

# Cloud – Enabled Humanoids: (and the Future of Distributed Intelligence)

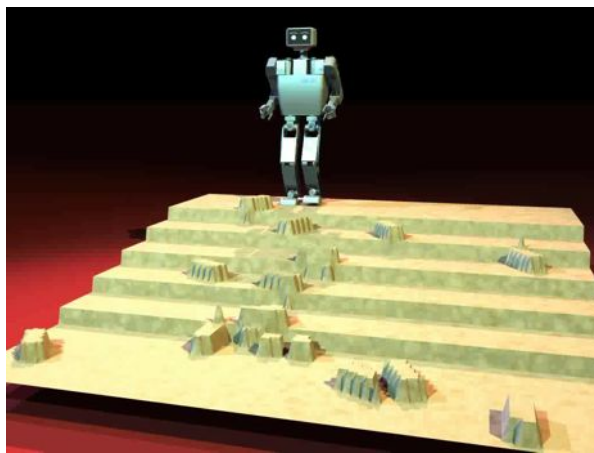
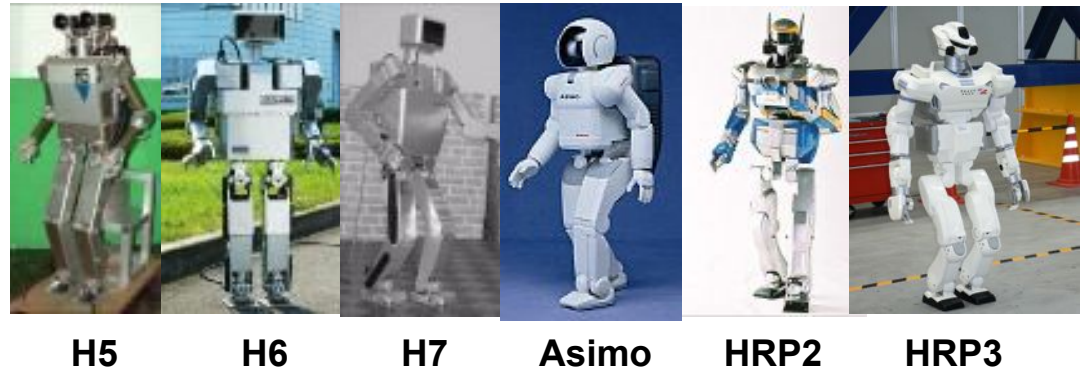
James Kuffner

*The Robotics Institute  
Carnegie Mellon University*



# Humanoid Motion Planning (1995-2011)

- Stanford University  
1995-1999
- University of Tokyo  
JSK Lab  
1999-2001
- Carnegie Mellon University  
The Robotics Institute  
2001-*present*
- Digital Human Research Center (AIST)  
2001-*present*



James Kuffner (CMU/Google)

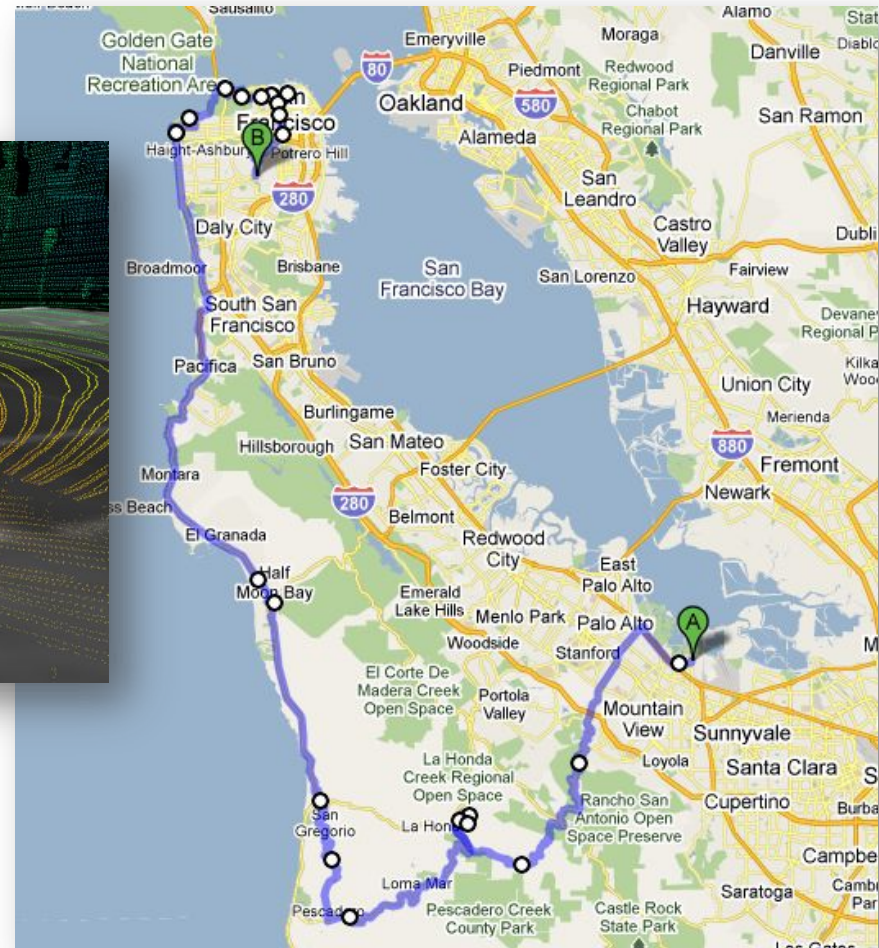
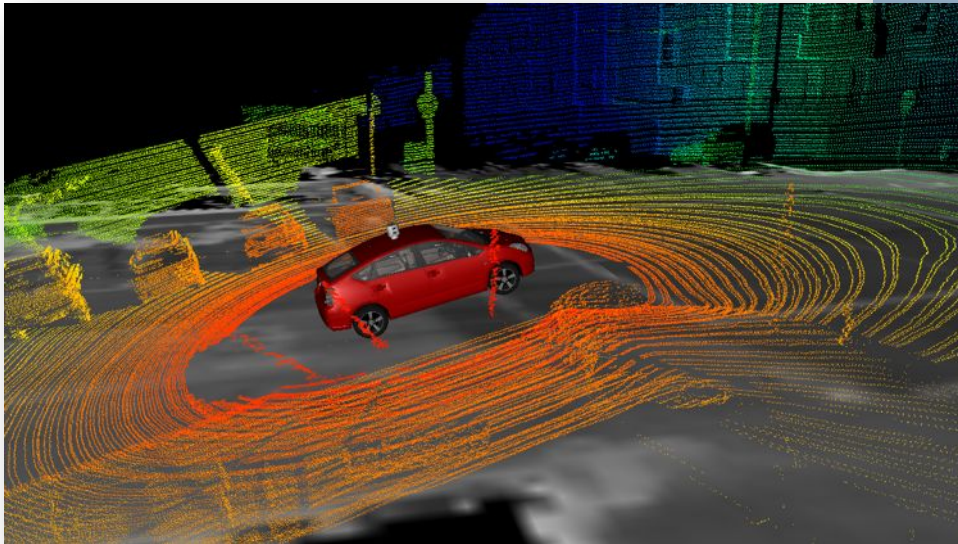
Cloud-Enabled Humanoids



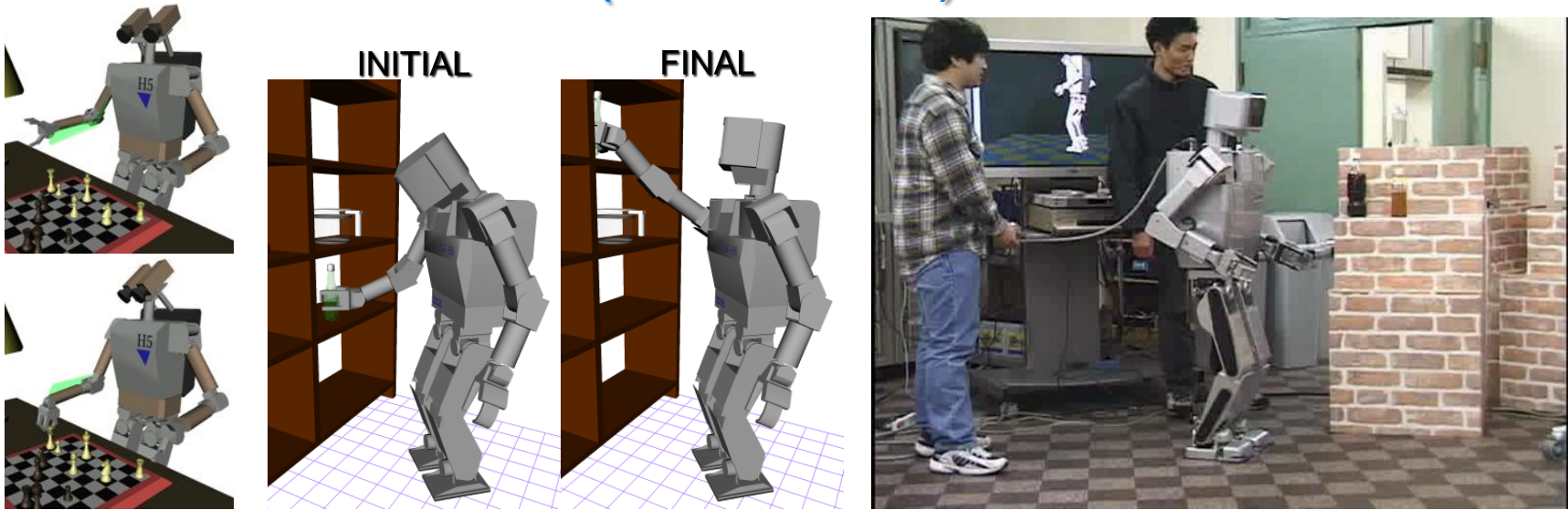
Humanoids2011 Workshop: New Bodies for Cognitive Humanoids

# Self-driving Cars

- A total of more than 145,000 autonomous miles
- 10 high-complexity routes of roughly 100 miles each without human intervention.



