

# Rawseeds and SLAM benchmarking



***M. Matteucci, G. Fontana, D. G. Sorrenti***

*European Robotics Forum 2011 - Västerås, 8 April 2011*

# What is Rawseeds ?

- EU Funded Project in the VI-FP
  - 1<sup>st</sup> November 2006 to 31 July 2009



- A ***Specific Support Action*** to collect and publish a benchmarking toolkit for (S)LAM research

- Involved Institutions:

- Politecnico di Milano (Italy – Coordinator)
- Università di Milano-Bicocca (Italy – Partner)
- University of Freiburg (Germany – Partner)
- Universidad de Zaragoza (Spain – Partner)



# What Does Rawseeds Provide?

- Multi Sensor Data Streams for SLAM Benchmarking
  - Laser, Cameras, IMU, Odometry, Sonars, Ground Truth
- Benchmark Problems (BPs) aim at testing algorithms:
  - Include detailed description of the task
  - Multi-sensor Data Set related to the task
  - Evaluation Methodology and Tools including Ground Truth
- Benchmark Solutions (BSs) extend BPs with:
  - Description of the algorithm for solving the BP and possible implementation (src or binary)
  - Algorithm output on the BP dataset
  - Evaluation (using the BP methodology)



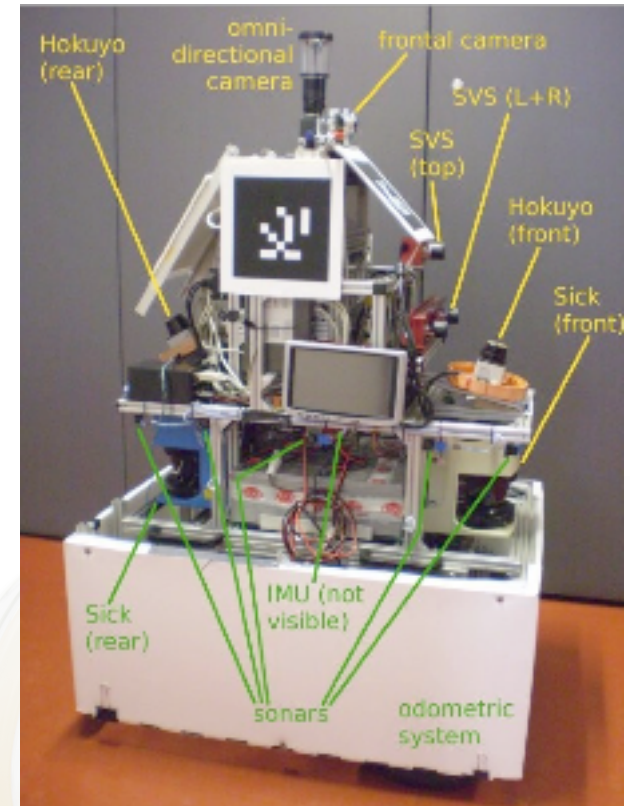
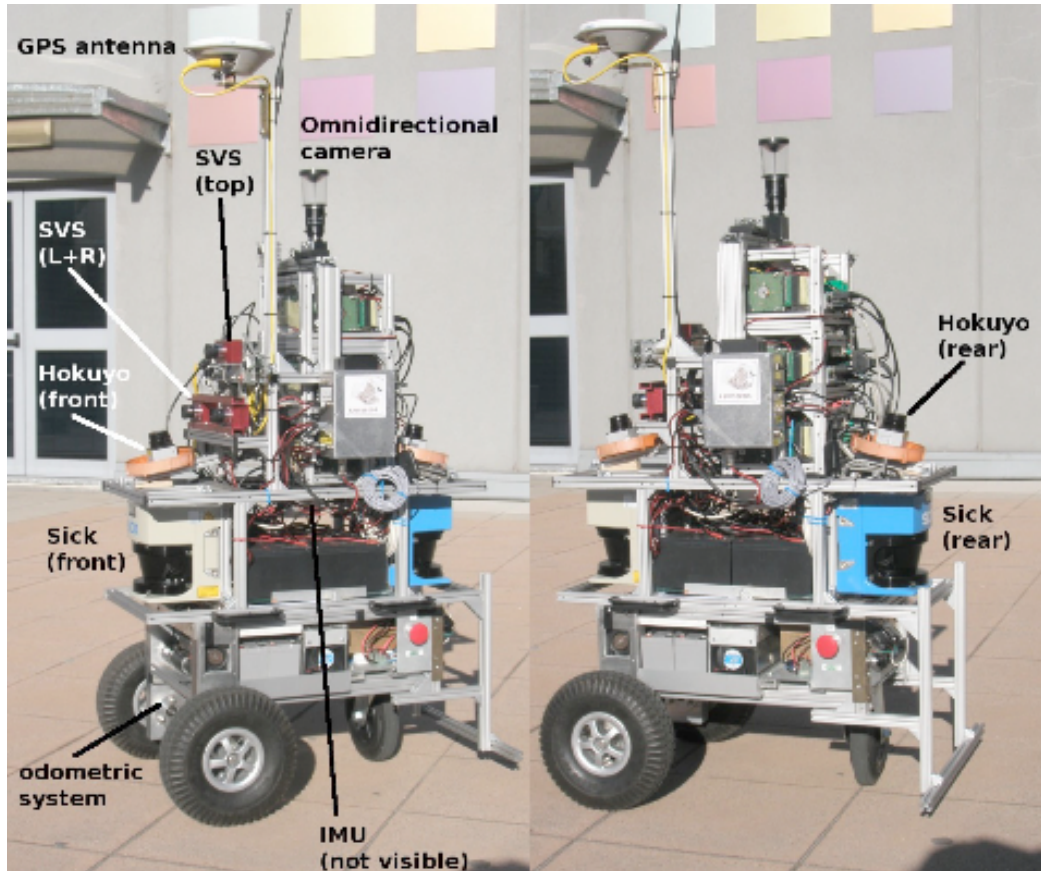
# Rawseeds Sensor Suite



