Cloud-Enabled Humanoid Robots

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(currently working at Google Research)
Humanoid Motion Planning (1995-2010)

- 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
Self-driving Automobiles

Google Cars Drive Themselves, in Traffic

Dmitri Dolgov, a Google engineer, in a self-driving car parked in Silicon Valley after a road test.

By JOHN MARKOFF
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MOUNTAIN VIEW, Calif. — Anyone driving the twists of Highway 1 between San Francisco and Los Angeles recently may have glimpsed a Toyota Prius with a curious funnel-like cylinder on the roof. Harder to notice was that the person at the wheel was not actually driving.
Search-based Artificial Intelligence
Autonomous Grasping & Manipulation (2000-2010)
OpenRAVE: Open-source Robotics and Animation Virtual Environment

http://openrave.programmingvision.com/
- OR -
http://www.sourceforge.net/
keyword: “openrave”
Robot Knowledge Database

- reachability
- base placement
- inverse kinematics
- Grasping
- self-collision
- distance metrics

CMU PhD thesis: Rosen Diankov
CMU PhD thesis: Rosen Diankov
Stable Grasp Generation

1. Approach Target
2. Close Fingers
3. Compute Contacts

CMU PhD thesis: Rosen Diankov
Precomputed Reachability

- Given the robot’s position, where can the arm reach?

CMU PhD thesis: Rosen Diankov
Object-Specific 6D Pose Extraction

- Modeling Object Pose Error

CMU PhD thesis: Rosen Diankov
Pose Sets due to a Curve
Mean Images of Induced Pose Sets

CMU PhD thesis: Rosen Diankov
Cloud Computing

- Documents “live” in the cloud (backed up and accessible anywhere)
- Netbook
- Supercomputing: (Heavy CPU or data-intensive processing handled by distributed network)
With Chrome OS, Google Doubles Down on the Cloud

SAN FRANCISCO — Google unveiled a beta version of its Chrome OS and an early test version of its branded netbook Tuesday morning, a big bet by the search giant to help drive computing to the cloud — and to the popular web-based services that are its bread and butter.

Google’s release of the new OS, related but separate to its mobile OS Android, comes after a year of development and at a time when cloud computing — and the simpler machines that access applications on distant servers rather than running them on a hard drive — seems to have passed a sort of tipping
“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
• **Recent proposals:**
  
  “DAvinCi: A cloud computing framework for service robots” [Arumugam, et. Al. , ICRA 2010 ]
  
  - Hadoop cluster with ROS communication infrastructure
  
  - FastSLAM map/reduce
Enabling Factors

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

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

- Recognition
- Translation
- Synthesis

Alex Waibel’s group (CMU & KIT)
• **Statistical Machine Translation**
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...”
Summary

• Cloud computing can enable cheaper, lighter, “smarter” robots
• The infrastructure exists and is rapidly evolving in terms of performance and accessibility
• Create a “shared knowledgebase” for robots
  – Information about the world
  – Robot experiences / history / behavior outcomes / learned skills can all be published or data mined.