# Autonomous Grasping & Manipulation (2000-2010)



James Kuffner (CMU/Google)

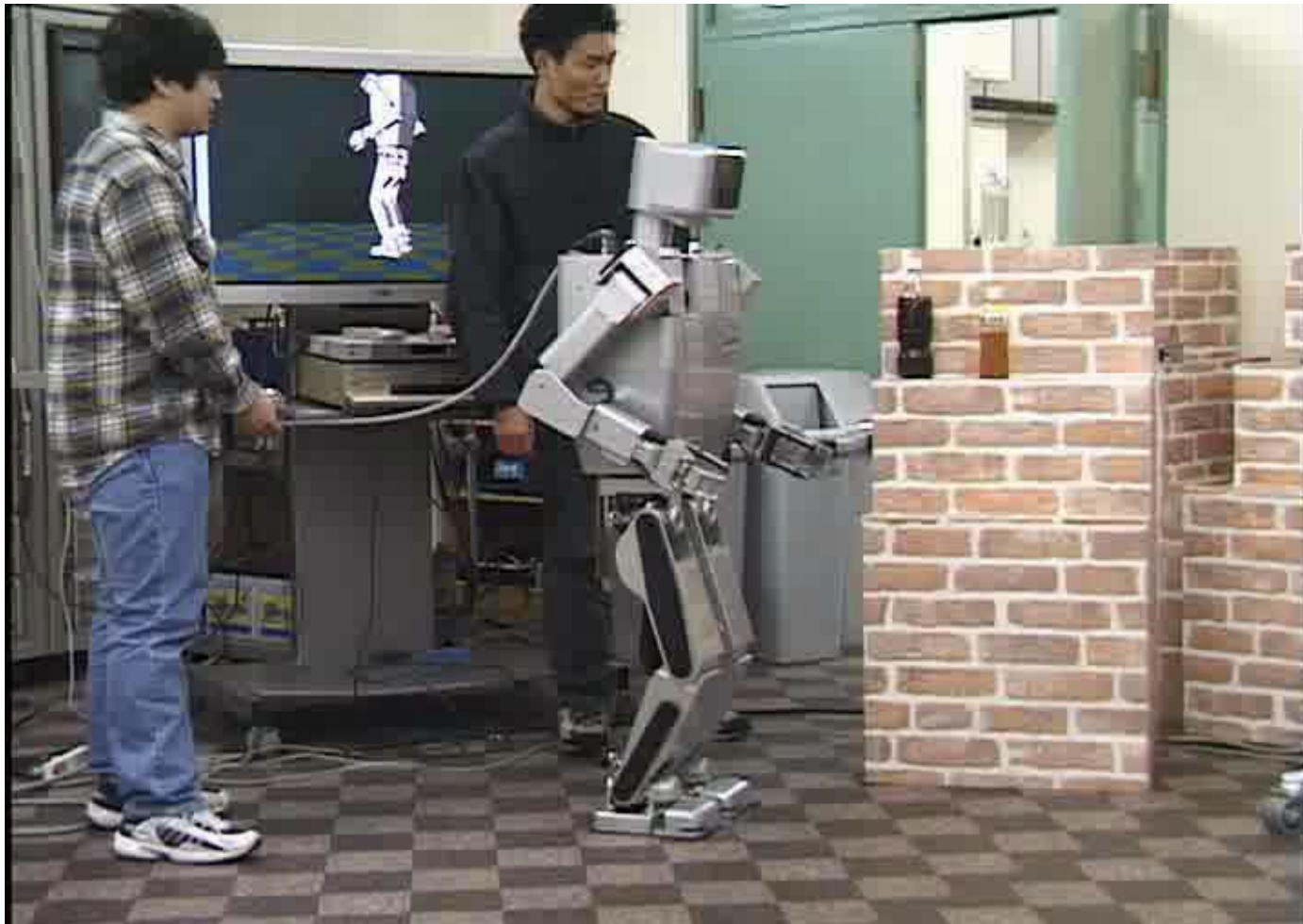


Cloud-Enabled Humanoids

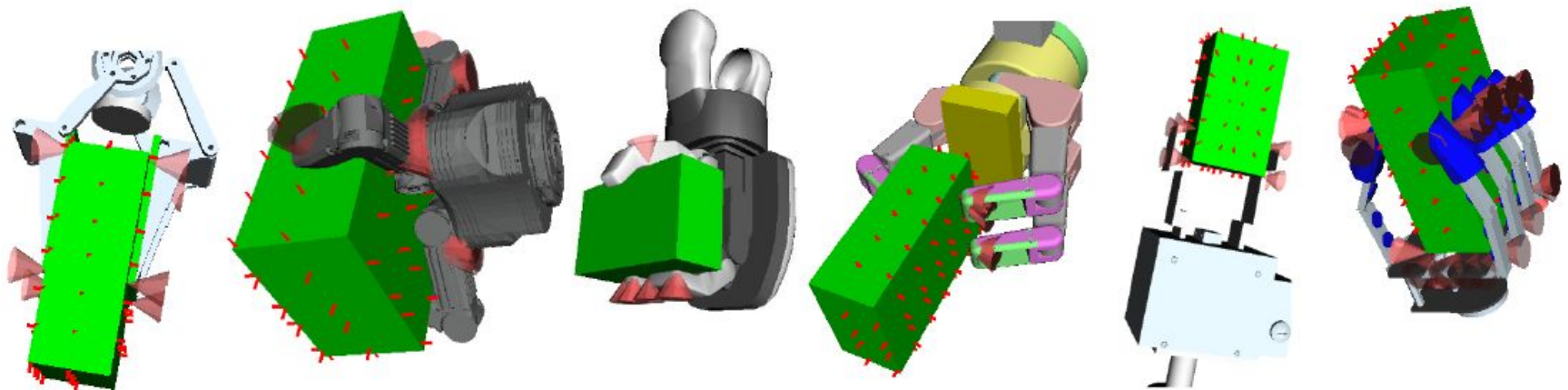
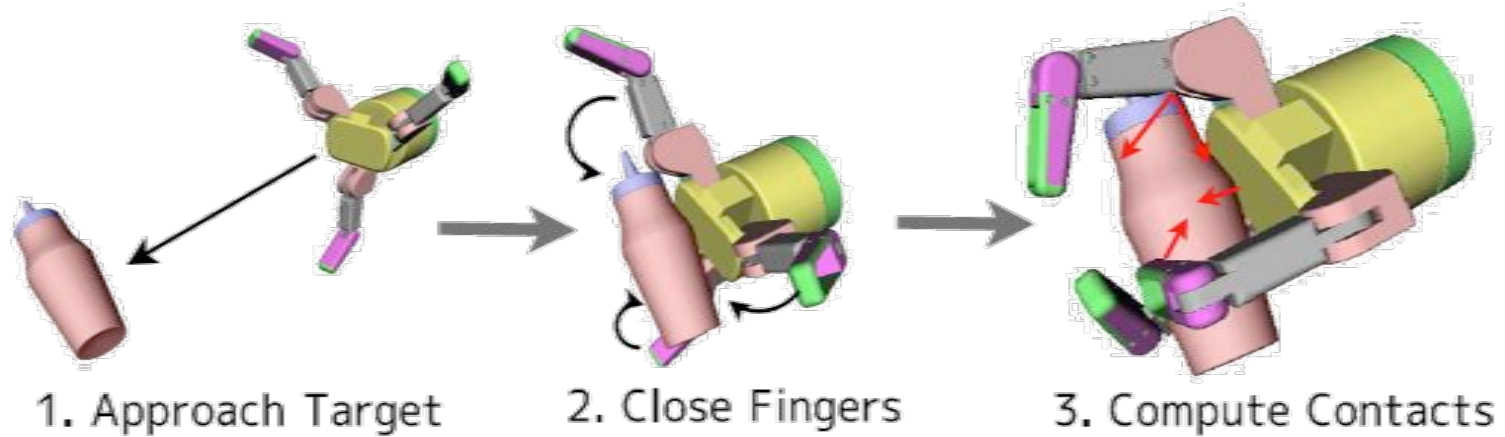