- Use of an extensive sensing suite
  - B/W + Color cameras (monocular)
  - Stereo cameras (SVS by Videre)
  - LRFs (SICK 2D & Hokuyo)
  - Omnidirectional camera (V-Stone)
  - Sonar belt
  - Other proprioceptives (e.g., odometry, Inertial Measurement Unit)
- RTK-GPS (Outdoor GT) and Visual/Laser (Indoor GT)
- Sensors are synchronized, and verified for synchronization and data quality



# Sensors and sensor frame



# Design of the Datasets

- Define relevant scenarios beforehand
  - **Indoor scenarios** with offices, halls, corridors, flat and non-flat walls, doors & passages, windows, horizontal floors, ramps, stairs, elevators, and several pieces of furniture
  - **Outdoor scenarios** where the robot moves in the open between buildings and the obstacles are comparable with those found along urban roads
  - **Mixed scenarios** parts of the robot trajectory is surrounded by walls and/or roof and parts are located in the open
- Different acquisition setups
  - Static and dynamic environments (i.e., people walking around)
  - Different lighting conditions (i.e., natural daylight & artificial light)



# Indoor Locations in Bicocca



# Outdoor and Mixed Locations in Bovisa



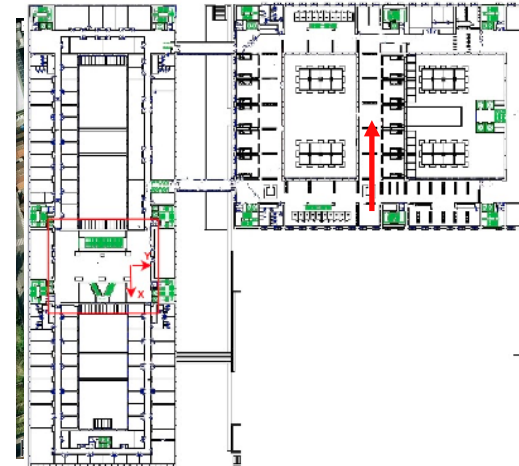
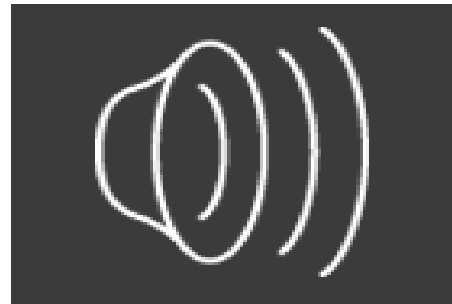


# 11 Datasets Collected & Validated

Many different scenarios:

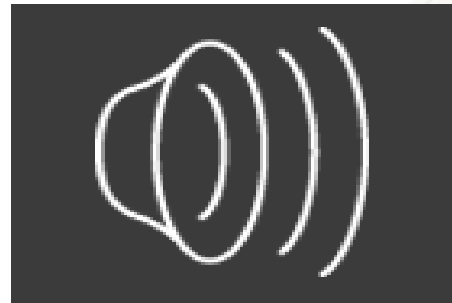
- Indoor

- 1 static lamps
- 1 static daylight
- 1 dynamic lamps
- 2 dynamic daylight



- Outdoor

- 2 static
- 1 dynamic

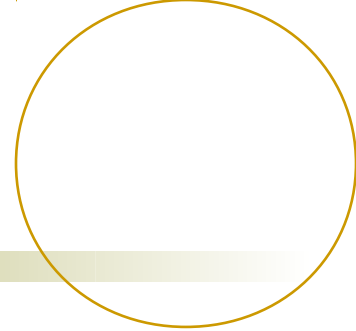


- Mixed

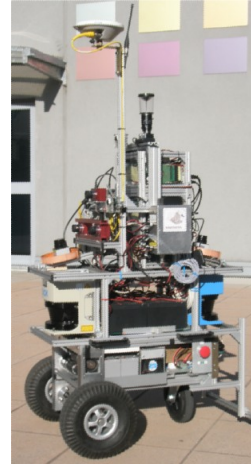
- 2 static
- 1 dynamic



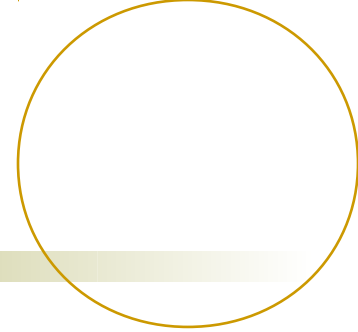
# Ground Truth Setup



- GT Collection Systems
  - Outdoor: RTK (Real Time Kinematic) GPS
  - Indoor: vision-based (*GT-vision*) and LRF-based (*GT-laser*)



