br/~fosorio>

E-mail: [fosorio@icmc.usp.br](mailto:fosorio@icmc.usp.br)

Laboratório de Robótica Móvel – ICMC/USP

<http://www.lrm.icmc.usp.br/>

**LRM Group** – Mobile Robotics Lab @ ICMC USP



Main Professors: **Prof. Dr. Denis Wolf, Prof. Dr. Fernando Osório**

**OBRIGADO  
PELA SUA ATENÇÃO!**

# JCRIS2014

Joint Conference on Robotics and Intelligent Systems 2014



- HOME
- PROGRAM
- IMPORTANT DATES
- REGISTRATION
- EVENT VENUE
- ORGANIZATION
- TRAVEL
- CONTACT

## Joint conference 2014

18-23 October 2014 / São Carlos, SP

**LARS**  
 XI LATIN AMERICAN ROBOTICS SYMPOSIUM

**SBR**  
 II Simpósio Brasileiro de Robótica

**Robocontrol**  
 6th WORKSHOP IN APPLIED ROBOTICS AND AUTOMATION  
**2014**

**OBR** **MNR**  
 Mostra Nacional de Robótica

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### CONFERENCES

JOINT CONFERENCE ON ROBOTICS AND INTELLIGENT SYSTEMS 2014

---

LARS/SBR

## Joint Conference on Robotics and Intelligent Systems 2014

Introduction **Events: LARS, SBR, RoboControl, LARC, CBR, OBR, MNR, WRE, BRACIS, ...**



# Robótica Móvel – Editora LTC



# Robótica Móvel – Editora LTC