Humanoids2011 Workshop: New Bodies for Cognitive Humanoids

# RAVE: Online Manipulation Planning (2001)

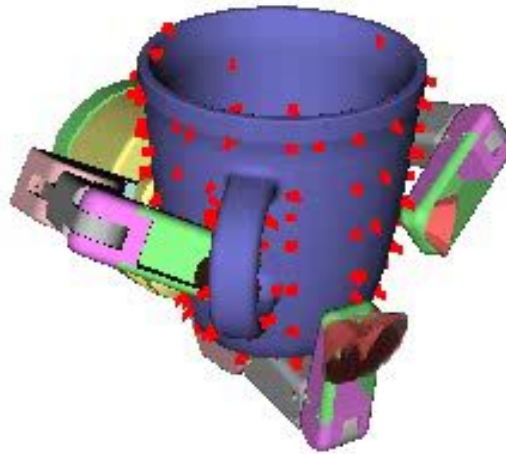


# Stable Grasp Generation

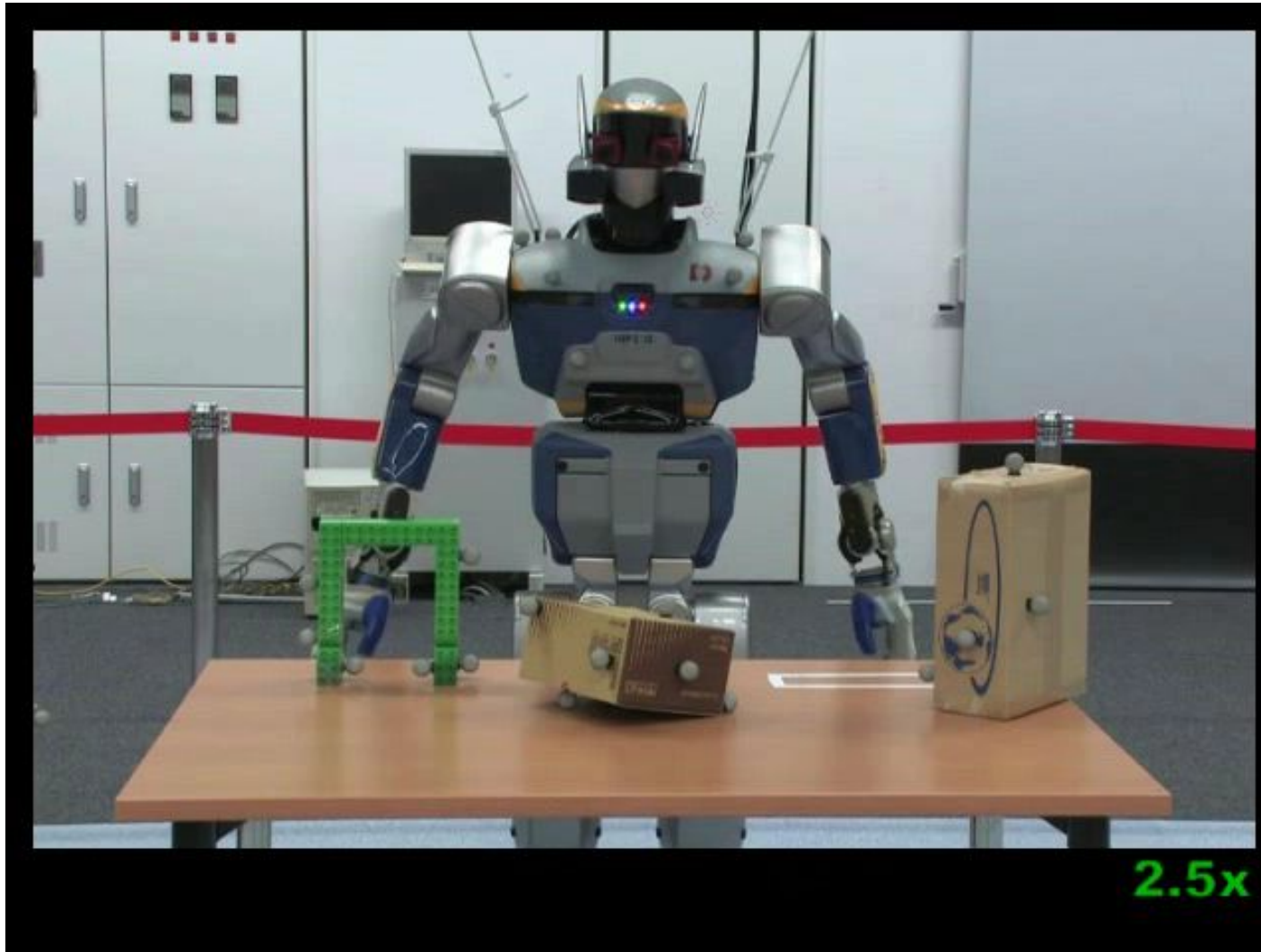


*CMU PhD thesis:* **Rosen Diankov**

# Feasible Grasp Generation



# Automatic Regrasping (2006)



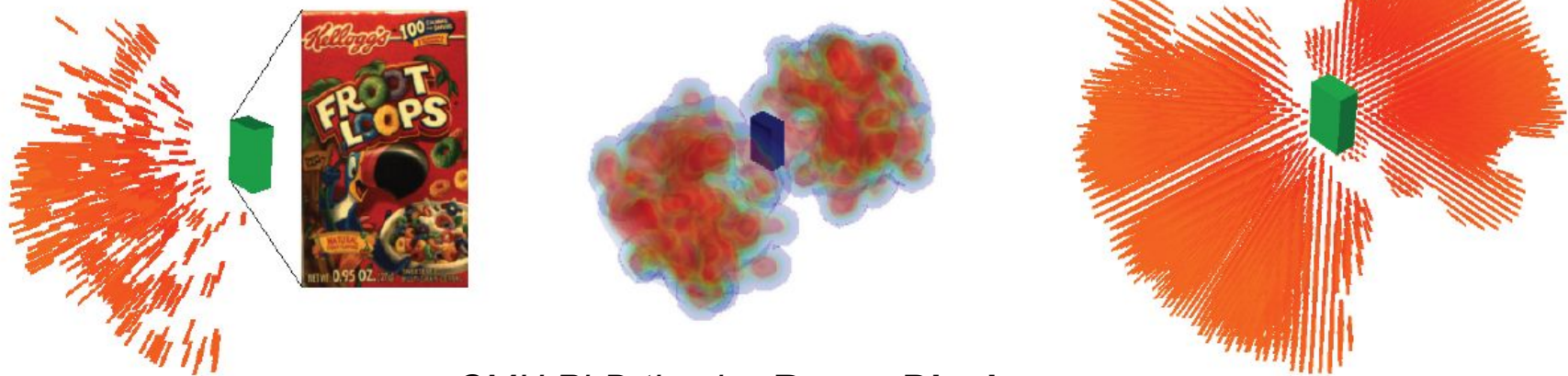
[ Berenson, Diankov, Nishiwaki, Kagami, Kuffner ] Humanoids2007