# Problems and Solutions



- BPs are the union of:
  - The description of a specific task
  - A dataset, as the input for the execution of the task
  - A set of rating methodologies (metrics), for the evaluation of the results of the task execution
  
- BSs are ready to use solutions for BPs
  - Laser Based (Scan-matching, RBPF, Graph-based SLAM)
  - Vision Based (Monocular SLAM, Stereo SLAM, Trinocular SLAM)
  
- User supplied solutions are foreseen through Rawseeds website ([www.rawseeds.org](http://www.rawseeds.org))



# How does a BP look like?



## Benchmark Problem "Monocular SLAM - Bicocca\_2009-02-25b"

Creator: GF

Labels: [first batch](#), [artificial light](#), [static](#), [indoor](#), [SLAM](#)



Perform a map building activity with SLAM (online), using the sensor data files provided below. Such files come from the Bicocca\_2009-02-25b data-collection session; they include output and calibration information associated to front color camera, IMU, odometry, and the ground truth for the specified session. Please note that the Bicocca\_2009-02-25b session also includes other data files, not used for this Benchmark Problem.

This BP belongs to the very first batch of problems published by Rawseeds; other BPs will follow.

### Attached Files

- Matlab scripts and data to automatically compute some of the evaluation metrics, given the trajectory data output by a SLAM algorithm. Includes an extended ground truth covering the whole path of the robot, obtained by manual scan matching performed on the data from onboard LRFs (indoor datasets only). - [Rawseeds Metrics Computation Toolkit](#)
- Set #04 of sensor positions on the robot - [SensorPositions\\_04.tar.torrent](#)
- Set #01 of file formats - [FileFormats\\_01.tar.torrent](#)
- CAD drawings of the Bicocca location - [Drawings\\_02.dxf.bz2.torrent](#)
- Results of Calibration 04. - [Calibration\\_04-Results.tar.torrent](#)
- Images from the front camera used for Calibration 04. Checkerboard has 100mm x 100mm squares. - [Calibration\\_04-Used\\_for\\_calibration-FRONTAL.tar.bz2.torrent](#)
- Set of images generated by the front camera from which the images used for Calibration 04 have been selected. Checkerboard has 100mm x 100mm squares. - [Calibration\\_04-All\\_images-FRONTAL.tar.bz2.torrent](#)
- Ground truth (trajectory data) - [Bicocca\\_2009-02-25b-GROUNDTRUTH.csv.bz2.torrent](#)
- Front camera: data - [Bicocca\\_2009-02-25b-FRONTAL.tar.torrent](#)
- IMU: data - [Bicocca\\_2009-02-25b-IMU\\_STRETCHED.csv.bz2.torrent](#)
- Set of list files associated to video streams. For each camera it includes: - a .csv file with the timestamps of all the frames in the data stream; - a .lst file with the filenames of all the frames in the data stream. - [Bicocca\\_2009-02-25b-LISTS.tar.torrent](#)
- Odometry: data - [Bicocca\\_2009-02-25b-ODOMETRY\\_XYT.csv.bz2.torrent](#)
- List of corner positions for the Bicocca location (extracted from the executive drawings) - [Bicocca-Corners.tar.torrent](#)

### Evaluation Methodologies

The provided solutions will be evaluated and scored with respect to the following evaluation methodologies:

- ATE compares the trajectory of a robot, as reconstructed by an algorithm using real sensor data as its input, to the actual trajectory (ground truth). ATE is a mandatory performance measure. Please ... - [Absolute Trajectory Error](#)
- ME compares the map of an environment, as reconstructed by an algorithm using real sensor data as its input, to the actual map of the location (ground truth). ME is a recommended performance measure. - [Mapping Error](#)
- RPE measures the accuracy of a SLAM result, as reconstructed by an algorithm using real sensor data as its input, by comparing the reconstructed relative transformations between nearby poses to the ac... - [Relative Pose Error](#)
- REC provides a basic estimate of how the running time of an algorithm (which uses real sensor data as its input) scales as the quantity of data available to be processed increases. REC is a mandatory... - [Rough Estimate of Complexity](#)
- SLE aims to evaluate the overall quality of a SLAM algorithm by actually using its output in a realistic application. The SLAM algorithm, fed with real sensor data from a robot, is used to build a map... - [Self Localization Error](#)

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# Rawseeds: One year later...



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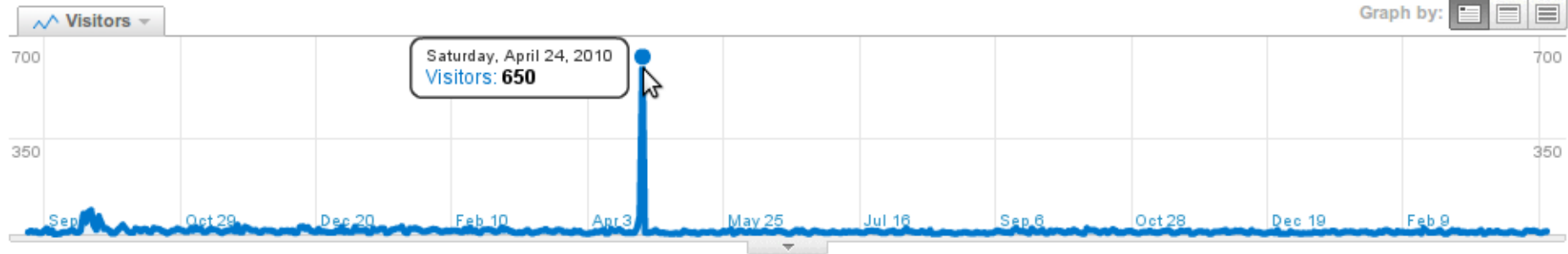
*European Robotics Forum 2011 - Västerås, 8 April 2011*

# Who knows about it?




## Visitors Overview


Sep 1, 2009 - Apr 5, 2011




4,447 people visited this site

 8,364 Visits


 4,447 Absolute Unique Visitors

 41,114 Pageviews

 4.92 Average Pageviews


 00:03:54 Time on Site

 49.45% Bounce Rate

 51.72% New Visits

## Visitor Segmentation

- Visitors Profile:** languages, network locations, user defined
- Browser Profile:** browsers, operating systems, browser and operating systems, screen colors, screen resolutions, java support, Flash
- Map Overlay**  
Geolocation visualization

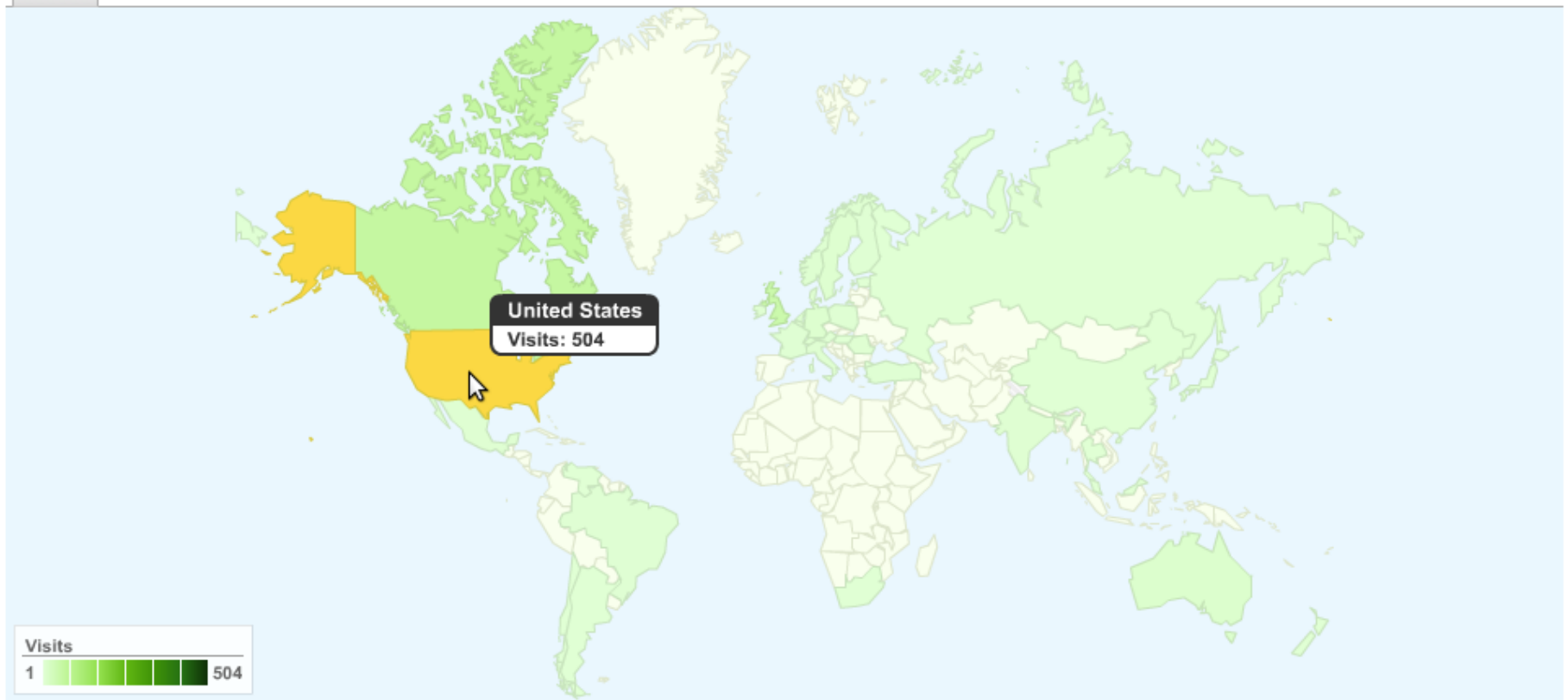
 **Try Google Ad Planner.**  
Understand the demographics and behaviors of your website's visitors.