# Object-Specific 6D Pose Extraction



- Modeling Object Pose Error



CMU PhD thesis: **Rosen Diankov**

# “HERB” : Home-Exploring Robot Butler (2008 – 2010)

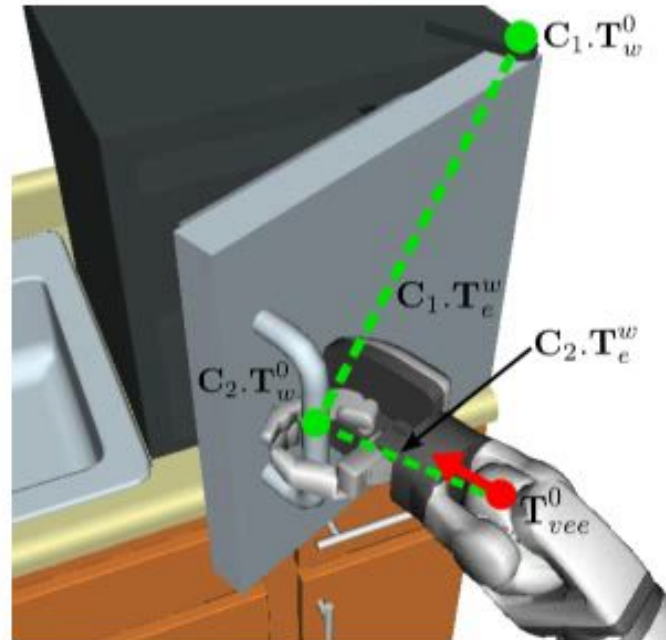


**Quality of Life Technology Center**  
a National Science Foundation Engineering Research Center



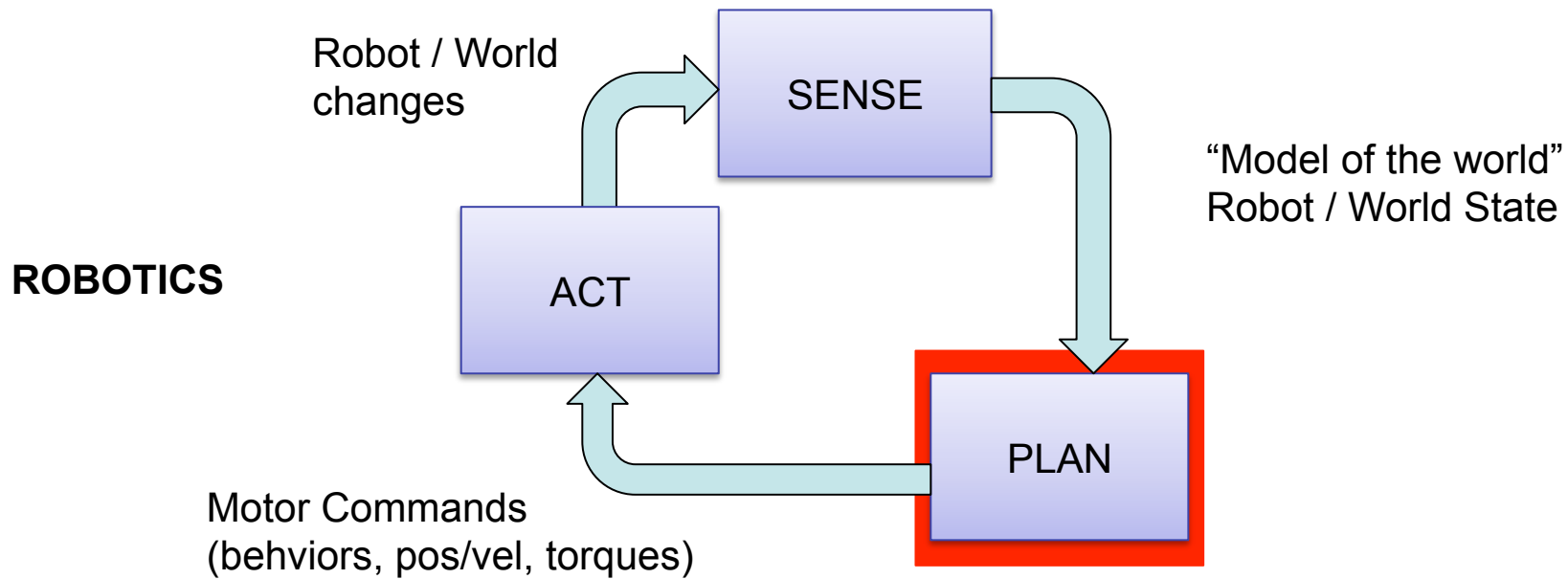
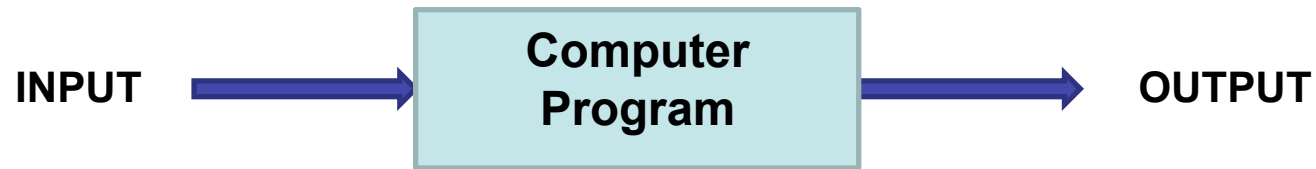
# Whole-body Constrained Planning

Simultaneous Constraints and Goal Sampling  
Using TSR chains



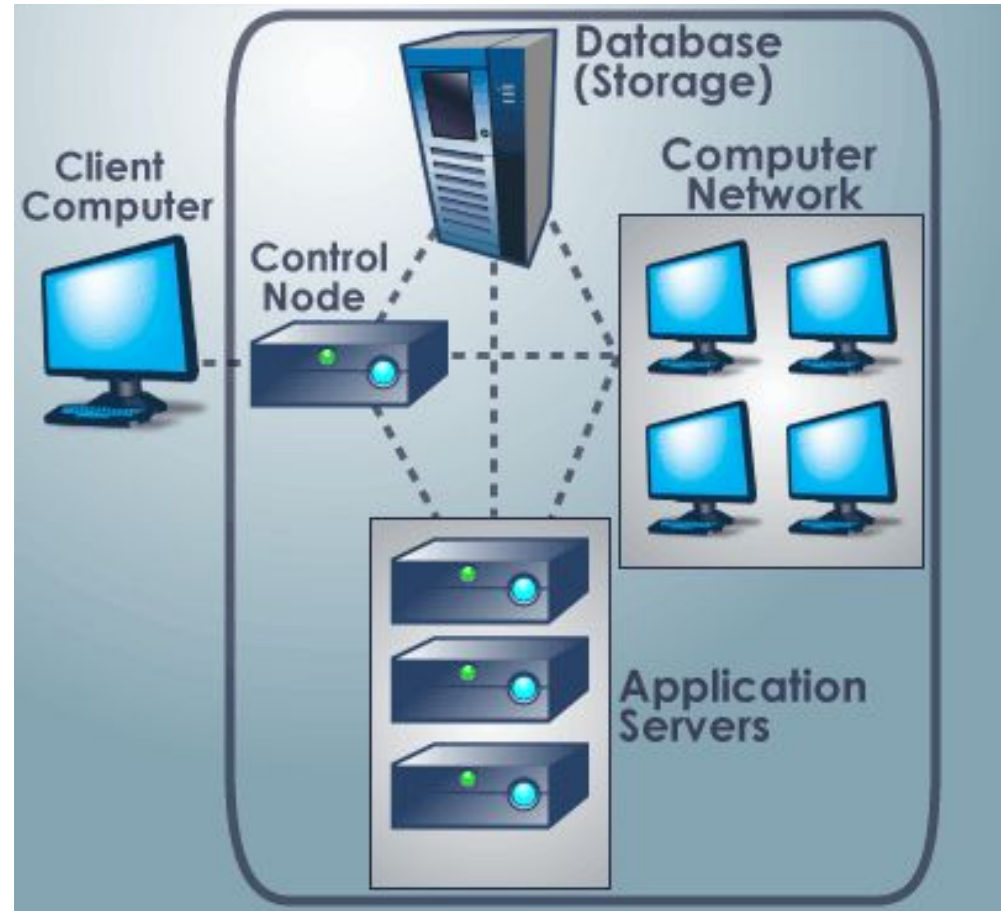
[ Berenson, Chestnutt, Srinivasa, Kagami, Kuffner , *Humanoids2009* ]