# Who knows about it?

## Map Overlay

Apr 23, 2010 - Apr 25, 2010

Visits



**723 visits came from 35 countries/territories**



# Who knows about it?

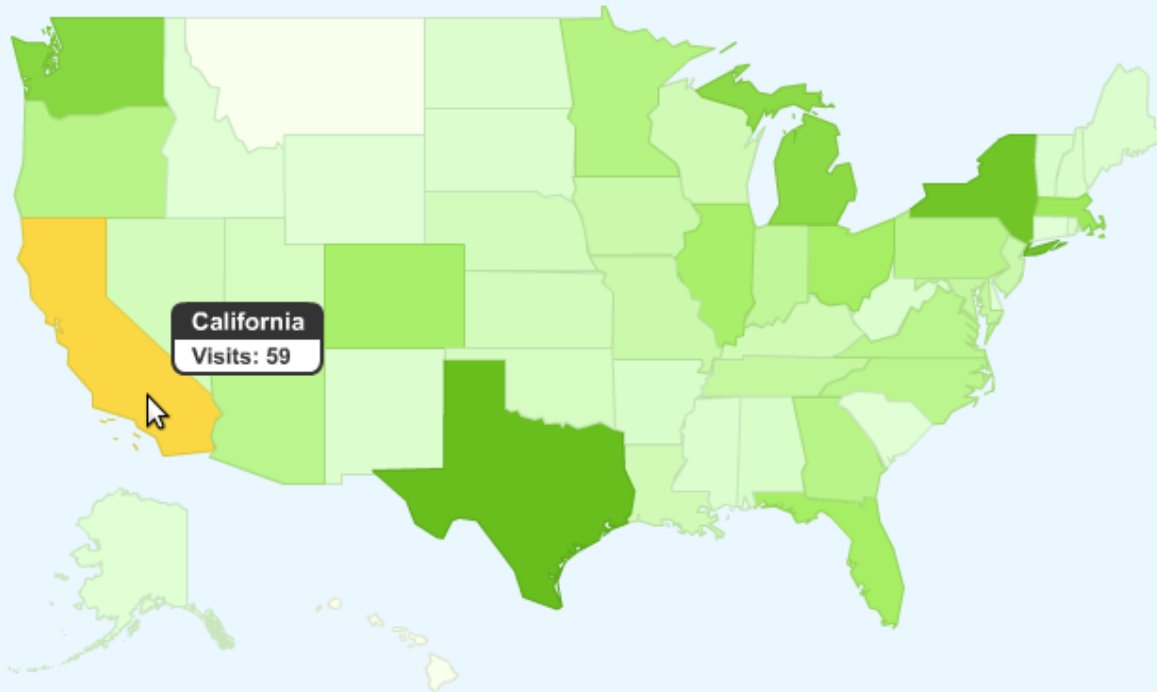
## Country/Territory Detail:

United States

Apr 23, 2010 - Apr 25, 2010

Visits

Zoom Out



**This country/territory sent 504 visits via 49 regions**

# Who knows about it?

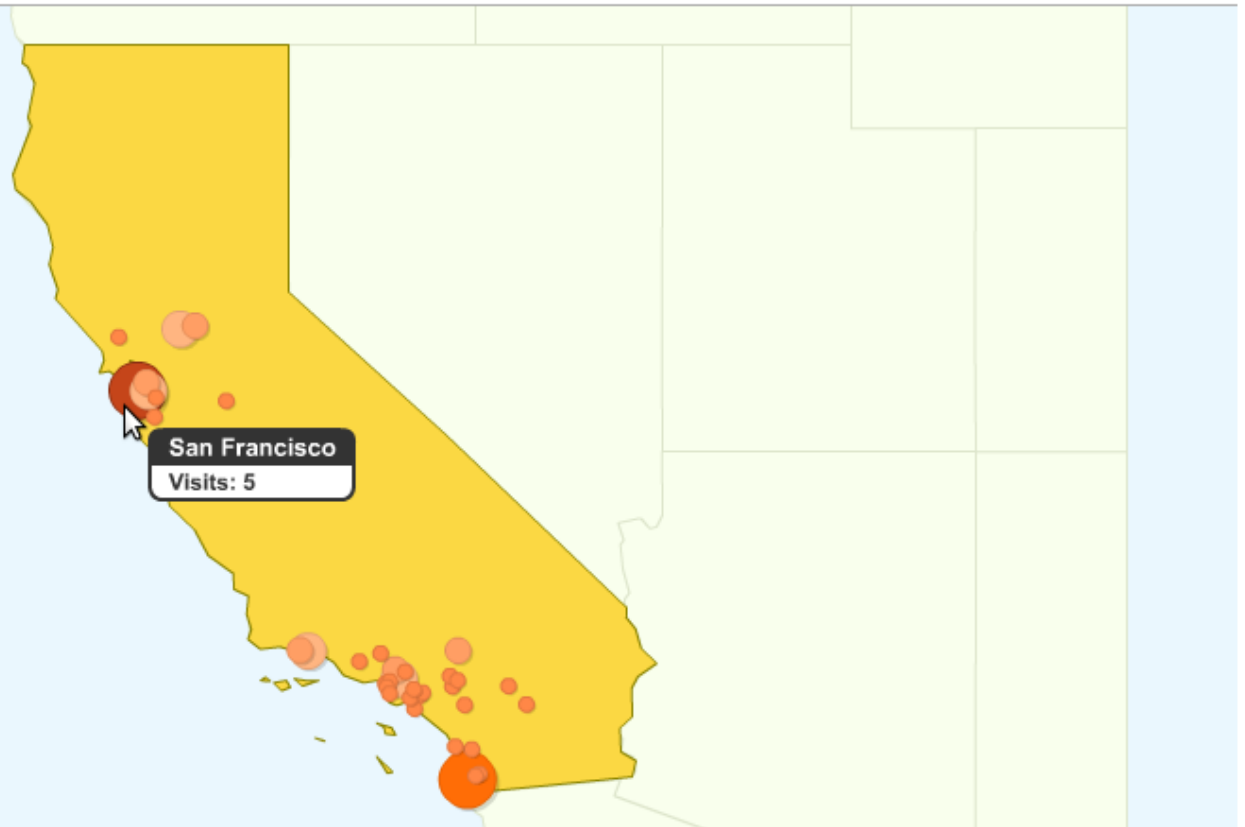
## State Detail:

California

Apr 23, 2010 - Apr 25, 2010

Visits

Zoom Out

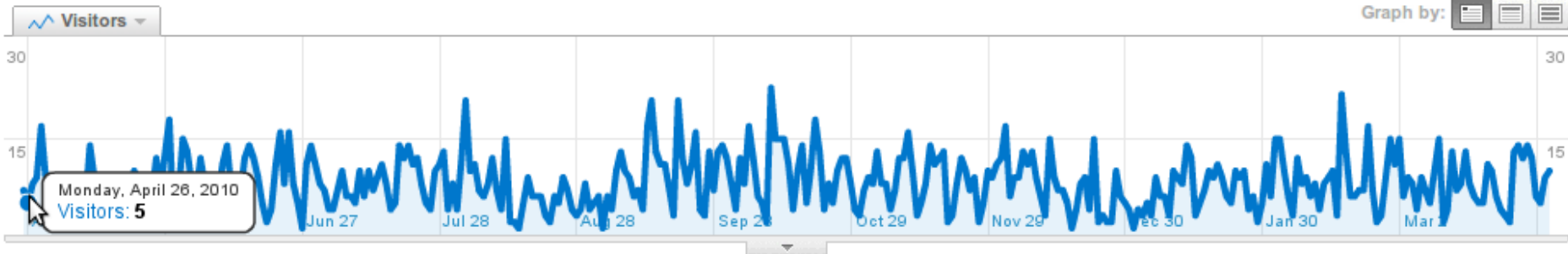


**This state sent 59 visits via 38 cities**

# Who knows about it?

## Visitors Overview

Apr 25, 2010 - Apr 5, 2011



1,571 people visited this site

3,642 Visits

1,571 Absolute Unique Visitors

17,028 Pageviews

4.68 Average Pageviews

00:03:51 Time on Site

48.98% Bounce Rate

40.75% New Visits

## Visitor Segmentation

**Visitors Profile:** languages, network locations, user defined

**Browser Profile:** browsers, operating systems, browser and operating systems, screen colors, screen resolutions, java support, Flash

**Map Overlay**  
Geolocation visualization

**Try Google Ad Planner.**  
Understand the demographics and behaviors of your website's visitors.

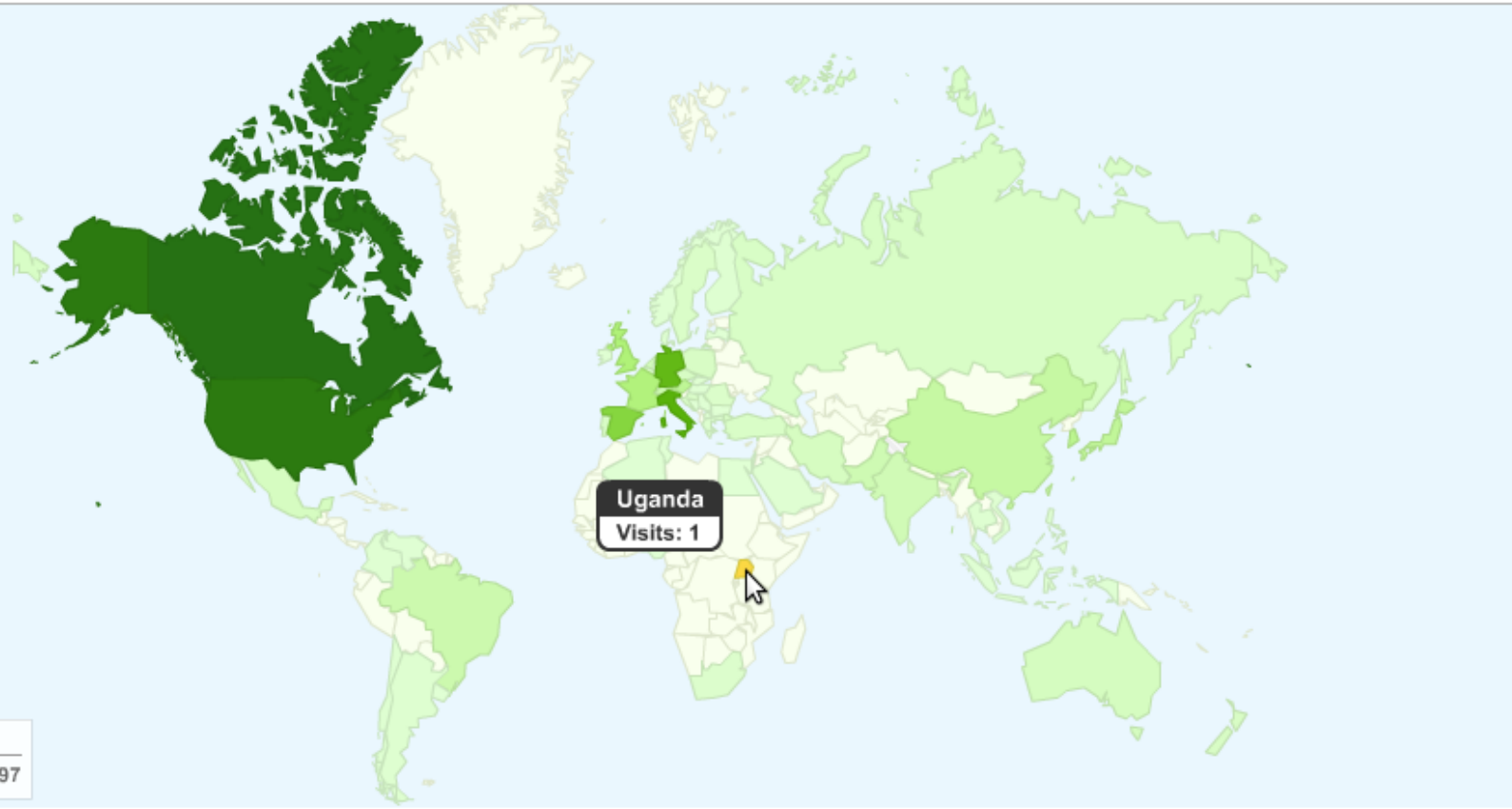
# Who knows about it?