# Model of Computation



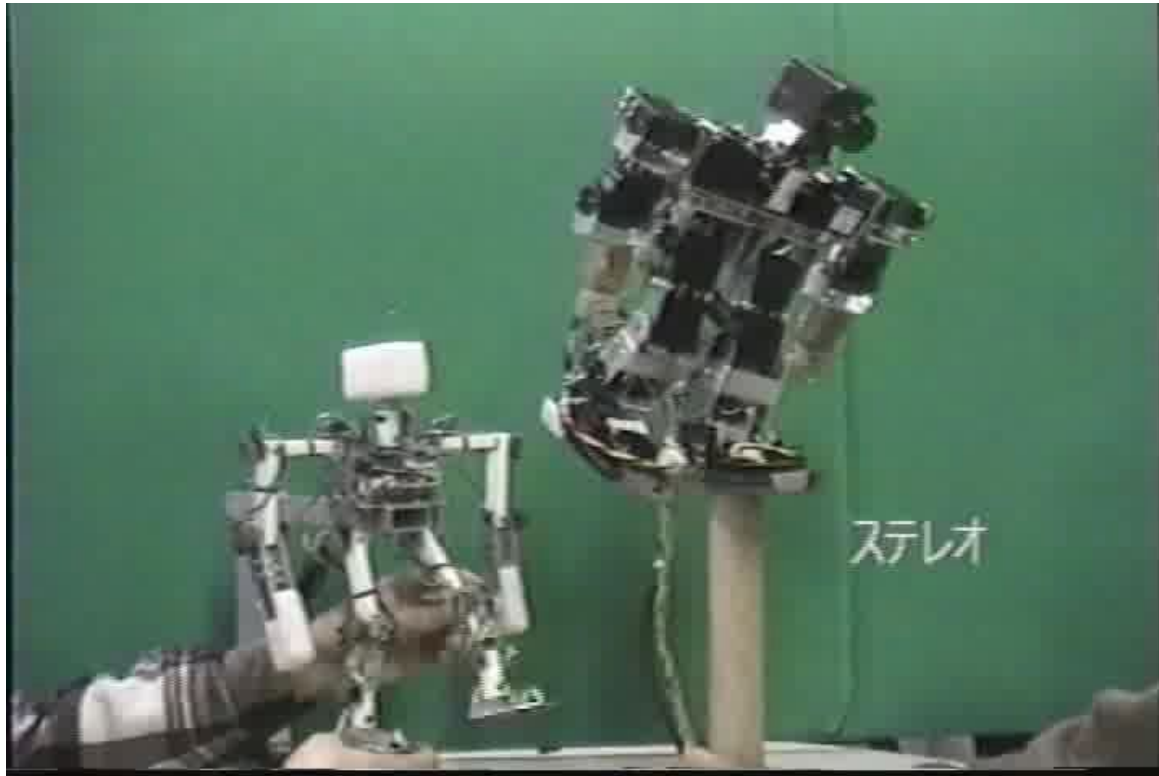
# Cloud Computing

- Documents “live” in the cloud (backed up and accessible anywhere)
- Netbook
- Supercomputing: (Heavy CPU or data-intensive processing handled by distributed network)



# “Remote-Brain” Robots

- Physical separation of Hardware (motors & sensors) and Software (high-level processes)



JSK (U.Tokyo) mini-Humanoids (1990s)

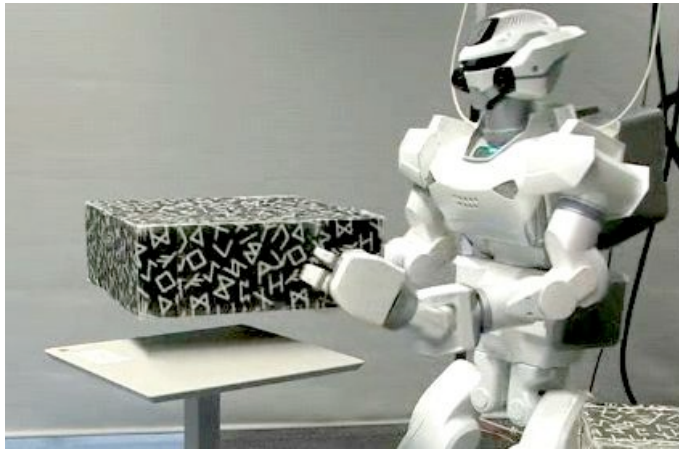
# Relationship to Teleoperation

- Human acts as the “remote-brain”
- Not suitable for all tasks
- Issues:
  - Latency
  - Data Bandwidth



NAIST-Hand I

# Cloud-Enabled Robotics



HRP3 (AIST/Kawada)



Google DataCenter

- “DAvinCi: A cloud computing framework for service robots” [ Arumugam, et. Al. , ICRA 2010 ]
- RoboEarth
- Cloud Robotics at Google I/O (May 2011)



# Enabling Factors

- Wireless networking:
  - Fast
  - Reliable
  - Ubiquitous
  - Sufficient bandwidth

(e.g: Mobile Broadband  
64 kbps to 150 Mbps  
in 10 years = 2400x)

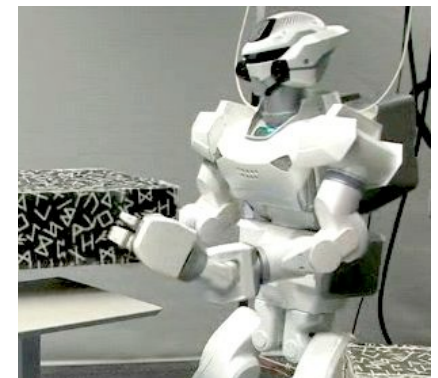
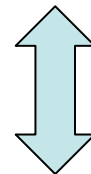
STANDARD	Rated maximum range (feet)	Frequency	Maximum speed
802.11a	25 to 75	5 GHz	54 mbps
802.11b	100 to 150 indoors 300 outdoors	2.4 GHz	11 mbps
802.11g	100 to 150 indoors 300 outdoors	2.4 GHz	54 mbps

Source: Ericsson



# Benefits of “Cloud Robotics”

- Provides a shared knowledge database
  - Organizes and unifies information about the world in a format usable by robots
- Offloads heavy computing tasks to the cloud
  - Cheaper, lighter, easier-to-maintain hardware (akin to desktop PC vs. a thin-client “netbook”)
  - Longer battery life
  - Less need for software pushes/updates
  - CPU hardware upgrades are invisible & hassle-free
- Skill / Behavior Database
  - reusable library of “skills” or behaviors that map to perceived task requirements / complex situations.
  - Data-mining the history of all cloud-enabled robots



# Example: Perception

- Cloud-enabled Object Recognition
  - e.g. “Google Goggles”



# “Robot” Goggles

- Upload image(s) → Download Semantics
  - Object name
  - 3D model, mass, materials, friction properties
  - Usage instructions (function, how to grasp, operate)
  - Context / Domain knowledge

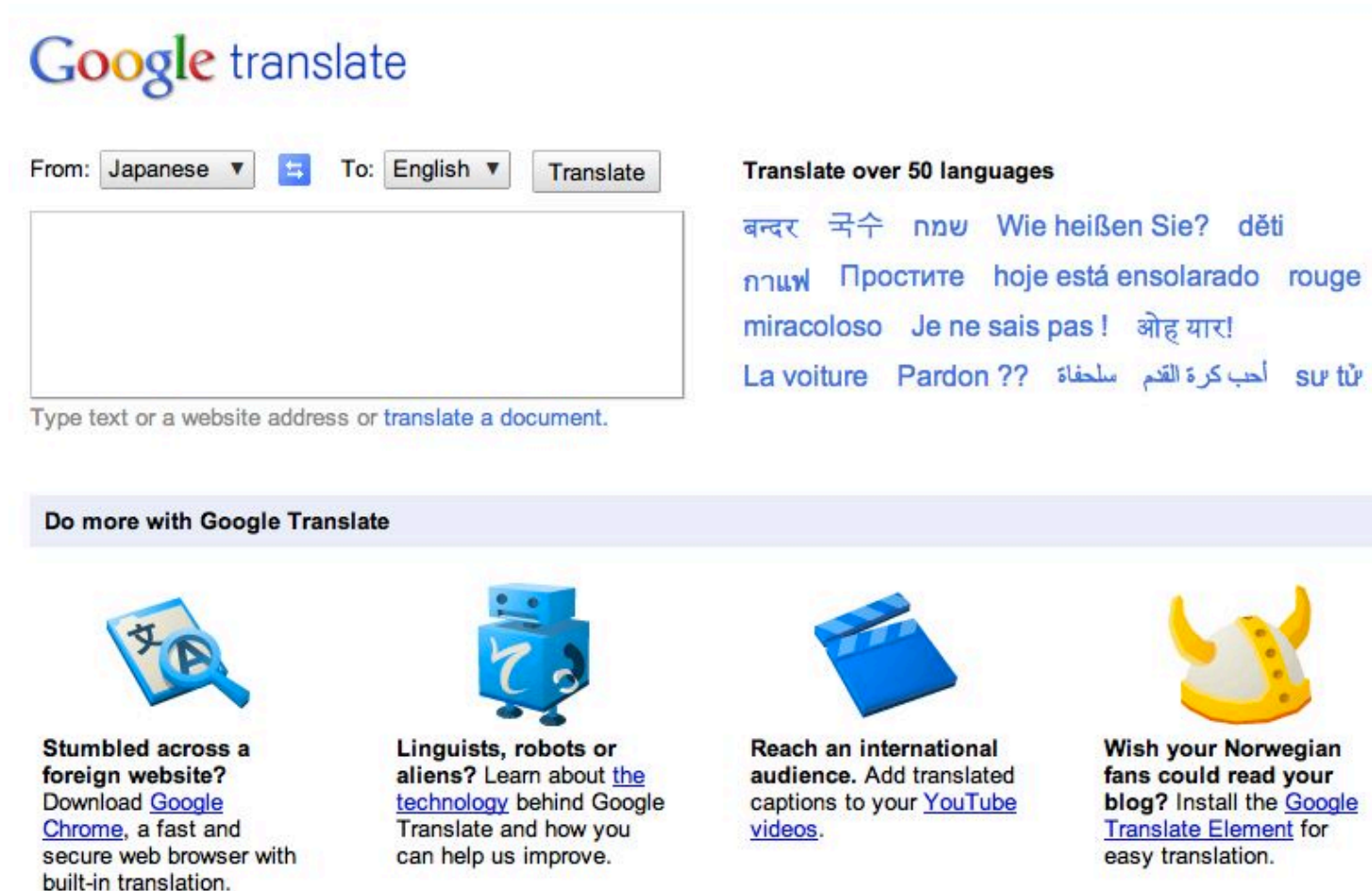


ARMAR III (KIT)



# Example : Speech

- Statistical Machine Translation



Google translate


From: Japanese ▼ To: English ▼ Translate


Type text or a website address or [translate a document](#).