## Map Overlay

Apr 25, 2010 - Apr 5, 2011

Visits



# Who knows about it?

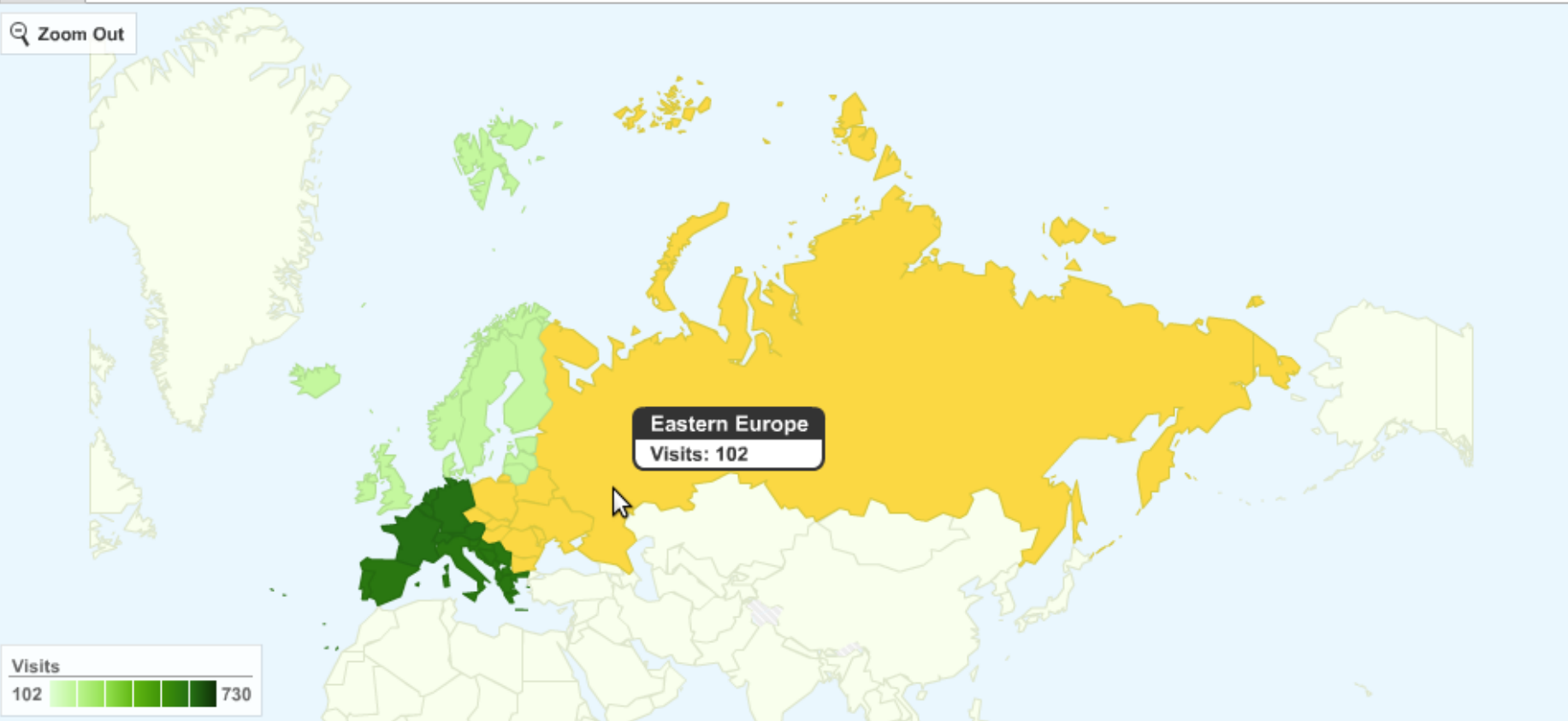
## Continent Detail:

Europe

Apr 25, 2010 - Apr 5, 2011

Visits

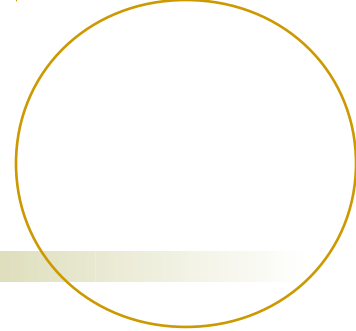
Zoom Out



**This continent sent 1,739 visits via 4 sub continent regions**

# Do people interact with us?

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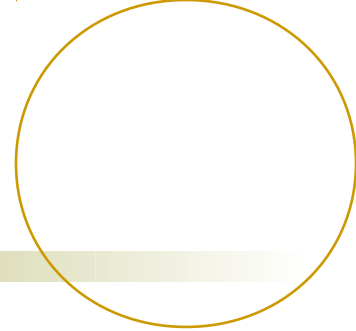


- Through the forum
  - Only 2 registered users and no real community
- Directly by mail
  - So far 25 email thread with unique users
  - Asking for clarification or point out issues (web site)
- Continuously monitoring
  - Seeder down at the beginning of February 2011
  - 6 users emailed us about it in less than 3 weeks
  - 1 user asked urgently for a file to complete his paper

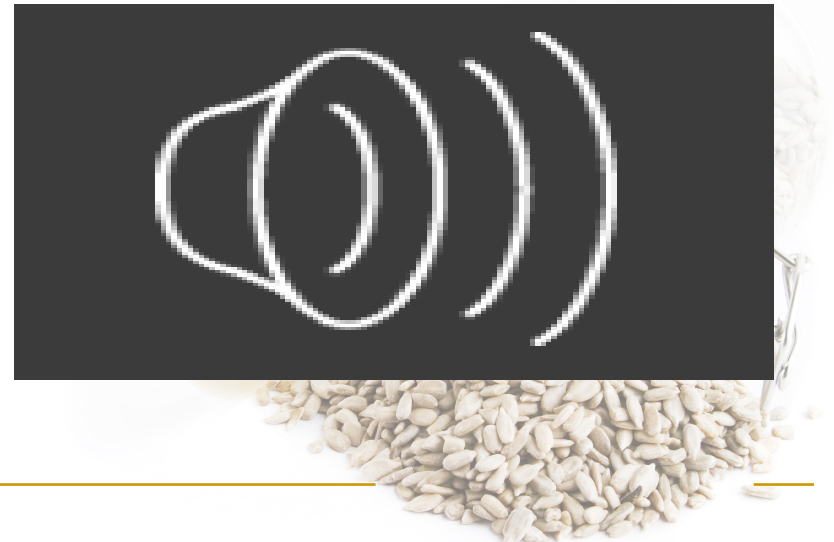


Filename	URL	Date	Comment	Downloaded ▲	Leechers	Seeders
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Calibration_04-Results.tar	/assets/torrents/eea95557d5feea4bbc4f0d91568799362a407993.torrent	2009-06-23 11:09:03		71	0	1
Calibration_02-Results.tar	/assets/torrents/c0c789aa5aa3051142913c411b1342844bcb477d.torrent	2009-06-23 11:04:50		66	0	1
SensorPositions_04.tar	/assets/torrents/328d32fb8258e99ecd5be76d558136481f52619d.torrent	2009-05-28 10:50:55		61	0	1
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Bovisa_2008-10-04-LISTS.tar	/assets/torrents/b5d0d337936e634d5e08ef2e5dafc5c10dc31086.torrent	2009-05-18 15:31:07		24	0	1

# Do people actually use it?



- Citations for “rawseeds” on scholar.google.com (05/04/11)
  - 80 papers and project deliverables refer to it
  - 41 actually funded by the project
  - 39 brand new papers/deliverables
- Of the brand new papers/deliverables
  - 22 just mention the project
  - 13 use the data
  - 4 discuss approach/results
- A couple of notes
  - 2 papers with media footage
  - None submitted a BS





# Do people actually use it?

“When available, GPS is the quick and easy solution to localizing a robot. However, because it is often not available (e.g. indoors) or not reliable enough, other techniques, using laser range finders or cameras have been developed that offer better performance. For 2D localization, Laser range finders are far more precise and easier to work with than cameras. We report here on the performance of several implementations of the main class of localization algorithms that use a laser, Simultaneous Localization And Mapping (SLAM) on the RAWSEEDS benchmark. SRI International's SLAM system has an RMS error in XY of 0.32m (0.22%). This is the best reported performance on this benchmark.”

*R. Vincent, B. Limketkai, M. Eriksen. Comparison of indoor robot localization techniques in the absence of GPS. In proceedings of SPIE Vol. 7664, 2010*



# Summing up ... and averaging

- On average in last 1.5 years
  - A full download (~600GB) per month ... how many by sneaker.net?
  - A paper per month using Rawseeds data
  - A paper every 2 weeks with reference to Rawseeds project
  - An email contact every 3 weeks asking for support



# RAWSEEDS: One year later...



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