Translate over 50 languages


बन्दर 국수 שמח Wie heißen Sie? děti  
ກາຟ Простите hoje está ensolarado rouge  
miracoloso Je ne sais pas ! ओह यार!  
La voiture Pardon ?? أحب كرة القدم su tū

Do more with Google Translate

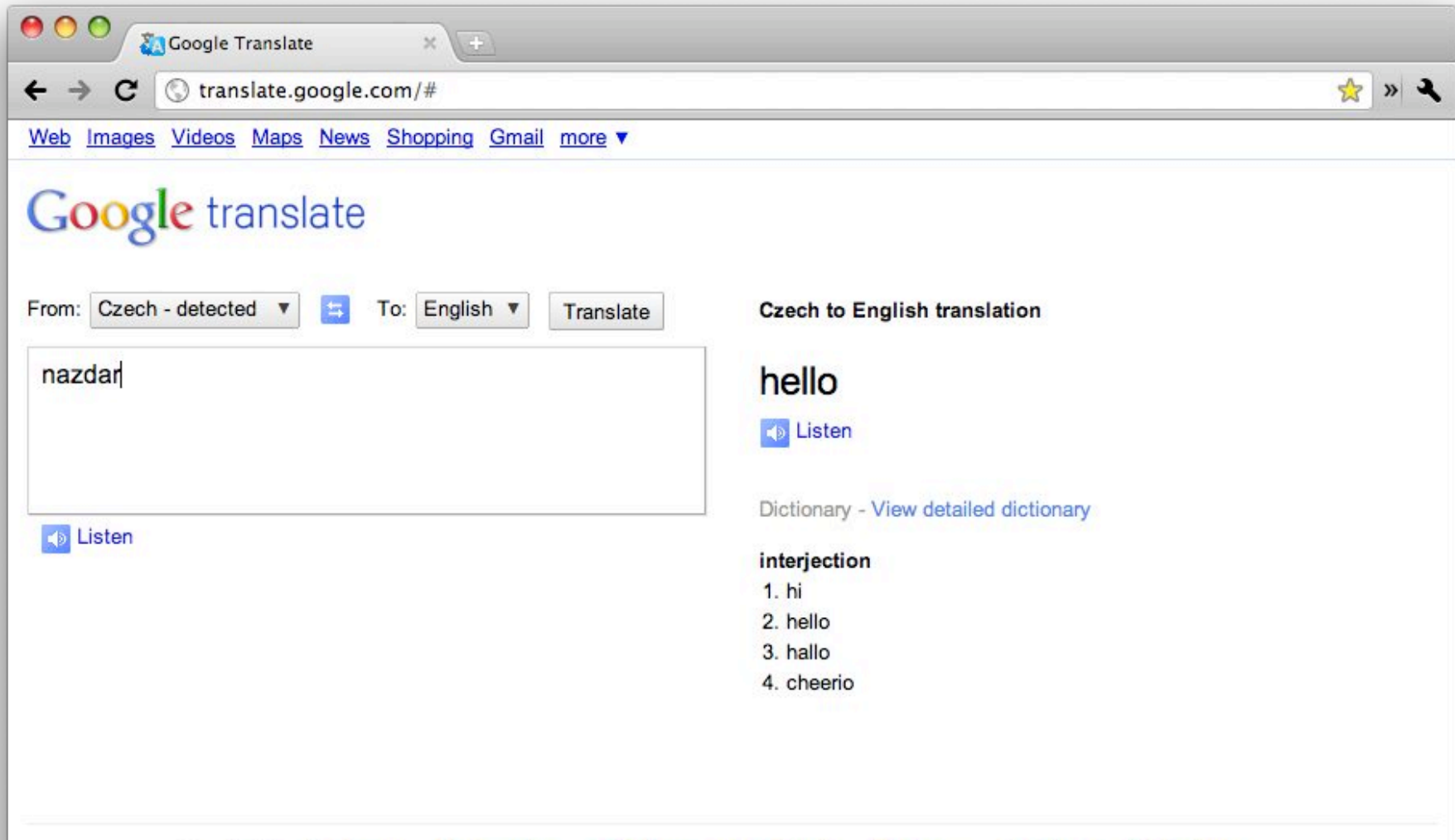
 **Stumbled across a foreign website?** Download [Google Chrome](#), a fast and secure web browser with built-in translation.

 **Linguists, robots or aliens?** Learn about [the technology](#) behind Google Translate and how you can help us improve.

 **Reach an international audience.** Add translated captions to your [YouTube videos](#).

 **Wish your Norwegian fans could read your blog?** Install the [Google Translate Element](#) for easy translation.

# Translation in the Cloud



# Cross-Language Search

Google   [Advanced Search](#)

Web > **Translated search**  [Hide options](#) Results 1 - 10 of about 216,000 for **restaurant reviews antwerp**. (0.24 seconds)

> **All results**

- [Images](#)
- [Videos](#)
- [News](#)
- [Blogs](#)
- [Books](#)
- [Forums](#)

> **Any time**

- [Recent results](#)
- [Past hour](#)
- [Past 24 hours](#)
- [Past week](#)
- [Past year](#)
- [Specific date range](#)

> **All results**

- [Visited pages](#)
- [Not yet visited](#)

> **Standard view**

- [Related searches](#)
- [Wonder wheel](#)
- [Timeline](#)

- [Standard results](#)
- [Images from the page](#)
- [Fewer shopping sites](#)
- [More shopping sites](#)
- [Page previews](#)

> **Translated search**

Translated results for **restaurant reviews antwerp** - My language: [English](#)

Language	Translated query	
Dutch <input type="checkbox"/>	<b>restaurant reviews antwerpen</b> - <a href="#">Edit</a>	<a href="#">200,000 results</a>
French <input type="checkbox"/>	<b>critiques de restaurants d'Anvers</b> - <a href="#">Edit</a>	<a href="#">16,800 results</a>

[Add language](#) ▼

[Antwerp Restaurant Restaurants in Antwerp Belgium...](#)

Translated from: Dutch  
Write a **review**...Nice Greek **restaurant** in a beautiful place near **Antwerp** Cathedral green place...**Restaurant** Name: WOK OF ANTWERP...  
 [Hide original text](#)

[Antwerpen Restaurant Restaurants in Antwerpen België ...](#)

Schrijf een **review** ... Leuk Grieks **restaurant** op een mooie plek in **Antwerpen** vlakbij kathedraal groenplaats. ... **Restaurant** naam: WOK VAN ANTWERPEN ...  
[www.antwerpenrestaurants.be/review.php](http://www.antwerpenrestaurants.be/review.php)

[Pasta & Vino, Restaurant, Antwerp, Restaurants in Antwerp](#)

Translated from: Dutch  
Brunello 41 **reviews**. Food: 7 Control: 8 Atmosphere: 7. (13-10-2008). We have a lovely lunch at this cozy **restaurant**. **Antwerp** is our favorite city...  
 [Show original text](#)  
[www.youropi.com/nl/antwerpen/restaurants/pasta-vino-550](http://www.youropi.com/nl/antwerpen/restaurants/pasta-vino-550)

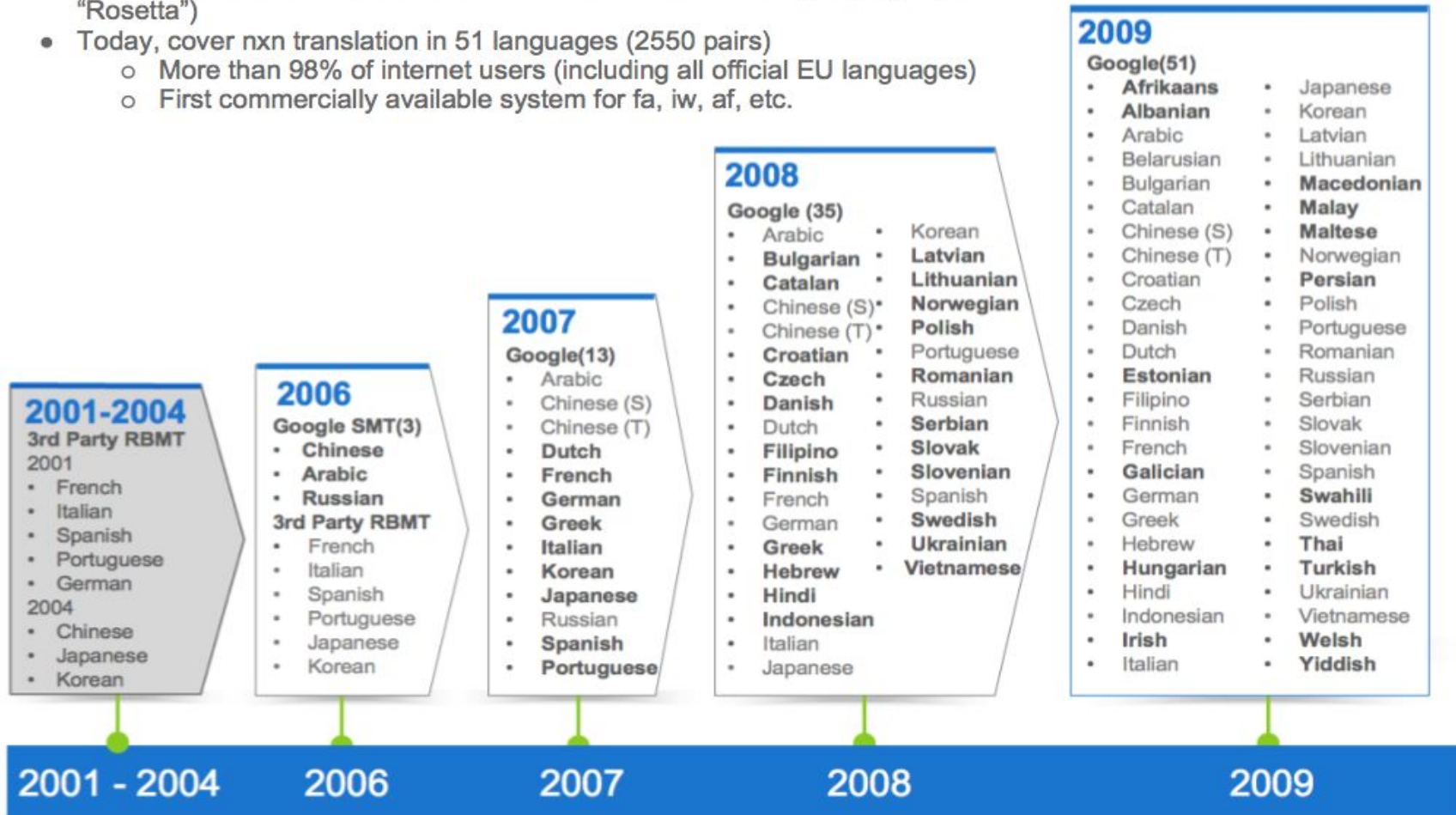
[In the Shadow of the Cathedral Review: Antwerp Best Restaurant...](#)

Translated from: Dutch  
In the Shadow of the Cathedral **restaurant review** by 10Best. This **restaurant** serves great food best **Antwerp** is one of the best places to eat in **Antwerp**.  
 [Show original text](#)  
[www.10best.com/Antwerp.../Restaurants/...Restaurants/.../In\\_de\\_Schaduw\\_van\\_de\\_Kathedraal\\_Antwerp/](http://www.10best.com/Antwerp.../Restaurants/...Restaurants/.../In_de_Schaduw_van_de_Kathedraal_Antwerp/)

[Restaurant reviews, cookbooks and culinary shop weblog | Special Bite](#)

# Language Coverage

- 2001-2007: Licensed Systran Rules-based machine translation
- 2006: Released our first Statistical Machine Translation Languages (project "Rosetta")
  - More than 98% of internet users (including all official EU languages)
  - First commercially available system for fa, iw, af, etc.





# Speech-to-Speech

- Recognition
- Translation
- Synthesis



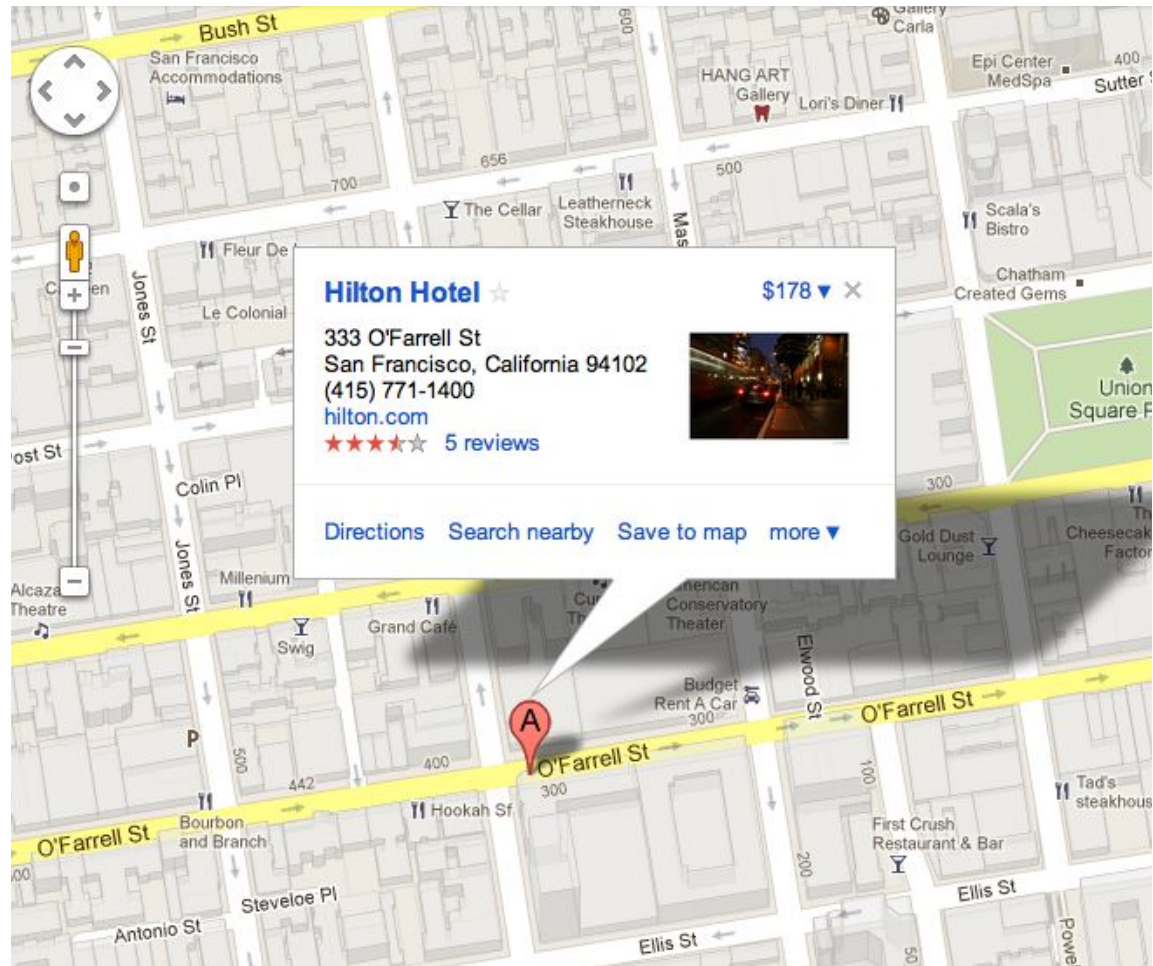
*Conversation Mode on Android*



*Alex Waibel's group (CMU & KIT)*

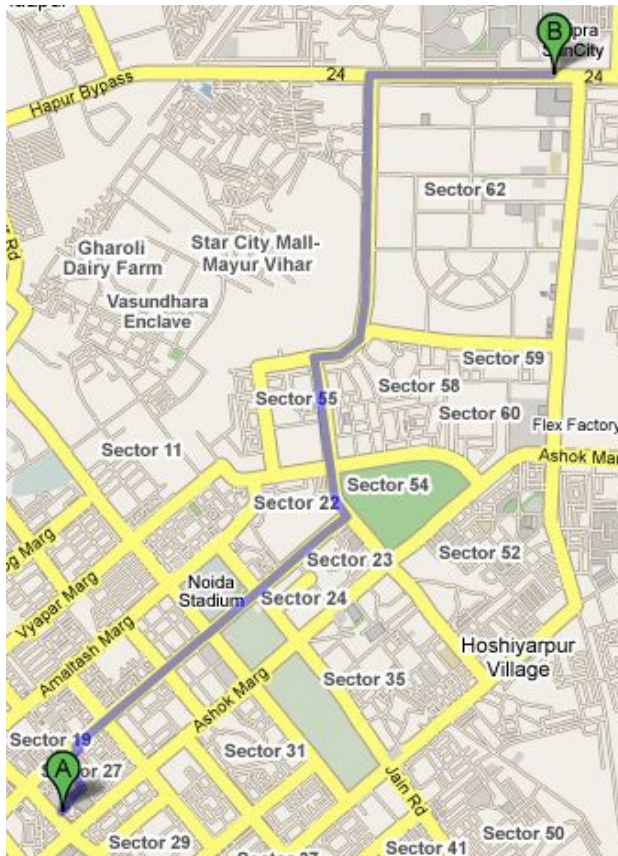
# Example: Maps & Localization

- Shared, highly-detailed maps of the world stored in the cloud
- Updates/changes can be published and immediately used



# Example: Planning

- Navigation



- Difficult task or motion planning problems solved in the cloud  
*(e.g “God’s Number”)*

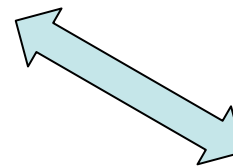
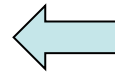
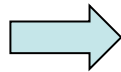


- 43,252,003,274,489,856,000 positions
- 35 CPU-years used

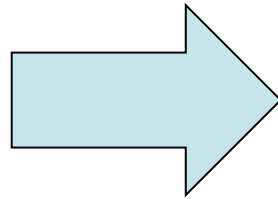
# Example: Skills

- An “App Store” for robots
- Task → Objects/Domain Info → Usage Instructions → Behaviors/Motor Skills

“Contact Tamim”



# “I Need a Helicopter Pilot Program...”



# AI and Google

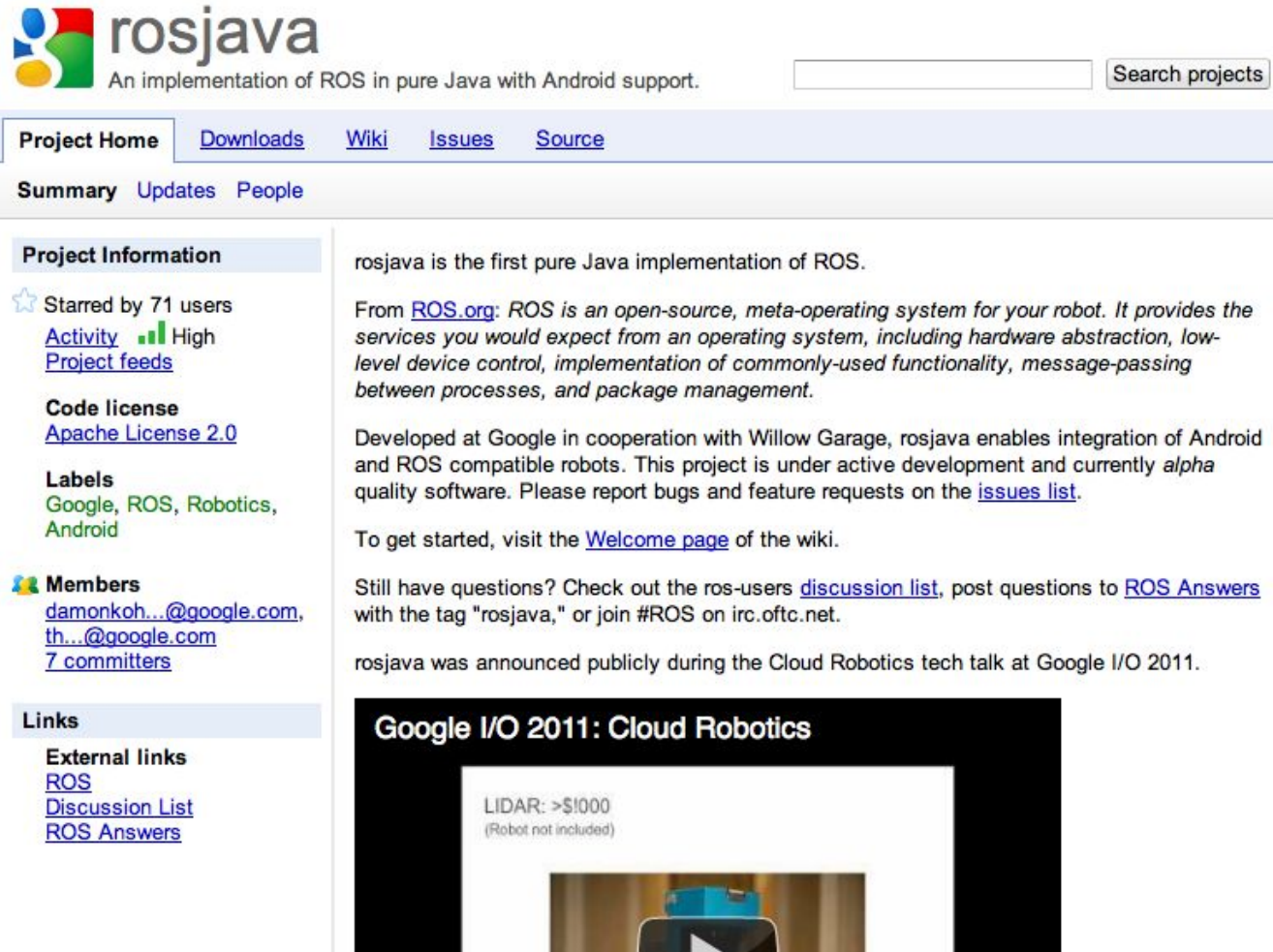
"The ultimate search engine will understand everything in the world."



Larry Page

# ROS on Android

<http://code.google.com/p/rosjava/>



The screenshot shows the Google Code project page for 'rosjava'. At the top, there is a logo for 'rosjava' with the tagline 'An implementation of ROS in pure Java with Android support.' and a search box. Below the logo is a navigation bar with links for 'Project Home', 'Downloads', 'Wiki', 'Issues', and 'Source'. Underneath is another navigation bar with 'Summary', 'Updates', and 'People'. The main content area is divided into two columns. The left column contains 'Project Information' (71 users, high activity, Apache License 2.0), 'Labels' (Google, ROS, Robotics, Android), 'Members' (7 committers), and 'Links' (External links to ROS, Discussion List, and ROS Answers). The right column contains a description of rosjava as the first pure Java implementation of ROS, a detailed paragraph about its features and development at Google, a link to the 'Welcome page' of the wiki, a note about user support channels, and a mention of its announcement at Google I/O 2011. At the bottom of the right column is a video player titled 'Google I/O 2011: Cloud Robotics' showing a robot with a blue sensor and the text 'LIDAR: >\$1000 (Robot not included)'.

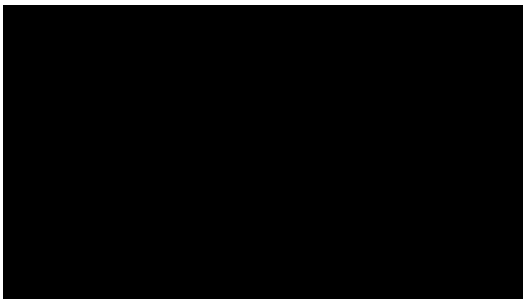
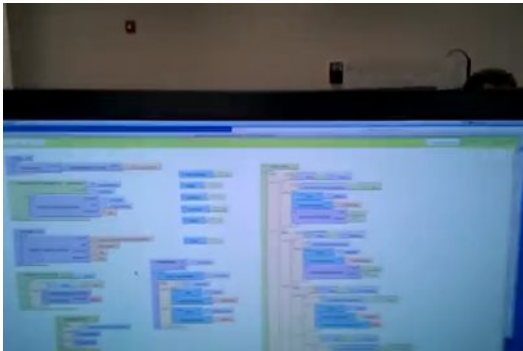
# Build your own cellbot!

- AppInventor interface for Android phones and tablets
- <http://www.cellbots.com/>
- <http://www.cloudrobotics.com/>
- ADK (Accessory Development Kit) for Android



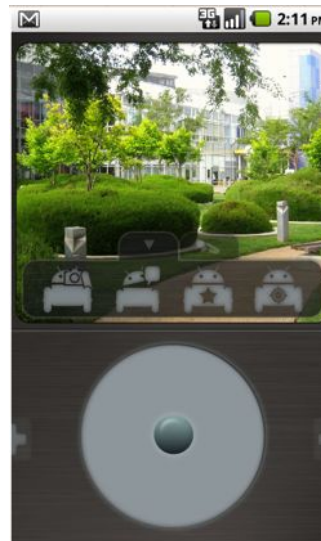


# Android-Based Robots



- App Inventor for Android and LEGO Mindstorms NXT
- NASA CubeSat Project
- Willow Garage TurtleBot with ROS on Android

 + 



# Google/Hasbro Project Phonedox



<http://www.engadget.com/2011/05/11/hasbros-experimental-nexus-powered-robot-toy-hands-on-at-google/>

# Summary

- Planning requires “models” of the world to be useful.
- Cloud Robotics means models are distributed across cloud computers.
- Cloud Robotics enables cheaper, lighter, and “smarter” robots
- A rapidly evolving infrastructure already exists.
- Creating a “shared knowledgebase” for robots will enable a robot revolution...
  - Deep knowledge and information about the world
  - Robot experiences / user interactions / learned skills

